Mineral Specimen Cleaning and Development for the Amateur

Steve Hardinger

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Never underestimate the possibility of injury from a chemical or piece of equipment, even if you have lots of experience. In general, the equipment and chemicals mentioned in this book are not likely to cause injury if the procedures are followed as written but if injury does occur it can be severe. Recall that safety is our primary Guiding Principle.

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Origin and Purpose

This book emerged from over four decades of experience in both academic and industrial chemistry, encompassing teaching and research roles, culminating in my retirement in 2018 as University Distinguished Senior Lecturer from UCLA. I hold a Ph.D. in synthetic organic chemistry from Purdue University. I have been an avid collector for almost 50 years and as a professional dealer as Dragon Minerals (www.dragon-minerals.com) for about half as long.

During my journey as a collector and particularly as a dealer I found myself increasingly frustrated with the prevalence of dirty minerals and the scarcity of comprehensive reference materials on how to effectively clean and further develop them. These frustrations, coupled with my enduring passion for tinkering in the lab, led to the creation of this book, which is aimed at the collector who is has little to no formal lecture or laboratory training in mineralogy or chemistry. The book includes sufficient detail and background information to make this work accessible to an amateur mineral collector. Especially important towards this goal are Sections 3.11–3.14, which

explain basic chemistry concepts and laboratory manipulations. These details allow the collector to make science-based decisions instead of just throwing chemicals together blindly and hoping for the best. The major procedures have been extensively checked. Important updates of older procedures and several new procedures are included.

In order took keep the price of this book accessible to the amateur, it does not have glossy pages or eye-candy photographs. The print version is produced on my laser printer, which is obvious in some of the images. The images in the pdf version are better.

The self-published format of this work allows for frequent updates, additions and (hopefully few) corrections. Any errors are my own. Should you find any errors or omissions please don't hesitate to contact me directly.

Acknowledgements

A project of this scope could not have been completed without the previous work of others. To see the present, I stood on the broad and lofty shoulders of some mineralogical giants including Robert King, Richard Pearl and John Sinkankas (to name a few).

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My greatest thanks to my wife Linda, without whose support, encouragement and patience during many cleaning experiments in the garage and endless hours at the camera and keyboard this project could never have happened.

I invite your questions or comments by email. Happy and successful cleaning!

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Uncredited images are by the author or in the public domain. All specimens are from the authors collection unless otherwise stated. Others used by permission. Figure 1-9: The Arkenstone (irocks.com). Figure 3-11 left: Dona Leicht. Figure 3-11 right: Collector's Guide to Herkimer Diamonds (Michael Walter). Figure 3-15: Geoff Cook specimen. Figure 3-19: Vaniman Manufacturing Co. Figure 3-20 left: The Arkenstone (irocks.com). Page 273, Red quartz: Geoff Cook specimen. Page 276, Quartz (locality unknown): David Lacy specimen. Page 283, Fluorite (Rogerley Mine): Christopher Lee specimen. Page 291, Neptunite: Richard Sittinger specimen. Page 302, Red beryl (Ruby Violet Claims): Geoff Cook specimen.

Mineral Specimen Cleaning and Development for the Amateur

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Accompanying website: www.mincleandev.com

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CHAPTER 1: Introduction and Guiding Principles

1.1 Introduction

Imagine encountering a mineral specimen fresh from the Earth's depths: a light blue green aquamarine crystal whose maximum beauty is obscured by layers of mud, rust, and uninspiring matrix rock (Figure 1-1). How does one transform this grimy mass into a stunning display piece while minimizing any compromise to its aesthetic and scientific integrity? This fundamental question serves as the central focus of this book.

Figure 1-1. An example of what can be achieved using the methods in this book. This aquamarine was cleaned using (in this order) - textile gun, hot alkali, Iron OUT and finally sonication.

Mineral cleaning and development methods are usually either touched upon only briefly or fully excled from the multitude of books and other resources on minerals and mineral collecting; hence the need to gather this information together into a single source, readily available to the mineralogical community. Brought together here in one place is information on mineral cleaning, development and related topics scattered among various print and electronic sources, plus observations from the author's own experiments and experience, many never-before published. Information is organized by the problem to be solved ("How do I remove rust?") instead of a nonsensical organization by chemical ("What can I clean with oxalic acid?") common in other works. Esoteric mineralogical and chemical lingo is deemphasized. Enough elementary chemistry is explained so concepts such as reduction and pH can be easily understood. Priority is given to procedures using equipment and chemicals available to the amateur in North America, although readers elsewhere will still find a wealth of valuable guidance and advice. In the last 25 years, the advent of internet chemical and equipment sources (Amazon, ebay, mineral dealers and home lab suppliers) has made a variety a mineral cleaning and development procedures more readily accessible to the amateur. Doubtful procedures from the literature are corrected or revealed as nonsensical. Photographs are of specimens whose quality is more likely to be encountered by the amateur, instead of 'eye candy' specimens seen elsewhere.

When searching for mineral cleaning and preparation development advice, a modern collector is likely to engage in web searches using such phrases as "how to clean minerals." These searches, however, are often too broad to be of much use. Much of the information on this topic residing on the web is conflicting, doubtful (lacking confirmation by experienced collectors or professionals) and downright wrong. Following some of these web recipes is often just a waste of time and in numerous cases irreparable damage to a precious specimen results. An additional annoyance is 'link rot' in which promising search hits are no longer available.

There has been no comprehensive publication for amateurs on mineral specimen cleaning and development since the now-dated works of Sinkankas (1972), Pearl (1982) and King (1982, 1983, 1985 and 1986). The recent *Mineral Cleaning for Collectors 3rd Edition* (Duthaler and Weiß 2024) has much useful information but is not directed at the amateur. Regardless of publication date or target audience, these works should be thoroughly studied by every mineral collector.

This work is not intended to be encyclopedic or an academic monograph. In the spirit of the classic Sinkankas book *Mineralogy for Amateurs*, this work is designed to be understandable and usable by the amateur with minimal knowledge of mineralogy and chemistry and only limited working facilities. Emphasis is given to accessible and applicable literature. Less emphasis is placed on esoteric or poorly accessible publications and those not in English, so that the reader does not depend on access to electronic or print resources of an academic library (although both are useful for a more thorough understanding).

Although frequently shunned by academics as legitimate information sources, web sites such as Mindat (www.mindat.org), Webmineral (webmineral.com) and the Friends of Mineralogy Forum (www.mineral-forum.com) have grown in both participation and accuracy (and accordingly in legitimacy). A new website (www.mincleandev.com) provides physical and chemical data useful for planning mineral cleaning and development projects. In the past two decades such sources have become a treasure trove of information and wisdom, but they must be considered with a critical mind. Therefore, any modern and comprehensive work on mineral cleaning and development must include references to such resources. These message board sites contain a multitude of facts, opinions and pooled experiences from a broad range of collectors, mineral professionals and the like. These resources are frequently referenced (when accurate) in this current work.

1.2 Cleaning versus Development

What is meant by 'cleaning' and 'development?' Cleaning is generally understood to be the removal of 'something that doesn't belong.' The 'something' might be natural such as a thin iron hydroxide/oxide crust ('rust') or plant remains. 'Something' might also be unnatural to the specimen's geological environment - dust, label residues, etc.

Regarding cleaning, King (1983, 54) says "Traditionally in Britain the word cleaning has been used to mean the physical removal of material such as dust, smoke blackening, etc. alien to the paragenesis of a mineral specimen. In other countries the word cleaning is used in a wider

sense and involves not only the physical removal of dust, etc. but also the chemical removal of associated minerals. Such [treatment] is better described as development, as used in the palaeontological sense. It is in this latter sense that [development includes] the artificial modification of a mineral paragenesis."

Removal of dust accumulated on specimens in a display cabinet is obviously cleaning but what about removal of iron hydroxide/oxide coatings (rust)? At the California State Gem Mine beautiful blue benitoite crystals are almost always covered with a natural deposit of massive, white natrolite that is routinely removed by acid treatment (Figure 1-2). Should this treatment, which destroys the natural paragenesis but significantly improves the specimen's beauty be considered as cleaning or as something else?

Figure 1-2. This benitoite crystal was obscured until the natrolite was removed with acid.

Development refers to improving the aesthetic, historical, scientific and/or monetary value of a specimen above and beyond a simple cleaning (Howie 1992, 7). The term has been used for over a century in reference to mineral specimen improvement (Hawkins 1917). Common development procedures include trimming, air abrasion, treatments for preservation, mounting on a stand, etc. Cleaning methods might be considered as a category of development methods. Development is defined somewhat differently in the fossil world; Converse (1984, 34) defines this term as "removal of fossil material from matrix" by any chemical or mechanical method.

There is no clear-cut boundary between cleaning and development and nor does there need to be. Some procedures used to enhance a specimen might be considered as both. For example, if used to remove rust, air abrasion is cleaning, but if the same technique is used to remove natural matrix to reveal crystals beneath then this technique is development. Instead of cleaning versus developmental methods, procedures in this book are divided into mechanical methods and chemical methods.

Mechanical methods are those in which no chemical change occurs, such as cleaning by sonication or application of a hydraulic mineral trimmer. Sonication is a mechanical method because the chemical makeup of both the mineral specimen and material removed are not altered. Chemical methods employ one or more chemical reactions, such as derusting with dithionite or removing calcite with acid. Dithionite treatment is a chemical method because iron-oxygen chemical bonds are broken down during the process.

A particular mechanical or chemical method might be applicable in many different circumstances. For example, air abrasion might be used to remove a clay coating on quartz or a cookeite coating on tourmaline. Treatment with strong acid might be used to dissolve encrusting calcite or to remove rust. However, one must also consider the specimen being treated. In this case acid can be used to dissolve calcite on quartz (quartz has excellent chemical resistance) but not to remove calcite from rhodochrosite (most carbonate minerals are attacked by acids to some extent). Accordingly, this book covers not only general descriptions of mechanical and chemical methods (Chapter 3) but also advice on treating specific mineral species as well (Chapter 4).

There are reasonable arguments both for and against cleaning and development of minerals, for example those presented by King (1982 and 1983). Allington-Jones (2017) provides an extensive and thoughtful discussion, as well as numerous useful references. ***Every collector considering cleaning and/or developing a mineral specimen should read these essays.*** Most collectors will agree for example that pyrite from the Huanzala Mine (one of the world's most prolific pyrite localities) can be cleaned and trimmed with impunity because of its abundance. But what about a rusty pyrite from Antarctica, collected 100 years ago? What scientific information or historical context might be lost when this specimen is treated in some way? A collector should consider these issues carefully and decide, based on their own collecting interests and collection focus, whether a specimen should be treated, and if so, to what extent. Discussing the specimen with fellow collectors as well as academic and museum professionals can also be quite informative.

1.3 Guiding Principles

Some amateurs believe most (if not all) cleaning problems can be resolved by immersion in muriatic acid (an impure form of hydrochloric acid). In more cases than not this will either be ineffective or do more damage than good. "[No] longer can we afford to learn from our mistakes, the material is too valuable to put at risk. It is part of the natural heritage, and its source of supply is rapidly diminishing" (King 1982). The following **Guiding Principles** for mineral specimen cleaning and development are useful and must be considered as part of the planning process before actual work begins.

1. Safety! Procedures discussed in this book may present a mild to significant physical or chemical hazard. Pay attention to the suggested safety equipment and procedures. *A little laziness can lead to a permanent injury* (Figure 1-3). *The best safety is proactive, not reactive*. Before starting work look around the workspace, considering the work to be done and ask yourself "What safety risks do I face and how do I avoid them?" instead of "That hurt! I must avoid doing that in the future."

2. Patience! We all want to see what beautiful crystals lie beneath the muck, but rushing can easily destroy the specimen. *Patience is your number one mineral cleaning and development tool.*

Figure 1-3. Every one-eyed pirate knows from a bad experience to always wear safety glasses when working with chemicals. This pirate still has not learned this crucial lesson.

3. For the greatest chance of success with the least risk of damage to the specimen, any procedure must begin by ascertaining (where possible) what mineral(s) are to be retained and what mineral(s) are to be removed. There is no general procedure that applies equally to every specimen. Every case is unique and depends on the physical and chemical properties of the minerals involved. For example, calcite is easily removed from quartz because calcite (Mohs hardness 3) is much softer than quartz (Mohs hardness 7), easily cleaved and more readily attacked by acids. Quartz readily resists all most all cleaning chemicals except HF (hydrofluoric acid) and NH_4HF_2 (ammonium bifluoride); these reagents attack only slowly. On the other hand, an unknown black coating on pyrite presents a bigger challenge. Air abrasion or a textile gun might be effective on any black coating. If the coating is tar (bitumen) an organic solvent may be needed. If the black coating is shale, hot alkali might be needed. For research purposes use the Mindat database (www.mindat.org) to explore species, associations and specimen photos for a given locality. Basic chemical tests may also be applicable: calcite reacts vigorously with dilute HCl (hydrochloric acid or muriatic acid), whereas other carbonates react more slowly or not at all (Hardinger 2024a). If unsure, ask other collectors. Take the time to accurately ascertain information about the specimen's physical and chemical properties first instead of rushing headlong into work based on poor assumptions and bad information that quite possibly will ruin the specimen (Chapter 4 and www.mincleandev.com). ***Behind safety, patience is the number one mineral cleaning and development tool.***

4. If unsure... don't. Carefully consider if the possible outcome of a planned procedure outweighs the risks to the specimen. *Err on the side of caution*. Most procedures in this book are irreversible. For specimens of high scientific, historical or personal value consider consulting an experienced mineral preparator first and possibly paying to have them work on the specimen for you. Consider also that mineral specimen preparation - trimming, chemical treatment, etc. - can result in loss of information such as mineral paragenesis or matrix. Even a lowly rust stain tells part of the mineralogical story. King (1983, 60) and Wilson, Dunn and Bentley (1986) provide thoughtful discussions of this issue.

5. Experiment on lower quality specimens first. This is especially important when trying an unfamiliar procedure on minerals you have not cleaned before. To avoid creating extra questions concerning the compatibility of a mineral to a particular procedure, use only test material from the same locality (if possible), having (if possible) only the same species/variety and the same mineral assemblage as the material in question (Figure 1-4). If lower quality material is not available, carefully consider experimenting on a small, inconspicuous area of the specimen. Take care in using specimens from one locality to plan work on similar specimen from another locality. Inclusions, nature of material to be removed, matrix, paragenesis and other properties may be sufficiently different to require an alternate cleaning plan. Build a library of 'research samples' (poor quality specimens, trimmings, etc.) for this purpose.

Figure 1-4. When trying a new cleaning method on (for example) tourmaline, experiment with lower quality material (left) first before ruining a beautiful, expensive specimen (right). Both samples are from the Himalaya Mine in San Diego County, California.

6. Before beginning work and after each round of work, examine specimens under magnification. A hand lens is useful, but a microscope is generally better. This examination assists identification and can reveal minerals otherwise not seen. Something hidden before cleaning began may appear after a round of cleaning, perhaps requiring the cleaning plan to be revised.

7. Always try the mildest possible method first. *Remember that patience is the number one mineral cleaning tool*. For example, for derusting use dithionite treatment first before strong acids. Try cleaning procedures at room temperature before attempting those requiring warming. Although heating accelerates chemical processes it also decreases selectivity and increases damage potential due to thermal shock. Try mechanical methods before chemical methods.

8. Not every cleaning or development problem can be solved. Some specimens just cannot be cleaned or otherwise improved by any known procedure (Figure 1-5).

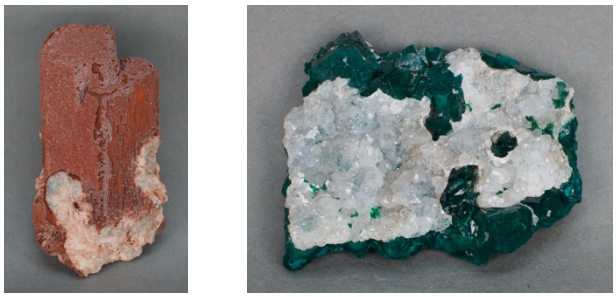


Figure 1-5. Left: This microcline cannot be derusted because the rust is included within the specimen. Right: This dioptase cannot be freed of its quartz coating because there is no known mechanical or chemical method that will attack the quartz but not the dioptase underneath.

9. Cleaning and development are not always beneficial. The procedure may leave a dull surface, remove material with a pleasantly contrasting color or destroy scientific information. For example, removing chlorite from quartz not only can reduce interesting color contrast but also frequently leaves the quartz faces pitted and dull. Other 'do not clean' examples include stibnite tarnish and pyrite iridescence; these may be self-protective layers (Allington-Jones 2017). Figure 1-6 gives a pair of tourmaline specimen examples.

Figure 1-6. Left: Should the crust on this Ponte do Piauí claim tourmaline be removed? The crust is zanazziite, a rare beryllium phosphate. Removing this crust might make the specimen prettier, but at the same time would significantly decrease its monetary and scientific value. A case of "do not clean." Right: Should this calcite-coated Himalaya Mine tourmaline cluster be freed of calcite? The association is rare at the locality and the calcite is likely holding the specimen together. Another case of "do not clean."

10. Subject most or all specimens from the find to at least a cursory cleaning. All specimens from the find should be given at least some superficial cleaning to remove the heaviest contamination. Examine the specimens under magnification before saving for the research library or discarding. In one example, numerous poor quality black tourmaline samples from the Elizabeth R Mine (San Diego County, California) were to be discarded. However, textile gun treatment revealed a small but significant find: the first recorded zircon crystal for the locality (Figure 1-7).

Figure 1-7. This tiny tan zircon treasure would have been lost had the low-quality black tourmaline samples not been given some cursory cleaning before discarding.

11. When making decisions, a specimen's scientific or historical value often outweighs its aesthetic or monetary value. For example, avoid derusting a specimen if such treatment will also destroy a historical label.

Use these Guiding Principles to develop a plan before starting work.

1.4 Develop a Plan

The Guiding Principles suggest a method for planning work on a specimen. Why is such a plan necessary? Consider a nonmineralogical example, in which you are hosting a dinner party. Which type of party requires less planning and less effort: Delivery pizza for two or a lavish, seven course, home cooked feast for twenty? The same thinking can be applied to mineral specimen cleaning and development. Which specimen requires less effort and planning from acquisition to display? A 'silver pick' (purchased) quartz crystal, slightly dusty but otherwise pristine and self-standing versus or a personally collected specimen, mud still adhering and obscuring, but azurite and other minerals (some of which, based on the locality information, are quite rare)? Any cook (even if you burn the water for pasta) and any collector can manage the pizza party and silver pick specimen cases with little effort. The latter cases require knowledge, patience and detailed planning to avoid the looming threat of utter disaster.

The Guiding Principles are an excellent basis for any mineral specimen cleaning and development plan, regardless of the preparator's skill level. When planning, review all the relevant sections of this book before beginning work.

What cleaning and/or development should a specimen receive, if any? Procedures often result in some loss of 'scientific truth' such as paragenesis or original (historic) appearance. These details may be unimportant to the casual hobby collector (for who aesthetic and economic value are often paramount) but their loss should be considered seriously if the specimen is to be part of a professional or research collection. In the latter case, all work on the specimen should be recorded

in detail in the collection catalog including before and after photos. Recall that these treatments cause irrevocable loss of information and so no treatment at all is sometimes better.

When cleaning and developing, should we only remove matter foreign to the natural mineral paragenesis or should we remove everything except a single mineral species? This decision must be tempered by the collection focus, the collector's sense of aesthetics as well as interest in conservation of the specimen's geological, historical, scientific and monetary value.

How to clean the specimen? What methods are most suited? King (1982, 42) noted "Avoid 'unscientific scrubbing': It is unfortunate to hear of the case in which an overly enthusiastic collector [by a failure to plan!] ... vigorously scrubbed off the minute but unnoticed well-crystallized plates of wulfenite from...a specimen of galena."

What should be removed and what should be retained? Should damaged crystals be retained or sacrificed? Should crystals of a common species always be retained? Consider an Ojuela Mine wulfenite/mimetite association - rather common for the locality - should some or all the damaged wulfenite be removed? What about the same association with the same damage from a rare locality? In the former case removing the damaged wulfenite is not a significant loss to any aspect of the specimen's value. Conversely for the rare locality specimen the wulfenite should be retained - even if unsightly - because this might be a unique specimen and removing the wulfenite is a loss of scientific information.

What procedures should be applied to the specimen? Some processes may strengthen the specimen (stabilization the matrix, remove decaying or potentially decaying species, etc.) whereas in other cases processes may weaken the specimen by enlarging cracks or initiating or accelerating decomposition such as 'pyrite rot.'

When is it acceptable to remove old labels? In general, old labels should not be removed even when the label appears valueless. Old dates, prices, locality names and related details add interest and can increase the value of an otherwise plain specimen. Future research may reveal that a 'valueless label' ties the specimen to a special collection. **Always work to preserve previous labels and related mineral specimen history**. Some collectors focus on old labels, such as those of A. E Foote (a 19th century Philadelphia mineral dealer; Figure 1-8) or Washington Roebling (who built the Brooklyn Bridge; Figure 1-9).

Figure 1-8. A. E. Foote occupied the Belmont Avenue address 1877 to 1890. Labels like these should be retained to preserve historical provenance.

Figure 1-9. By themselves these number labels appear meaningless, but they indicate the specimen was in two important collections. 'R2647' ties it to of the Washington Roebling collection (NMNH 2025). '6780' is typical of the Kay Robertson collection (Wilson 2025). This provenance adds historical provenance as well as scientific and economic value for the specimen, so these labels should be retained when cleaning.

Planning a mineral specimen cleaning and development project can be summarized in three steps:

- Identify what task(s) are to be completed.
- Determine what method(s) are necessary to complete these task(s).
- Determine the best order to execute these tasks.

Remember this and plan accordingly: Most mineral cleaning and development actions are irreversible so when unsure...don't (Guiding Principle 4). Consult a more experienced collector first.

For more thoughts on planning and ethics that should be read by every collector see the following references. In English: Allington-Jones (2017), Duthaler and Weiß (2024) and King (1982, 1983, 1985 and 1986) and in German: Kipfer (1972), Rohner (2000) and Sury (1991).

1.5 More Resources

There are numerous print and online sources discussing mineral cleaning and development in a broad sense. While specific pages of many of these sources are cited in later chapters of this book, it is useful to list a just a few of these here for the reader who might want a broad overview. These resources should be in the library of anyone who routinely needs to clean and develop specimens: Betts (2025a), Duthaler and Weiß (2024), Howie (1992), Pearl (1982) and Sinkankas (1972). A four-part series in the *Journal of the Russell Society* (King 1982, 1983, 1985 and 1986) is also highly recommended. Brunton, Besterman and Cooper (1984) provide advice for institutional collections. The Field Manual for Museums (Burns 1941) contains many interesting but mostly untested (by this author) recipes which may be applied to cleaning minerals. Good references in German include Rohner (2000) and Sury (1991).

Online forums about mineral cleaning, development and conservation are places to read expert opinions and ask questions. Examples include: Mindat message boards (www.mindat.org),

Friends of Minerals Forum, Discussion and Message Board (www.mineral-forum.com) and the Mineral Specimen Cleaning and Preparation Facebook group.

A basic knowledge of mineralogy is important when planning and executing a cleaning and development plan. Learning how to identify mineral species and the environments in which they form can be crucial. Excellent and very readable texts on introductory mineralogy include Cairncross and McCarthy (2016), English (1934) and Sinkankas (1964).

In a broad sense, lapidary work (cutting, polishing, gemstone faceting, etc.), fossils, meteorites and related fields might be considered 'mineral specimen development.' These topics are well-covered elsewhere in numerous excellent resources and so are not included in this work.

CHAPTER 2: Getting Started: Safety and Workspace

2.1 General Safety Considerations

Legal Disclaimer: The equipment, chemicals, procedures and advice in this work may cause injury if used improperly. The author assumes no liability of any type for any direct, indirect, incidental, consequential, special or exemplary damages arising resulting from the text, images and procedures contained herein. The author disclaims all liability or responsibility for any resulting damage, injury or expense. The information herein is supplied for educational purposes only. By following any procedures in this book, you agree to hold harmless the author of this work. Work at your own risk. You are strongly advised to read appropriate *Material Safety Data Sheets* (MSDS) and *Safety Data Sheets* (SDS) for all materials and chemicals mentioned herein before their use. Follow all safety procedures. Use appropriate protective gloves, safety glasses, protective clothing, adequate ventilation, avoid ignition sources, etc. The information contained in this work should not be considered exhaustive. This work cannot be assumed to include a complete and exhaustive list of all hazards possible with the procedures given herein. The user should consult experienced professionals if any questions exist. Furthermore, the author does not control or guarantee the completeness or accuracy of any reference cited within this work.

Never underestimate the possibility of injury from a chemical or piece of equipment, even if you have lots of experience. In general, the equipment and chemicals mentioned in this book are not likely to cause injury if the procedures are followed as written but if injury does occur it can be severe. Recall that safety is our primary Guiding Principle.

Workspace safety is a critical topic neglected in nearly all other mineral cleaning and development discussions. Safety is discussed first because no specimen is worth an eye or a finger (Figure 1-3). *Safety considerations always come first.* The methods discussed in this book present no significant hazards if the safety procedures are executed faithfully as described.

Safety planning can be either reactive or proactive. A **reactive safety plan** is safety based on unsafe events that *have already occurred* whereas a **proactive safety plan** is based on careful consideration of *what might happen*. When a worker practicing proactive safety enters a workspace, he mentally surveys his environment and considers all potential safety hazards present. Hazards which can be mitigated before work starts are addressed immediately. Work procedures are modified to reduce or avoid potential hazards which cannot be immediately mitigated.

Reactive safety doesn't prevent an avoidable accident from happening in the first place, whereas proactive safety becomes a habit which greatly reduces the chance of an accident. The most common proactive safety habit that one must learn to adopt in the mineral workshop is the use of *eye protection*. Donning safety glasses as one enters (or better even ***before*** one enters) the workspace should become so routine as to be instinctive. With some lab workers eye protection is so much a part of their work that they feel underdressed (or even naked) without safety glasses!

Accidents don't care about how smart the victim is but instead wait to ambush those who are careless and fail to always practice proactive safety. For example, two-time Nobel Prize winner Professor Barry Sharpless lost an eye due to glass fragments from a small explosion close to his face. In this single circumstance he failed to practice proactive safety, neglecting his safety glasses. After this accident, Sharpless stressed "there's simply never an adequate excuse for not wearing safety glasses in the laboratory *at all times*" (Sharpless 1992). *Proactive safety may seem inconvenient but be thankful when its practice prevents injury. In this way it is like insurance that no one wants to pay but is grateful that it is there when needed.*

Below is a list of essential safety equipment and rules for the mineral cleaning and development workspace.

Eye protection: Human eyes are easily damaged by flying debris or splashed chemicals. Both are common hazards during mineral cleaning and development procedures. ***Eye protection must always be worn.*** *Safety glasses with impact or shatter resistant lenses* (usually made of polycarbonate plastic; Figure 2-1) are best. Typical eyeglass lenses are likely made of this material, but best to verify with an optician if unsure. *Your eyes may depend on it!* Safety glasses must also have *side shields* to protect areas to the left and right not directly protected by the lens. Unless specifically prescribed as safety glasses, eyeglasses do not routinely have side shields, but these can easily be added. Although safety glasses tend not to be stylish your eyes will not care.

Safety goggles (Figure 2-1) are a less satisfactory alternate to safety glasses as googles may interfere with peripheral vision and frequently fog up. If you wear prescription glasses and cannot find safety glasses that comfortably cover them a face shield is a useful alternative.

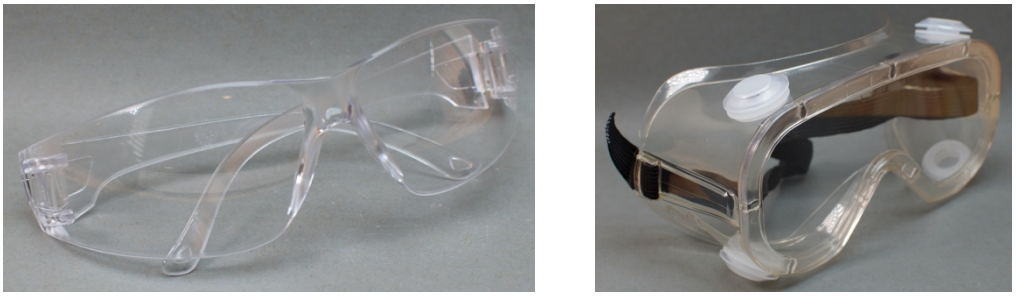


Figure 2-1. Left: Always wear safety glasses with eye protection at the sides while working in the mineral workspace. Right: Safety goggles are less preferable.

Should anything get into the eye do not poke or rub the eye. Immediately and thoroughly rinse with cold water for fifteen minutes. A personal eyewash is very useful for this. If redness or irritation persists, seek medical attention immediately. For more on eye contamination see Mayo Clinic (2024a).

Personal eyewash: Also called an eyewash bottle, this simple but very effective device consists of a squeeze bottle filled with saline solution and topped by a cup which fits over the eye socket. If the eye becomes contaminated, seat the cup over the eye socket then rinse by gently squeezing the bottle. The eyewash bottle is not a replacement for a thorough rinse, but instead is a

first line treatment to be used until more thorough rinsing can be accessed. This device should be stored where access is quick and unimpeded.

Gloves: Quite often during mineral cleaning and development hands may contact materials ranging from mildly irritating to significantly hazardous. *Wearing gloves for hand protection should become a proactive safety habit, just like use of safety glasses.* Nitrile gloves have excellent chemical resistance but are thin and therefore easily ripped or punctured and may be slippery when wet. They are disposable and designed for single use, adding a cost consideration. Heavy rubber gloves also have excellent chemical resistance but are tougher than nitrile gloves and generally provide a better grip (especially when they have a textured surface). These gloves are designed for repeated use. Latex gloves should be avoided as they are easily damaged, have poorer overall chemical resistance and may cause an allergic reaction. Gloves may be available in different colors, but it is the material of their manufacture (nitrile versus rubber versus latex) which is important. Caution: Nitrile and rubber gloves are not heat resistant! Form-fitting gloves provide the surest fit and therefore least chance of an accident.

Before each use gloves should be examined for pinholes, rips and other damage. If damaged, discard the gloves. If damage occurs immediately remove the gloves, wash the hands thoroughly with soap and water then dry before donning fresh gloves.

Gloves must be worn when handling minerals that are known or suspected to be toxic, asbestiform or radioactive. When in doubt assume the specimen is hazardous. Even if gloves are worn hands must be washed thoroughly after handling any mineral known or suspected to be hazardous.

When removing a specimen from a cleaning solution, gloves are preferred over tweezers or tongs. Glove-covered fingers provide more 'feel' and thus less chance of dropping the specimen or crushing delicate crystals.

Dust masks: Dust hazards may exist during some mineral cleaning and development processes such as handling chemical powders, cleaning a dusty mineral display or when sawing. When in doubt assume dusts from these processes to be hazardous and therefore protection is needed. The N95 and KN95 masks - familiar from the recent Covid pandemic - are widely available, disposable and generally provide adequate protection. A chemical respirator - significantly more expensive than a disposable dust mask - is not necessary for any procedures detailed in this book. Working in a well-ventilated space or (better yet) outdoors further reduces dust hazards. To be fully effective a mask requires a tight fit to facial skin, so facial hair may be an issue. Wearing a mask with facial hair is better than wearing no mask at all.

Clothing: Proper clothing is important to a proactive safety plan by providing protection from chemical contamination and burns from fire. For working in the mineral lab, 'normal' clothing should provide maximum protection. Long pants must be worn, with heavy jeans preferred instead of lighter fabrics. Shoes should not be opened-toed. Sneakers are less preferable to heavy work boots, especially boots with steel toes. A lab apron or coat made of flame-resistant cloth is an excellent wardrobe addition. A normal kitchen apron of cloth does not provide much protection against chemical spills whereas a plastic apron provides good protection against most spills but

does not resist fire well (and the hot melted plastic may cause additional injuries). The apron (or better yet) a fire-resistant lab coat should be of a type easily and quickly removed if it becomes contaminated or catches fire.

Do not eat, drink, smoke or vape in the workspace. Save these activities for outside the workspace where there is less chance of ingesting contamination or igniting a fire if chemicals with flammable vapors are in use.

Fire extinguisher: A fire extinguisher, as its name implies, is a device to put out fires. Several types are available through hardware or home supply stores. Select an ABC (dry powder) type for the mineral workspace. This extinguisher type propels a powder to smother the fire. An extinguisher's pressure charge typically lasts several years unless it is discharged to fight a fire. Recharge or replace the extinguisher when indicated by the gauge. Store the extinguisher where it is readily accessible.

To use a fire extinguisher, use the **PASS technique** (OSHA 2025):

1. **P**ull the pin.
2. **A**im at the base of the fire.
3. **S**queeze the handle to discharge the extinguishing agent.
4. **S**weep the discharge back and forth across the base of the fire (and then wherever else needed) until the fire is extinguished. Wait a few moments to see if the fire re-ignites.

First aid kit: A well-stocked and up to date first aid kit should be stored where it is easily accessible. These kits are readily available at many drug stores, hardware stores and home supply stores. Before commencing work in the mineral workspace, learn about basic first aid kit use (Sheba 2019). First aid is only the first step in wound care. Seriously consider professional medical help, especially if a burn is extensive or a cut is deep, wide and/or continues to bleed.

Poisoning: Poisoning from the chemical methods described in this book is unlikely if proactive safety and common sense are used. Take reasonable measures to avoid ingesting chemicals by not eating, drinking, smoking or vaping in the workspace. Wear chemically resistant gloves. If a procedure produces noxious vapors work outside. During any chemical procedure the workspace must be well ventilated. Children and pets must be kept away. Consult appropriate **SDS (Safety Data Sheets)** or **MSDS (Material Safety Data Sheets)** for all chemicals used. These are readily available online. A notebook having copies of this information immediately available if needed is a good addition to the workspace and proactive safety.

If poisoning is suspected immediately contact emergency medical services and the local poison control center. If a poison is ingested do not induce vomiting unless instructed by emergency personnel. If fumes are the issue move to a well-ventilated space, preferably outdoors. Learn more about basic poison prevention and treatment (Mayo Clinic 2024b) before beginning work with any hazardous chemical.

Method-specific hazards are covered in the detailed discussion of each mechanical and chemical method presented in this book. Mineral-specific hazards such as radioactivity and toxicity are also discussed in later chapters.

2.2 Workspace

The ideal workspace for mineral cleaning and development has certain requirements discussed in the following paragraphs. Key among these requirements is safety. *The workspace location and equipment should be made with the key points of Section 2.1 in mind.* A permanent space, dedicated to the task, is ideal. A temporary space is usually more troublesome than worthwhile, because of setup/teardown, electricity, water, safety, etc. issues. Good ventilation is often needed for which a well-ventilated indoor space may be suitable, but some procedures are best executed outdoors. Never use the kitchen or bathroom, due to safety hazards and the mess created by certain cleaning and development tasks.

The workbench top (ideally) will have good chemical resistance. Laboratory bench tops are usually made of soapstone, slate or an artificial equivalent. A wood benchtop is acceptable but expect it to become damaged and stained. Cover the wood benchtop with a plastic sheet to allow rapid cleanup of spills. If possible, coat or seal the workbench surface with chemically resistant paint or epoxy. An overcrowded workspace is another safety hazard, so the bench should also have adequate surface area so that projects and equipment are not crowded together. Excess workspace is far better than not enough space.

The bench should also be close to a tap water source unless hauling a bucket of water every now and then is acceptable. Avoid routing water to the workspace via a garden hose, as this may create a tripping hazard. A sink is also very useful, but because odors of solutions washed down the drain might carry into the house, this sink should not drain into the household sewage line. Most chemical wastes produced by methods in this book should be rinsed down an outdoor drain (not an indoor drain) as described in each individual method's instructions.

The workbench should also have an adequate electrical supply with numerous sockets. Avoid plugging more than one device into a socket, as this can create an electrical hazard. Each socket should have ground fault circuit interrupter protection (GFCI; also called GFI). Avoid routing electricity to the workspace via extension cords, as this may create a tripping hazard.

Good lighting is essential. Poor illumination is another safety hazard. The workspace should be equipped with some basic safety equipment, including a personal eyewash, a fire extinguisher and a first aid kit. Storage space is another necessity, with room for possible expansion.

2.3 Before Cleaning or Developing a Specimen

In this section are presented things to have in mind before conducting any procedure given in this book.

- **Review and always obey safety procedures (Section 2.1)!**

- Minimize handling including trimming, sawing and brushing of toxic, asbestiform and radioactive specimens. Always wear gloves. A dust mask and working outdoors are needed if the procedure creates dust. Wash hands and face immediately afterwards.

- Not every mineral species can be exposed to every method described in the following chapters. Be aware of a specimen's physical and chemical properties before planning a procedure. Such properties include hardness (Mohs), cleavage, brittleness and chemical compatibility. Consult the **Mineral Properties and Compatibility Tables** (www.mincleandev.com). Additional information can be gleaned from Sinkankas (1972).

- It is frequently necessary to apply multiple mechanical and/or chemical procedures to complete the cleaning plan, or to repeat the same procedure several times. For example, initial sonication, derusting then trimming may reveal rust accumulation hidden within the matrix. In this case additional derusting and sonication are necessary.

- Wetting (or more generally soaking in water) prior to cleaning is often recommended to close pores and prevent entrance of cleaning agents. This is nonsense! If clean water can invade pores and cracks, then what prevents a cleaning solution from mixing with the water in these same pores and cracks?

- A specimen suffers **thermal shock** when it is subjected to large, rapid temperature change, such as placing a specimen at room temperature into a hot water bath (or a hot specimen into cold water). Heating causes expansion and cooling causes contraction. A rapid temperature change frequently causes cracks and breakage. Borosilicate glass (usually labeled as Pyrex or Kimax) has a low thermal coefficient of expansion - it does not expand or contract very much during temperature changes - so a Pyrex baking dish can be taken from the hot oven and placed on a cool dinner table without danger of cracking. Minerals that are already cracked, have inclusions (solid, liquid or gas; Figure 2-2) or are easily cleaved are more likely to be damaged. A spot where crystals meet can also be a source of thermal shock damage, because these minerals may expand or contract at different rates. A specimen may have internal stress not visible to the naked eye which can be a susceptible to thermal shock damage as well. It is best to play it safe and assume the specimen is susceptible to thermal shock damage and avoid rapid temperature changes accordingly. For example, at the end of cleaning in a hot chemical bath, turn off the heat source and allow the specimen and solution to slowly cool to room temperature together (often overnight) before removing the specimen from the bath. Also consider that heating occurs during sonication so avoid placing a room temperature specimen into a warm ultrasonic bath (or a warm specimen into a cold bath). Change the sonication bath water frequently if

necessary. It is also useful to allow the water and specimen to equilibrate at room temperature overnight before placing the specimen in the warmer (or cooler) water.

Figure 2-2. These included quartz crystals are prone to thermal shock damage.

For more detail on the physical processes leading to thermal shock damage see Howie (1992, 29–31). For the susceptibility of individual mineral species to thermal shock damage see www.mincleandev.com.

- **Water spots** can be a nuisance. They are especially problematic on highly reflective surfaces such as crystal faces. To minimize water spot formation gently blot dry with a lint-free cloth after any aqueous procedure. (Cotton fibers not visible to the naked eye can appear under magnification or under longwave ultraviolet light.) If the spots persist, rinse with distilled water and blot again. Or just make a habit of always rinsing with distilled water.

- **Lint, hair, fabric fibers and other fuzz** often present a special challenge for complete removal. These annoyances tend to intertwine with crystals making removal with a gas stream difficult. Fuzz must be removed before any aqueous cleaning treatment, as it tends to become even more matted and intractable after wetting and drying. Fuzz which is not removed by gas stream treatment can be removed (with little risk to the specimen) using needle point or hair removal tweezers (Lindstrom TL5-TA or equivalent; Figure 2-3). The process can be quite tedious, and much patience is needed. Use caution with needle-point tweezers as (implied by the name) these tend to be quite pointy and can easily draw blood. The tips are easily bent and rendered useless so store these tweezers with tip protection (perhaps a short length of plastic tubing) in place when not in use.

- If the equipment needed for a task is unavailable to you because it is too expensive or because you don't need it often enough to justify a purchase send the specimen to a friend who does have the equipment (and appropriate expertise) or join a local club which has a well-equipped workshop.

Figure 2-3. Needle point tweezers are quite useful for extracting fuzz, especially from a mat of acicular crystals such as this actinolite variety byssolite.

- Many of the procedures in the following chapters involve water or water solutions of chemicals. To determine when a specimen with porous matrix is completely dry weigh the specimen as accurately as possible, allow it to sit for 24 hours or more, then weigh it again. When the weight does not drop significantly from day-to-day then the specimen is dry. In some cases (an Ojuela Mine limonite matrix or some porous feldspars, for example) this may take a week or more. Avoid hastening the drying process by heating, as many minerals can be damaged by thermal shock (see above). Recall Guiding Principle 2: Patience is your number one mineral cleaning and development tool.

- Written **lab notes** are important when applying a procedure for the first time, modifying a procedure or developing a new procedure. Keeping notes makes it easier to remember what worked and (equally importantly) what failed. Record the notes in a notebook or (better) in a computer document. Before and after photographs are often useful. More detail is better than less detail.

CHAPTER 3: Cleaning and Development Methods

This chapter is the core of this book: Methods for mineral specimen cleaning and development, ranging from dry mechanical methods such as trimming and air abrasion to wet mechanical methods such as sonication to chemical treatments such as derusting and carbonate removal. This is a more logical organization than some other works on this subject which, for example attempt to differentiate wet/dry and physical/mechanical methods. Such a division is confusing: Trimming with a mechanical trimmer or by air abrasion is obviously a dry/physical/mechanical method whereas trimming with the textile gun is a wet/physical/mechanical method. Wet treatment such as derusting is clearly a cleaning method (because iron hydroxides/oxides are usually not part of the normal mineral paragenesis) whereas removal of a carbonate (frequently part of the paragenesis) is not.

For some 'must read' general references on specimen cleaning and development see King (1982, 1983, 1985 and 1986), Pearl (1982; somewhat dated and with some unusual recipes but still worth reading) and Sinkankas (1972).

Read and thoroughly understand the safety and other considerations presented in Section 2.1 before conducting any procedure in this chapter. Review Section 2.3 when necessary, as well the appropriate entry in Chapter 4. The physical and chemical properties of the minerals to be treated by methods in this chapter must also be considered before planning any procedure. If in doubt research this information at the **Mineral Properties and Compatibility Tables** web site (www.mincleandev.com) and the resources listed there before starting work.

The mechanical methods discussed in this chapter can impart some degree of physical force to a specimen, creating a damage risk when cracks, loosely held crystals and other issues exist. In these cases, stabilizing and protecting the specimen by application of removable glue, resin or other material may be necessary. For example, Behling (2011) reports the use of an unspecified epoxy resin to stabilize the matrix while using a saw and an air chisel to remove granular quartz to prepare a significant Kagem Mine emerald specimen. Some general guidelines on mechanical cleaning methods can be found in Sinkankas (1972, 234). Additional ideas are often found in works on fossil preparation; see for example Converse (1984).

Large or heavy specimens may be supported on a bed of sand or bean bags during work. This frees up one or both hands for holding tools, etc., and can aid in positioning the specimen at best angle for work. Easily removed supporting materials such as mineral tack or wax are also useful in these cases. For example, Converse (1984, 34) recommends polyethylene glycol wax 4000 (PEG 4000) for fossil work; this should also work for minerals. This wax has a low melting point (50°C) and is water soluble for easy removal.

Cutting rough is often examined wet to access quality because wet material is closer in appearance to the final polished product. In addition, wet material often 'just looks better.' Apply this observation when using wet methods to clean or otherwise develop a specimen and allow it to dry thoroughly before deciding if further work is needed.

3.1 Dust and Other Loose Debris

Accumulation of dust, hair, fibers and other loose debris - even when displayed in a well-sealed cabinet or closed boxes - is a persistent nuisance for the mineral collector. This annoyance can be significantly reduced or even eliminated by display or storage in an air-tight environment, but this precaution is rarely practical for the amateur collector.

Dust consists of fine particles such as soil, volcanic ash and air pollution particulates as well as dead skin cells, plant pollen, hair, fur, paper fibers and others. These components can make the dust abrasive so removal by wiping with a dry or wet cloth - even minerals having high Mohs hardness (quartz, tourmaline, beryl and others) - can cause micro scratching and thus should be avoided. Dust removal methods which force contact between the mineral surface and the dust particles must be avoided. These same dust components can damage a specimen in what might be a surprising variety of ways, as discussed in Allington-Jones (2017, 3).

Brushing might be considered, but still runs the risk of scratching with soft minerals. When brushing use the softest brush possible, usually a fine camelhair painting or makeup brush. Use only the minimal amount of force necessary to get the job done.

A gas stream is preferred to brushing for dust removal. Breath should be avoided because normal breath excretions can cause hair-like (acicular) crystals to fuse together upon drying. Water vapor, exhaled mucus and other materials ('spittle') can dry on the specimen causing residue spots. Do not breathe on water-sensitive materials such as hanksite. A gas stream devoid of these contaminants is therefore preferable; these are discussed in the following paragraphs.

An electronics duster (also called aerosol duster; Figure 3-1) contains a compressed, liquid propellant which vaporizes upon release. The liquid is usually a hydrofluorocarbon (an HFC; the refrigerant in modern air conditioners and refrigerators) but in some dusters carbon dioxide (CO_2) or dimethyl ether are used (Chemtronics 2025). While readily available and easy to use, these dusters contribute to global atmospheric greenhouse gas loads and so a responsible collector should try to avoid their use. Some of these propellants are flammable and so they cannot be used around open flames or other ignition sources. As the propellant changes from liquid to gas phase it cools significantly. The internal tube connected to the spray head extends only about 1 cm into the can, thus preventing discharge of liquid when the can is held upright. Do not shake or invert the can before spraying as this will cause the release of very cold liquid (as cold as -45^{o}C!) which may cause thermal shock damage to the specimen being cleaned and painful frostbite to the fingers. For an even finer tip to get into deeper crevices or provide a more focused gas stream, warm the plastic outlet tube and draw it thinner (Beckham 2023).

Air is a cheaper, more plentiful, less expensive and a more atmospherically friendly alternative to electronics duster. Common tools to create an air stream for mineral cleaning include a camera lens cleaner bulb, a tire inflator (or other air compressor) and a hair dryer. A camera lens cleaner bulb (Figure 3-1) delivers a very mild puff of air upon squeezing. It is perhaps the gentlest method of using air pressure to clean a mineral and is preferred for micromounts. However, the pressure may be insufficient for more stubborn debris. Large specimens require repeated hand-

squeezed puffs, a process which can become quite tedious. Keeping with the idea of using the gentlest methods first, the camera lens cleaner bulb should be the first choice for cleaning via an air stream. An eyedropper or syringe also both provide very mild air streams.

Figure 3-1. Left: Electronics duster is convenient for removing dust, but at an environmental cost. Right: Squeezing this camera lens cleaner bulb provides a very gentle air puff.

A handheld electric air compressor is also useful. This tool provides an air stream of variable strength and duration, so it is especially useful for larger specimens. (An electronics duster is often the choice in this case, but an air compressor is more environmentally friendly and in the long run less expensive than canned gas.) Lithium-ion battery powered tire inflator tools are readily available from hardware or home improvement stores. Adding the bicycle tire inflation needle at the end of the inflator's hose provides for greater control. When a hot glue gun is also needed, save money and purchase both devices from the same manufacturer so only one battery pack style is needed.

A hair dryer provides an easily controlled, modest flow of ambient to hot air. Although one might be tempted to use hot blowing air to clean and dry a specimen...don't! This air can be quite hot (82ºC from a randomly selected unit) and can easily cause thermal shock damage. Hair dryers tend to collect hair, dust and other debris which can be blown onto the specimen, defeating the purpose of using this tool to clean a specimen in the first place.

Regardless of its source, the gas stream force is easily controlled by varying the distance between the source and the specimen. When unsure start far away and decrease the distance until the desired effect is achieved.

Hold the specimen upside down when brushing or blowing so dust and other debris falls away from specimen. Slowly rotate the specimen so the surface being cleaned is always facing down or perpendicular to the floor.

When brushing or gas jet treatment are inadequate, soap and water, a water jet tool or sonication may be necessary. In any case, remove as much loose debris as possible before any wet mechanical or chemical treatment. Water often causes fuzz and related debris to become matted and (even after drying) significantly more challenging to remove.

Lint, hair, fabric fibers and other fuzz often presents a special challenge for their complete removal. For the mineral photographer, cotton fibers are particularly annoying. It seems that even if no more fibers can be seen before taking a picture, they manage to appear in the final photograph.

This is especially the case for photos taken in longwave ultraviolet light (blacklight) under which these fibers glow a bright blue-white due to fluorescent whitening chemicals added during manufacturing or by a laundry detergent. To test for complete removal of these fluorescent fibers, examine the specimen with a longwave ultraviolet light source and remove any residual fibers with a gas stream or needle-point tweezers. Allington-Jones (2017, 3) suggests using a small piece of Groomstick (an adhesive, moldable rubber product) on the end of a wooden probe - a bamboo sliver or a toothpick for getting into tight spots or working around delicate crystals. (A bamboo sliver is preferred over a toothpick because the former is stiffer and can be sharpened to a finer point.) Standard mineral tack also serves for this purpose. Small vacuum wands or tweezers designed for cleaning electronics, removing solder or even personal hygiene (some with a camera and cell phone app!) may also be useful.

Cleaning filiform minerals is also discussed in Section 3.3 and for specific minerals in Chapter 4. Removing dust from acrylic mineral stands is detailed in Section 5.6C. Wight (1993, 70) provides advice for remove loose debris specific to micromounts.

3.2 Soap and Water

A typical specimen cleaning plan begins with a water rinse, accompanied sometimes with mild detergent and/or very gentle scrubbing with soft brush unless the specimen in question is known or suspected to be water sensitive. Avoid hot water (possible thermal shock damage).

For an initial removal of loose debris, try this modification of a method suggested by Sinkankas (1972, 232): Place the specimens face down in an inclined tub, then rinse with a gentle stream of water. The water carries loose debris to the lowest part of the tub. Continue rinsing until all debris is removed. When the dirty face contains fragile crystals, place the specimen face up. Avoid this procedure for filiform (hair like) crystals.

Sometimes a soak in room temperature tap water with mild dish detergent is needed. Only in rare cases are minerals intolerant to dish soap (usually mildly alkaline). Many soap or detergent products intended for commercial, industrial or laboratory use contain chelating agents (Section 3.15A). EDTA (ethylenediaminetetraacetic acid or its sodium salts) is a commonly used calcium, iron and magnesium chelator. Chelation (especially of calcium in calcite) may cause a lustrous crystal face to become dull or slightly frosted. Check the SDS or label to see if a product contains a chelating agent.

Also avoid cleaning products containing abrasives such as silica (more likely to be present in a solid product than a liquid product). Again, review the SDS or product label.

When soap or any other cleaning agent is used, rinse thoroughly as cleaning agents commonly contain ingredients which fluoresce under longwave ultraviolet. If fluorescence is an issue, rinse thoroughly after cleaning (distilled water is best here) and examine under UV light. Re-clean with a different detergent (or no detergent at all) if needed.

When brushing, use the least amount of force needed, and the softest brush to get the job done without causing damage. Avoid brushing all but the most robust specimens. Better yet, avoid brushing completely. Avoid water with water-sensitive minerals; use an organic solvent instead.

3.3 Cleaning Filiform, Acicular and Other Delicate Minerals

Filiform (hair like) and acicular (needle) crystals are usually quite delicate and therefore require special, gentle techniques for cleaning. Start by using needle point tweezers (also called watchmaker's tweezers or beading tweezers; Figure 2-3) to remove as much hair, fuzz and biological residue (roots, etc.) as possible. Needle point tweezers are also useful to remove glue stringers after mounting. Fluorescent mineral photographers are frequently aggravated by the bright blue-white longwave fluorescence of cotton fibers which persist even after the specimen appears to have been thoroughly cleaned; needle point tweezers and magnification make fiber removal easier. Using needle-point tweezers is tedious work and requires a steady hand to avoid damage but this is the best way to avoid matted or tangled crystals. *Caution! The fine tips of these tweezers are easily bent and needle-sharp.* Good needle point tweezers can be somewhat pricey but can quickly become a very useful tool.

A gas stream can also be used, but it must be only as forceful as needed to get the job done. Start with the lens cleaner bulb before using the compressed gas electronics cleaner (Figure 3-1). Avoid blowing with your breath, as mucus in the breath contains substances which cause crystals to cling together when dry. Try gas stream cleaning before water cleaning, as water can cause some filiform or acicular minerals to become irreversibly tangled or matted.

When liquid cleaning is necessary, consider that these delicate crystals are easily broken by forceful water jet tools such as an oral irrigator or (especially) a textile gun. To clean with a liquid, hold the specimen with the crystals pointing down and at an angle before gently rinsing with water from an eyedropper. Gentle spray from a spray bottle can also be useful to get liquid into deeper recesses of the specimen. (Swishing in a water bath has been recommended by some authors but can easily cause damage.) Continue holding the specimen upside down to allow as much liquid as possible to drain away before setting the specimen upright for final drying. Drying can be accelerated by briefly (and gently!) rinsing with acetone or isopropanol (also called rubbing alcohol or 2-propanol; use 90–99% purity when possible) after the water wash. These organic solvents dissolve the water, evaporate much more quickly than water and are flammable, so their vapors may cause issues; work in a well-ventilated space or (preferably) outdoors.

Use of organic solvents in place of water has also been suggested (for example with xonotlite; Hochleitner and Weiß 2018, 7). Most minerals tolerate this treatment without damage but check www.mincleandev.com first.

Filiform and acicular minerals may also be treated by sonication. Grasp the specimen with tongs (not the fingers) and gently immerse into the ultrasonic bath just enough to cover the crystals. Sonicate for a minute, then check the cleaning progress. Repeat the brief sonication a few times, if necessary, then dry as described above.

Duthaler (2011) describes a method for cleaning delicate specimens using CO_2 gas effervescence. The specimen to be cleaned is completely immersed in a solution containing 60 grams $NaHCO_3$ per liter of water. Slowly add portionwise (5–10 mL or less at a time) a solution containing 200 grams citric acid (the dihydrate or anhydrous forms are both useful). Vigorous carbon dioxide is evolution occurs. Cleaning is provided by the localized mechanical force of bubble expansion. Add the next citric acid solution portion only after reaction of previous portion has mostly subsided. Monitor the cleaning bath pH; an excess of citric acid can cause the solution to become sufficiently acidic to attack some acid sensitive minerals (calcite, aragonite). When cleaning is complete (or fails to progress any further) the specimen is thoroughly rinsed with clean water and allowed to dry.

3.4 Water Jet Tools

Cleaning with a forceful jet of water is one of the most broadly useful methods available to the amateur. Hardinger (2020) provides a useful overview. Water jet tools are useful to remove clay, especially after it has been softened by an overnight water soak. In keeping with the idea of trying the mildest method before moving on to a harsher method water jet tools are discussed below in order of increasing water jet force (and as it turns out increasing effectiveness and usefulness).

A **garden hose** provides an unlimited water volume but with minimal force. Useful mostly for initial removal of dirt and dust.

A **constricted garden hose** (Figure 3-2) provides more force than either an unmodified garden hose or most oral irrigator models and has an unlimited water supply. This device - modeled after the suggestions of Tschernich (1992, 27) and Sinkankas (1970, 279 and 1972, 232) - is simple to make from parts readily available at hardware and home improvement stores (Hardinger 2020). A brass cap which screws over the end of the hose is drilled with a 1/32" diameter hole. (A small hole size is critical to maximum stream focus and cleaning force.) A well-fitting hose washer is placed inside the drilled cap and the cap tightened firmly into place. A trigger can be added by including a squeeze-operated nozzle between the hose and cap. Choose materials to make the device as cost-effective as possible without sacrificing usefulness. Plastic nozzles are usually cheaper than the least expensive metal counterparts which are often cited as failing in their first year of use. While plastic and brass hose caps are of roughly equal price, half the plastic hose caps tested gave holes which produced an erratic, unfocused and/or low-force water stream.

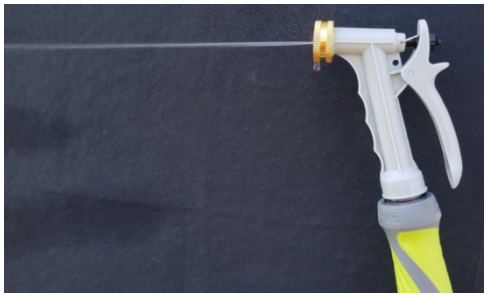


Figure 3-2. A constricted garden hose is easily made with just basic tools and parts.

A **toy squirt gun** or a **laboratory wash bottle** are useful and inexpensive alternatives to the garden hose, but wrist fatigue is an issue when many specimens are to be rinsed or cleaned.

An **oral irrigator** (also called a dental water jet, water flosser or waterpik; Figure 3-3) provides more force than a garden hose. These devices provide a focused, continuous stream of water by pumping from a small tank. Some models have adjustable water stream force. In one unit, the tank holds 600 mL water, which empties in 90 seconds to 5 minutes depending upon the pressure setting. This time is often adequate for cleaning a single specimen which lacks severely encrusted dirt. Although the tank is easily refilled and with some ingenuity can be rigged to remain continuously full (for example with a siphon) an oral irrigator is typically limited to about twenty minutes of continuous operation before the motor seizes. The water pressure produced is weak to moderate so the potential for specimen damage is small but cannot be ignored. Oral irrigators are typically available for $50-100 for a new unit (you don't need a unit with all sorts of bells and whistles) and much less for a used unit at a second-hand store. Overall, an oral irrigator is a moderately-priced but only occasionally useful mineral cleaning tool.

Figure 3-3. Left: An oral irrigator. Right: A textile gun produces a powerful water jet and is very useful for mineral cleaning.

By far the most useful water jet tool for mineral cleaning is the **textile gun** (also called a **spot cleaning gun**; Figure 3-3). This handheld, electrically powered device produces a powerful, pinpoint water jet. Numerous brands are available; there is no general brand preference among collectors. Comparing photos of various brands reveals similar if not identical styles and features, suggesting that units of different brands may in fact be identical in manufacture. While prices vary, this is one of your most important cleaning tools, so don't skimp on quality.

The water stream is quite forceful so work safely. This is a messy tool to use; water and debris spray all over. Work outdoors. Wear an apron or old clothes. ***Safety glasses are absolutely required!*** To attenuate the appreciable discomfort caused by water stream impact on bare skin, a heavy rubber glove (not a thin nitrile glove) should be worn on the hand holding the specimen. Some guns are quite noisy, so ear protection may be required.

Soft or loosely attached materials such as clay, decomposed feldspar or limonite matrix are readily removed. Easily cleaved minerals such as calcite, fluorite, baryte, galena, gypsum, spodumene, kyanite, stilbite and many others are readily damaged. The textile gun can also be used to gently remove soft matrix and further expose crystals therein, as well as for trimming and shaping of such matrix. The powdery, brown limonite matrix common with Ojuela Mine which readily soils the fingers is conveniently reduced or completely removed with the textile gun. Be careful, however, to avoid removing too much matrix as this will weaken the specimen (maybe to the point of falling apart). Remove the last traces of fine dust by sonication. In some instances, a textile gun may be used in place of air abrasion to remove soft, decomposed and/or poorly cohesive matrix. For this purpose, the textile gun is a more economical and more easily mastered tool.

With practice and by maximizing the distance between the gun and the sample easily cleaved minerals can often be cleaned without damage. Thin plates such as prehnite should be supported from behind with the palm of the hand (or when in doubt the textile gun is not used). Water sensitive minerals such as halite and hanksite cannot be cleaned with a textile gun. When a lower or higher water pressure is needed, do not adjust the nozzle or other gun settings as this can lead to premature failure. Fine tune the water pressure at the specimen by starting with the gun and specimen at arm's length then slowly bring the gun closer to the specimen until the desired cleaning effect occurs. Bathe the specimen in the water stream until the runoff is clear, or if some damage has occurred, until the accumulated damage outweighs the cleaning effect.

Changing the water stream's angle of attack by holding the gun still and rotating the sample can also be effective. In some cases, directing the stream perpendicular to the specimen surface will be most effective whereas in other cases a water stream at shallow angle or parallel to the specimen surface is better.

As with any other mechanical or chemical cleaning method involving water, pay attention to thermal shock by using water which is the same temperature as the specimen being cleaned. Warm water provides no cleaning advantage over cold water but might be somewhat more comfortable for the user when many specimens are to be cleaned in the same session.

A typical textile gun with a full tank can weigh two kilograms so prolonged use can lead to wrist fatigue. Sitting down and resting the gun on a knee avoids this. A five-gallon bucket makes a convenient stool. When sitting change the distance and angle by manipulating the specimen instead of the gun.

During prolonged use the gun can become quite warm, perhaps even hot enough to cause a minor burn. Not only is a warm textile gun uncomfortable to grip, but overheating can also cause a malfunction. If the gun becomes too warm to hold allow it to cool before using it again. This precaution protects both the operator's hand and the gun's operational lifetime.

After a using a textile gun safety glasses lens may be covered with debris. *Imagine safety glasses were eschewed and there was nothing to protect the eyes from assault by all this stuff!* Simply wiping the glasses can cause the accumulated debris to scratch the lenses. Instead, rinse thoroughly with clean water before towel-drying.

Some users find their unit malfunctions after only a few uses while others rely on their gun for years without an issue. The key to a textile gun's longevity is proper treatment after use. When cleaning is done, remove the water tank and run the gun for a few seconds until all water is expelled from the inner workings. Every tenth session or so apply one or two drops of high-quality machine oil (such as 3-in-One Multipurpose Oil) to the oil hole. Invest in the life of your gun by using a high-quality oil; cheap oils tend to decompose over time, becoming gummy and hindering the gun's smooth operation. If oil blows out of the hole during operation, the gun is being oiled too frequently. A new textile gun should be oiled before its first use. With proper maintenance, a high-quality gun will last years, even with heavy use.

Although designed to work with organic solvents, no chemicals should be used with a textile gun. Cleaning chemicals require time - even if just a few seconds - to work but the water stream/specimen contact time is much too short for effective chemical action. In addition, chemical solutions may damage the gun's inner components. Mist containing cleaning chemicals created by the textile gun may be an inhalation hazard ranging from mildly irritating to life-threatening.

Lint, hair, fabric fibers and other fuzz often present a special challenge for their complete removal with a water jet tool. Very fine crystals tend to be quite delicate and easily broken by the force of most water jet tools. A brief, gentle water stream from an **eyedropper** or **syringe** (with or without a needle) is useful in such cases.

Avoid a **high-pressure washer** of the type used to forcefully clean concrete and other surfaces. Except for large, robust specimens this tool will do more damage than good to precious minerals. Duthaler and Weiß (2024, 25) suggest steam cleaning, but this creates a significant and unwarranted thermal shock risk. Although surprisingly frequently recommended also avoid placing minerals in the **dishwasher**, as the forceful water streams may damage your specimens. Dirt and mineral fragment residues easily clog the filters and drain. These residues are violently tossed about and may damage the dishwasher (at which point the spouse may damage the collector).

3.5 Ultrasonic Cleaning (Sonication)

An **ultrasonic cleaner** (Figure 3-4) is a device which uses high frequency sound (typically 20 to 40 kHz) for cleaning. (Humans can hear about 20 Hz to 20 kHz whereas dogs can hear up to 60 kHz.) Rapidly vibrating transducers mounted underneath the cleaner's tub produce high frequency sound waves, forming millions of microscopic bubbles (cavitation) in the water. Collapse of these bubbles releases enormous energy (localized temperatures to 5,000 K and 135 MPa) which in turn causes localized shockwaves (high pressure). This results in breakup and dislodging of particles from an object's surface. Exposure to ultrasonic energy is often called

sonication. Like the textile gun the ultrasonic cleaner is an indispensable tool which should be in every mineral collector's cleaning laboratory.

Figure 3-4. A typical laboratory-grade ultrasonic cleaner with basket and timer. This unit has a six-quart capacity, adequate for most mineral cleaning jobs.

When **selecting a cleaner**, the following should be considered: capacity, drainage, timer, basket, power output and cost. If micromounts or miniatures are the only specimens to be cleaned, two-quart capacity is adequate. For larger specimens or numerous specimens at a time, a larger unit - typically six quarts - is needed.

A drainage port greatly facilitates changing the bath water and is thus a convenient but optional feature. A built-in timer is another useful but also optional feature. A heater is not useful and in fact may lead to thermal shock damage.

Specimens must not be placed on the bottom of the tub as this can damage the transducers, so a method for suspending the specimens is needed. A basket specifically designed for the unit is optimal, but any other suspension method can be used. Some collectors use a produce net or cheesecloth. Others hold the specimen with their fingers, but this should be avoided (see **Safety notes** below).

The device must have sufficient power output to provide effective cleaning. Most scientific and industrial models meet this need. Avoid units designed to clean jewelry ('jewelry ticklers') as these are generally too small and of insufficient power. Adjustable power and sound frequency are not necessary (or even particularly useful) features in an ultrasonic bath for mineral cleaning.

An acceptable price depends upon one's budget and needs. If frequent use is anticipated, a larger unit which costs more is needed. Quality new units can be expensive, whereas a used unit will be cheaper. At the time of this writing a new 6.5-liter capacity Branson unit (Figure 3-4) is priced at $1200–1400, whereas other less-known brands having similar capacity and features can be had for $150. (Although Branson ultrasonic cleaners can cost $1200 or more the unit shown in Figure 3-5 was salvaged from a university discard pile. All it needed was a standard electrical cord!) Similar used units are available for significantly less (Amazon, ebay). Tony Nikischer of Excalibur Minerals (Nikischer 2023) recommends the Raytech TS-6000 digital ultrasonic cleaner. This unit has all the features needed for routine mineral cleaning and at the time of this writing is available for a very competitive price. For more on ultrasonic cleaner selection see Best Technology (2025).

General notes on ultrasonic cleaning of minerals can be found in Sinkankas (1972, 233). Start by filling the tank to the indicated volume with clean, room temperature tap water. (Distilled water is a waste of money because cleaning minerals will just make the water dirty.) Warm water may be more comfortable for the operator but does not make the cleaning any more efficient. *Pay attention to the possibility of thermal shock*. Operating the ultrasonic cleaner with the bath level too low is a common cause of failure, especially in less expensive units. Add a squirt of household dishwashing detergent; this assists the cleaning action as a surfactant, lifting dirt from the specimen surface and keep it suspended in the water. Numerous specialized ultrasonic cleaning detergents exist but their expense is not justified for cleaning minerals. When removing clay, cooking or smoking residues use a few mL of household NH_3 instead of soap.

Remove as much dust and other fuzz as possible before sonication.

Place the specimen(s) in the basket, with the side to be cleaned facing towards the bottom of the tank (towards the transducers). Cleaning is more effective this way. Sonication occurs throughout the bath water, so if the one side is delicate effective cleaning can still occur if this side faces away from the transducers. Avoid placing anything directly on the tank floor as this added weight can reduce the transducer lifetime. (Transducers are essentially irreplaceable so treat them with respect.) If the absence of a basket designed for the specific ultrasonic cleaner, one must either purchase a basket (a worthwhile investment) or use some ingenuity to suspend the specimens in the bath. Some collectors use a mesh produce bag for this purpose. Very small items can be placed in a small water-filled container (jar, beaker, etc.) which rests in the basket (not on the tank floor). The container must be heavy enough to remain submerged. A glass jar is a better choice than a plastic bottle because plastic attenuates the ultrasonic wave energy and decreases cleaning efficiency (Sinkankas 1972, 233). Use this 'double bath' technique in the unlikely circumstance that a sonication during chemical treatment is needed.

Don't overload the basket. A single layer, spaced out, is best. An overloaded basket greatly reduces the cleaning effectiveness. Running two loads takes more time than a single load but is more effective. *Recall that patience is the primary mineral cleaning tool*.

The time required for effective cleaning depends upon several factors including basket load, nature of the specimens and the dirt to be removed. In some cases, only a few minutes are required for complete cleaning and in others, hours may be needed. Typically, one should clean for 30 minutes, remove the specimen from the bath and blot dry. (A lint free rag is advised to avoid fibers contaminating your freshly cleaned specimen.) Examine the specimen (magnification is useful) to judge if cleaning is satisfactory. If not clean again for another 30 minutes. A shorter time is advised for specimens which might be damaged by sonication (see below). Small specimens are effectively cleaned on all faces simultaneously. As the specimen size increases, the cleaning effect is decreased on the sides and top. It may be necessary to position the specimen on its side for sonication, and/or rotate 180 degrees between cleaning cycles for maximum cleaning effect. Cleaning is faster when the surface being cleaned is hard (such as quartz or gemstones); in these cases, a few seconds to a minute may be adequate. Soft, flexible or resilient surfaces or deposits (clay, cookeite, chlorite, etc.) usual take more time; several minutes to an hour or more is common.

Sonication for 10–30 minutes is routine unless the mineral is known to be particularly sensitive to sonication.

When the water is clean, the progress of cleaning can be seen by 'clouds' of dirt being released from the specimen. The absence of such clouds does not mean cleaning is complete or that no cleaning is occurring; the amount of dirt removed may be too small or the water may be too dirty to observe the effect.

Ultrasound imparts energy to the cleaning medium, so the bath temperature will rise over time. In one set of experiments, a temperature increase of 7–12^{o}C was noted during one hour with continuous sonication of 6.5 L of clean water and an empty basket. Do not place a room temperature specimen in a warm cleaning bath (thermal shock damage). Change the water if it becomes too warm,

Safety remains paramount! Mineral specimen sonication will result in dispersal of soluble and/or very finely divided, insoluble materials in the bath water. These materials may include H_2SO_4 from decomposing sulfides and dissolved toxics such as arsenic, lead or thallium. In one experiment, sonication of heavily decomposed pyrite caused the bath pH to drop from 7 to 2.5 after thirty minutes. When cleaning acid sensitive minerals or after cleaning sulfides (sulfide decomposition products tend to be acidic). Monitor the bath pH frequently. Change the bath water if the pH drops below 6–7. Some of these bath contaminants will irritate and/or be absorbed through the skin. As a precaution always wear gloves when placing specimens into or removing them from the ultrasonic bath. Some workers advise using tongs for this purpose, but gloves provide a surer, firmer grip and thus reduce the possibility of dropping or otherwise damaging the specimens.

Do not place your hand in an operating ultrasonic cleaner; unprotected and repeated or prolonged exposure to ultrasound can cause a range of biological effects, from mild discomfort to pain to significant tissue damage. A thick rubber glove provides some protection from ultrasound but is still far from optimal.

Use only water in the tank. Some chemicals may attack the steel tank. Vapors created by sonication of organic solvents create inhalation and fire hazards (but see below).

An ultrasonic cleaner normally creates a buzzing sound during operation. This buzzing may sometimes be rather loud, in which case ear protection should be worn.

For more on information on ultrasonic cleaner safety see for example Iultrasonic (2025) and NIST (2025).

To sonicate or not to sonicate? Some authors advocate only very limited use of ultrasonic cleaning for mineral cleaning, while others reject it completely. Many mineral species tolerate sonication well, but some sensitivities must be considered. In some cases, reports of sonication incompatibility stem from thermal shock damage caused when a specimen at room temperature is placed in a hot water bath. Hard, nonabsorbent specimens are cleaned more effectively than soft or porous ones. Sonication compatibilities for many species are listed in Chapter 4 as well as at www.mincleandev.com.

Cracking is possible due to thermal shock but can also occur in specimens having good cleavage or inclusions (especially liquid or gas bubbles). Species with good cleavage which may (or may not) become cloudy or crack when sonicated include baryte, calcite, fluorite, galena, kyanite, spodumene and others. Note that sonication-induced cracking is a *possibility* and *not* (as some authors insist) *a certainty*. Sury (1991) suggests that crystals with internal stress (inclusions), hairline cracks, specimens with cracked matrix, needle or acicular crystals should not be sonicated. This is perhaps an overly paranoid philosophy, as some specimens with one of these properties can be stable to ultrasound. Ultrasonic energy reaching the specimen (and consequently possibility for damage) may be attenuated by placing the specimen in a water-filled plastic container fully immersed in the bath. Sury also recommends limiting exposure time to no more than one minute (20–30 seconds is typical), but again, this depends on the specimen and its contaminants; exposure times of 30 minutes or longer are frequently successful. As always, experiment with lower quality material before subjecting your best material to an untried procedure.

It is not necessary to replace the water after every cleaning cycle, but very dirty water (Figure 3-5) is a less effective sonication medium than clean water and can sometimes carry acidic contamination which may damage sensitive specimens.

Figure 3-5. Time to change the water!

Soft and/or friable matrix such as clay, marl (for example with pyrite from the Ampliación a Victoria Mine, Spain), kaolinite (for example with azurite from the Malbunka Copper Mine, Australia) or gypsum (for example with boleite from the Amelia Mine, Mexico) may disintegrate. Very soft minerals such as gypsum may become frosted; this is most likely a combination of the mineral's softness (Mohs hardness 2) and its moderate water solubility. Caution is advised when considering sonication of jewelry and cut stones (GIA 2015).

Before proceeding check cleavage, hardness and acid sensitivity Chapter 4 and www.mincleandev.com. When in doubt follow the Guiding Principles by trying ultrasonic cleaning on a lesser specimen of the same species and (if possible) from the same locality before risking a better piece. Sonication-sensitive minerals may sometimes be cleaned without damage by placing first them in glass (not plastic) container (plastic attenuates sonication energy much more effectively than glass). The container is filled with the sonication medium then placed in the cleaner's basket (never directly on the tank floor) and sonicated in the usual way. As always test with low quality material first before committing your best specimens.

To sonicate a water-sensitive mineral, a nonaqueous medium can be used (Hardinger 2024b). Place the specimen and cleaning medium (xylene) in a glass bottle with lid and sonicate as needed. (Some plastics may be attacked by organic solvents.) The bottles need not sink to the basket; cleaning can still be effective if the bottle floats. The used cleaning medium can be reused until it becomes significantly contaminated.

3.6 Picking, Brushing and Scraping

Cleaning some specimens will require removing a surface coating. If dust is the issue, use only the gentlest methods for removal. Ideally, coatings of almost any sort can be removed by air abrasion but many amateurs do not have the necessary budget or skill for this technique. If the coating is thin, try ultrasonic cleaning. A thin brown or black coating of iron hydroxides/oxides (rust) is often removable by dithionite treatment, whereas thicker rust coatings require more vigorous methods such as hot oxalic acid. A black coating not removed by dithionite or oxalic acid treatment might be a manganese hydroxide/oxide crust. Picking and brushing can be quite effective to remove clay from all but the softest minerals such as gypsum and calcite (Pearl 1982, 35).

When these methods fail more rudimentary measures, including mechanical brushing and scraping, may be needed. Brushing is preferred to scraping because the latter is more aggressive and more likely to damage the specimen in some way. Consider mineral hardness and cleavage when applying these methods. Chemical methods (for which hardness is irrelevant) may be preferred to picking, scraping or brushing.

When choosing a picking tool, consider hardness: Wood toothpicks or bamboo splinters are acceptable for most minerals except the softest species such as gypsum or calcite. Steel dental tools (common steels have a Mohs hardness of 5–6) can only be used for harder minerals such quartz, tourmaline and beryl. Whether using wood or steel tools, always check for compatibility on an inconspicuous portion of the specimen.

When brushing, start with the softest brush possible. A camelhair brush is very soft and pliable and can be used on all but the most delicate minerals. A nylon brush (such as a toothbrush) is stiffer than camelhair and notably softer than a brass or steel wire brush. Brass or steel wool can be used instead of a brush of the same material. Use a manual brush before trying an electric (rotary) tool; the rotary tool makes the process faster but is somewhat more brutal.

Apply only the minimum force to achieve the desired effect, as excessive force may leave scratches. Experiment with cleaning a small area first (or better, a poorer quality specimen from the same find; Guiding Principle 5), away from the main face of the specimen, before committing the entire specimen.

In one series of experiments a nylon toothbrush was found to scratch gypsum (Mohs hardness 2) and calcite (Mohs hardness 3) but not fluorite (Mohs hardness 4). Brass and steel brushes were found to scratch fluorite but not amazonite (Mohs hardness 6 to 6 1/2); in both cases a metallic residue (burnished surface) was left behind. This residue is often not removed by sonication alone but instead required soaking in concentrated HCl 15–60 minutes followed by

sonication. The acid soak/sonication cycle is repeated as needed until the residue was fully removed.

Thoroughly clean any brush before using it again, as trapped particles may scratch the next specimen. Avoid using toothpaste, as some brands contain silica, feldspar or other abrasive additives (Colgate 2025) which may scratch minerals softer than quartz. Sinkankas (1970, 286) suggests some encrustations (especially on hard surfaces) can be removed by "brisk scrubbing with stiff brushes using thin slurries of pumice powder or carborundum grit." This should be considered as a last-choice method because scratches to the underlying surface may very well result. Sinkankas does note that pumice (which is softer than carborundum) has been used to remove cookeite from pegmatite pocket minerals such as tourmaline. Like Sinkankas, Rohner (2000) recommends "removing the last traces of dirt with abrasive or polishing agents...even ordinary toothpaste." Cleaning with an abrasive will often leave the surface with an unnatural gloss, with concentric, circular or parallel, straight scratches will visible under magnification.

Scraping and picking at a coating is more brutal than brushing and should be considered a 'last ditch' approach. As with brushing, try a softer tool (bamboo splinter or wooden toothpick) before harder tools (steel sewing needle or small sharp knife). A wooden toothpick scratches gypsum but not calcite. Steel tools will scratch most minerals whose Mohs hardness is less than 7. Picking or scraping must be used with caution on easily cleaved minerals.

Coating removal by air abrasion is usually preferred to scraping as air abrasion is more precise and with the proper abrasive choice reduces chance of collateral damage.

Coating removal is not always advised (Figure 3-6). The coating may be ingrown with the underlying mineral, leaving a scarred, etched or otherwise rough surface. This situation is common with chlorite coatings on quartz. Removing an overgrowth of a rare or otherwise interesting mineral - especially when the underlying species is much less interesting - should be avoided (Figure 1-6).

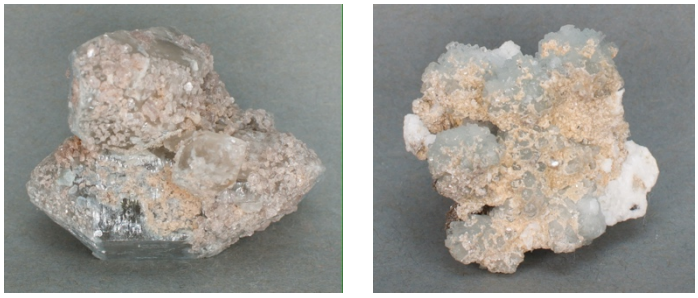


Figure 3-6. Removing the cookeite overgrowth on this quartz cluster (left) or muscovite from this aquamarine cluster (right) would likely leave dull and pitted faces.

3.7 Trimming

Trimming (also called **formatting**) is the removal (reduction) with physical force of some portion of a specimen, such as excess matrix or damaged crystals, to improve the specimen's aesthetic or other appeal. 'Trimming' is often applied to any matrix reduction technique including sawing or chemical treatment but for our purposes the term is matrix reduction via a pressure tool. (Removal of matrix by chemical means, such as acid dissolution of calcite is not, for our purposes, trimming.) The mechanical device to achieve this reduction is called a **trimmer**, breaker or stone press. For general reading see Sinkankas (1970, 281).

A trim may be executed with the goal of producing a more pleasing form (square is often considered best, followed by rectangular, with triangular being least appealing, but this is all in the eye of the beholder), emphasizing the specimen's best crystals (by removing excess matrix or damaged areas while leaving a pocket intact) or most interesting associations in the middle of specimen, produce a specimen which is self-standing, etc. Widening a cavity opening to better reveal its crystal contents is another common reason to trim. Trimming can also be done to reduce the size for a particular collection focus such as thumbnail or micromounts. A dealer might seek to increase economic value by breaking up a larger specimen - often harder to sell - into several smaller, less expensive and usually more quickly sold specimens (Gabriel, M. 2024). Trimming is a common procedure with which all collectors should have some experience. It is both a science and an art, requiring time and practice to gain mastery. Figure 3-7 shows an example.

Figure 3-7. A vanadinite specimen before (left) and after (right) trimming barren matrix with the Zuber MP-5 hydraulic trimmer (Figure 3-9).

An old, imprecise method for trimming involves unfocussed brute force: Place the specimen on a solid surface and pound with a hammer and chisel (Figure 3-8). While this might be more economical, it is usually very imprecise for all but the very roughest of trims, and so the outcome will, very likely, be far less acceptable than if a screw or hydraulic pressure trimmer (described below) is used. This caveman trimming method also imparts significantly jarring energy to the specimen, quite probably cracking or dislodging easily cleaved or poorly adhering crystals. If you must use this method (perhaps the rock is just too big, or you don't care if the result is trash), then use a wooden railroad tie or iron anvil for the hard surface (a big rock is generally not flat or

steady enough), a rock hammer or small sledge (a carpenter's hammer is too soft, resulting in flying metal shards) and a rock chisel. Eye and hand protection are an absolute must (Smith 2005).

Figure 3-8. An archaic, imprecise way of trimming.

The two most common modern trimming methods involve sawing or a concentrated force at the edge of one or two triangular points (chisels) via a press. In a chisel trimmer, force is applied to the hardened-steel chisels via a hand-tightened screw or by hydraulic pressure. Less expensive trimmers tend to employ just one chisel whereas more expensive units such as the Zuber MP-5 (Figure 3-9) use two. When only a small or very precise trim is needed, a vibratory impact tool or air abrasion are often better choices than a chisel trimmer. The Zuber trimmer was first introduced in the 1980's and remains the 'gold standard' among commercially available trimmers on the market today. A Zuber knockoff was also marketed some years ago, but its quality is suspect and should probably be avoided.

Figure 3-9. The Zuber MP-5 screw and hydraulic trimmer.

Commercially available chisel trimmer styles have varied and evolved over the years (Wilson 2008). Three 19th-century screw trimmers are illustrated in Figure 3-10. These trimmers are all quite rare, so consider yourself lucky if you happen to acquire one.

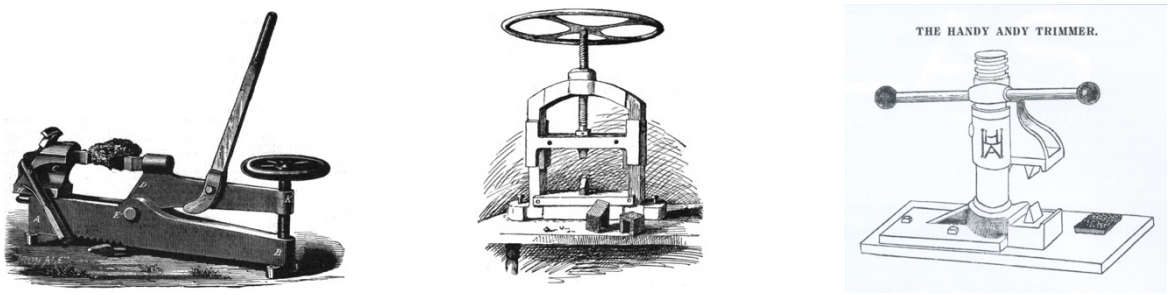


Figure 3-10. Trimmers from the 19th century. Left: Canfield Mineral Dresser as advertised by A. E. Foote in 1880 (Foote 1880). Center: George English's Improved Mineral Trimmer from his 1894 catalog (English 1894). Right: Handy Andy Trimmer advertised by Roy Hopper in 1899.

In the 1960's and 1970's popular commercial units included the Yost and Meister trimmers (Figure 3-11). The Yost trimmer, essentially a C-clamp with screwed chisels stabilized by a crossbar, was available in steel and a cheap aluminum alloy knockoff. The aluminum units were rather useless, as they tended to warp and break easily. The Wydar trimmer (Figure 3-11) is similar in design to the (steel) Yost, but no longer available. Used Yost, Meister and Wydar trimmers rarely appear for sale, but in general these remain very reliable tools.

Figure 3-11. Screw trimmers. Left: Meister design. Right: Wydar design.

Several ingenious homemade trimmer designs are presented in Figure 3-12. Fox (1941) gives details for a homemade trimmer specifically for micromounts. The Swarf Systems trimmer (www.swarfsystems.com) is especially well designed, sturdy and affordable. Designs based on a pipe vise are described by Agos (1969) and Toothaker (1939); the latter modified by Morong (1996). Kidwell (1895), Grenzig (1918), Levison (1919) and Yedlin (1976) supply details for a splitter having a standard bench vise as its core. Additional hydraulic designs are given by Hinman (1965) and Yedlin (1973a). Modified brick or paving tile splitters have also been used, as have drill core splitters.

Figure 3-12. Homemade trimmer designs. Left: Scott Braley. Center: Donald Lapham. Right: Swarf Systems.

Selecting a trimmer. Among the collector community, opinion is divided as to which trimmer style is better. A screw trimmer supplies less breaking force than a hydraulic trimmer but offers more 'feel' (feedback) and greater control over the applied force. A screw trimmer requires more human-applied force to achieve the same trimming effect as a hydraulic trimmer. Screw trimmers require less maintenance and are usually less expensive than hydraulic trimmers. Trimming smaller or more delicate specimens are best done with less force and more precision, so a screw trimmer should be selected for this task. (Very small trim jobs - requiring exquisite precision - may be best accomplished with a vibratory impact tool or tile nippers.) Trimming larger specimens or those with tougher, thicker matrix require more force, best provided by a hydraulic trimmer. For the collector who trims a wide range of specimens frequently, one trimmer of each style is necessary. Having one smaller trimmer for miniatures and micromounts and an additional larger trimmer for larger specimens can also be useful.

When considering purchasing a trimmer invest in the best as inexpensive units have a reputation of short lifetimes. Used units - especially of higher quality - are hard to find but may occasionally be found at a mineral show or an online auction site.

Construction of a homemade trimmer (Figure 3-12) requires machinist skills and a suitable shop, with design and construction being fun challenges. Be aware that homemade units may have safety hazards above and beyond those of engineered and tested commercially produced units.

Whether the trimmer is commercial or homemade, screw or hydraulic, the force available at the chisels and the precision of the trim are both improved when the trimmer is very stable. The all-steel construction of the Zuber MP-5 provides this durable unit with a heavy, stable base and a well-controlled trimming experience. In other cases, bolting to a workbench is usually adequate. Only when the matrix is soft and the specimen is small can a fully handheld unit be used, but in this case two hands are required for the trimmer leaving none to secure or catch the specimen. Stability is a critical issue when considering which trimmer to procure.

Chisel force can also be improved with 'cheater bars' - sliding lengths of sturdy pipe over the screw handles increases leverage.

In some units such as the Zuber MP-5 chisels may be interchanged. If this option is available, secure a set of chisels with different angles for different matrix types. Chisels with a narrower inside angle (such as 45^{o}) are better for a softer matrix such as Ojuela Mine limonite

(wider chisels tend to crush, instead of break, soft matrix). Wider angles (such as 90º) are routine chisels, suitable for harder matrix. A little practice with the various chisel and matrix type combinations will give you a feel for which chisel to use in each circumstance. If your budget allows, invest in a variety of chisels.

When a chisel needs repair or replacement, buy a new one instead of regrinding the tip. To avoid spalling under high pressure these chisels are made of hardened steel. Heat caused by grinding may destroy the steel's annealing, leading to dangerous failure when under pressure. If choosing to grind an old chisel have the work done by a skilled metal shop.

After reviewing the prices of quality mineral trimmers, the budget-minded collector might think to avoid an 'expensive' trimmer and instead use a hammer and chisel (just like in the field; Figure 3-10) especially for large specimens. This is a bad idea! Trimming this way is imprecise in both the force and placement of the chisels; crystals may be lost, and the specimen may not split where desired. More significant is possibility of severe hand injury if the hammer slips. If a good quality trimmer is unavailable ask a friend with the appropriate equipment to trim the specimen for you.

Additional, inexpensive trimming tools include pliers, tile nippers and horse hoof trimmers. These are suitable when the matrix is thin or to crush small matrix nubs around the edge of the specimen. Large specimens or those with particularly tough matrix (such as Deccan Traps basalt) are often best given their initial trim with a saw. A vibratory impact tool, familiar to fossil preparators, may also be useful. Friable or soft matrix (such as Ojuela Mine limonite or Ampliación a Victoria Mine marl) can sometimes be carved with a small, sharp knife or file. This leaves the specimen with an unnaturally smooth, carved appearance which can often be roughened up a bit by textile gun treatment or brief sonication.

Not every specimen which can be trimmed, should be trimmed. *Trimming is irreversible.* It cannot be undone if the matrix breaks in the wrong direction or if crystals that were to be retained are lost. Avoid any temptation to trim excessively. A proper trim produces a specimen having an aesthetic balance of both crystals and matrix. Over trimming can result in weakened specimen integrity, loss of associated minerals, increased chance for undesired fracture and other issues. Recall Guiding Principle 4: "When unsure...don't."

Wilson, Dunn and Bentley (1986) have published a thoughtful discussion on the scientific, philosophical and esthetic aspects of mineral specimen trimming which is a must-read for every mineral specimen preparator. Also consult Pezzotta (2018). Gabriel, M. (2024) asks "Is it worth dividing up specimens in order that more collectors can have a specimen of a rare mineral, or would you consider it a sacrilege?"

If the specimen is particularly valuable or precious to you and you feel your trimming skills are not yet up to the task, consider sending the specimen to a professional preparation lab.

Minimize (or better yet avoid if possible) trimming, sawing or grinding of radioactive minerals (Figure 3-13), highly toxic minerals (those containing thallium, water soluble arsenic compounds, etc.) or asbestiform minerals. When conducting any trimming process with these minerals or in any case where dust might be formed, wear gloves and a dust mark. Work outdoors

or in a well-ventilated space. Wash your face and hands immediately after the work is concluded. For example, the yellow or orange portions of bumblebee jasper are rich the arsenic sulfides realgar (AsS) and orpiment (As_2S_3); their dust should not be inhaled.

Figure 3-13. We hope the collector who cut and polished this intensely radioactive uraninite (black) and gummite (orange) slab took precautions to avoid inhaling radioactive dust.

When planning a trim safety is foremost! Trimming often creates flying rock fragments which can cause serious eye damage. *Always wear safety glasses when using any type of trimmer*. When using a pressure trimmer, the specimen can break with explosive force. If it is necessary to stabilize the specimen with fingers, wear heavy gloves as flying rock fragments can be quite sharp.

Trimming with a saw is milder (transfers less potentially damaging energy to the specimen) and is (in general) more precise than pressure trimming. However, sawing leaves obvious notches and/or flat faces which most collectors find objectionable (and require more labor to remove; see below).

To what size should a specimen be trimmed? This varies as widely as the specimens themselves. For example, is the goal of the trim to remove excess matrix or damaged crystals? Or is the desired final specimen size a function of fitting into the collection's size theme (miniature, cabinet, etc.) or because of space limitations? Albrecht (1947) provides a practical discussion. Trimming to micromount size has frequently been discussed in the mineral collecting literature; Wight (1993) is an excellent resource.

Visualize how the specimen should look after the trim, perhaps with a 'virtual trim' (Pezzotta 2018): A photograph of the specimen is 'trimmed' using Photoshop or other image processing software. This allows numerous trim plans to be explored before committing chisel to rock.

When considering the removal of 'excess' matrix consider specimen aesthetics, specimen integrity (trimming may weaken the entire specimen by widening seen or unseen cracks) and potential loss of scientific information. Soft matrix, such as Ojuela Mine limonite is often partly to completely removed by trimming because it can make the specimen unpleasant to handle (soils the fingers, labels, boxes...) but exercise care. The matrix may be integral to the specimen's structural integrity and its partial or complete removal may cause the specimen to become unacceptably fragile. Soft matrix can often be conveniently trimmed and shaped by (gentle!) use of a textile gun or vibratory impact tool.

Practice on low quality material of various sorts to get a feeling for the technique as a whole and how matrices vary in their response to attempted trimming. Look for existing cracks and weak spots (such as vugs). (Cracks can often be spotting by wetting the specimen, then watching it dry. Cracks will be highlighted, as they retain moisture and remain darker longer than areas of solid matrix.) For example, zeolite-bearing basalt from the Deccan Traps in India or topaz-bearing rhyolite from the Thomas Range in Utah tend to split in a predictable and controllable way, whereas massive quartz is a most uncooperative, unpredictable and frustrating material to work with. Fine grained granite behaves well under the chisels, but less so when the crystal boundaries are larger. A soft, granular matrix such as Lengenbach Quarry dolomite tends to be uncooperative (Smith 2005). Slate, mica schist and related rocks with highly directional fracture usually do not break in predictable ways. Copper tends to deform and tear instead of yielding to trimmer chisels; sawing is often a better option here. In general, exploit the weaknesses if they will assist the trim, but steer away when these weaknesses will interfere.

When the matrix to be reduced is particularly tough or thick, or shaped in a way that the trimmer chisels have difficulty gripping, it can be useful to make several shallow cuts (kerfs) with a trim saw to weaken the matrix and give the trimmer chisels a place to grip. Sawing may also be necessary to remove some matrix when the specimen is too thick to fit between the trimmer chisels. Contact metamorphic rocks and similar materials (wollastonite, miserite, epidote, vesuvianite, jade and others) tend to be tough, in many cases due to a network of interlocking crystals (Smith 2005).

Examine the specimen for matrix 'grain' and cracks. These are potential weak spots which can be exploited to help trim or may cause break specimen in undesired manner. To use grain or a crack to your advantage, align the trimmer chisels parallel to these features, and avoid if possible, applying force perpendicular to the grain or a crack. In some cases, the best way to trim a specimen with an uncooperative crack is to saw it (this avoids 'break shock') and/or stabilize the crack with removeable adhesive first. Stabilization methods for sawing provided by Swisher (2011) are most likely equally applicable to trimming. When possible, practice on lesser material from same locality to get a feel for how the matrix reacts to trimming. In the same way as a crack can guide where to apply trimming force, a mineral's cleavage can work to your advantage (or disadvantage).

Matrix cracks and loose crystals which may be detached by the energy imparted to the specimen when the matrix breaks can often be stabilized to some extent by generous application of mineral tack or a removable resin such as Paraloid B-72 (Zoic Palaeotech 2025a). Rand (1897) recommends embedding the specimen in a mixture of water-based glue and sand. The consistency should be "fluid when warm, jelly-like when cold." After the trim the glue and sand may be removed by a soak in cold water. Like many other mineral preparation skills, use of a stabilizing agent requires some practice to perfect the technique.

Grenzig (1918) suggests this method for trimming a specimen with delicate crystals: Surround the specimen with a 'dam' (mold) of some suitable material, then cover the specimen with barely melted wax. (Wax which is too hot creates a risk of thermal shock damage; Section 2.3.) After trimming, dewax the specimen by immersing in room temperature water (not hot water - thermal shock) containing a little dish soap. Slowly heat until all the wax floats, then allow to

cool slowly. Other embedding materials might include a water-soluble wax such as polyethylene glycol 4000 (PEG 4000). Paraloid B-72 or Duco cement may also be suitable.

Rand (1897) details a laborious but ingenious method for trimming way protruding matrix which prevents a specimen from being self-standing.

Some sources recommend placing the specimen inside a plastic bag before trimming. This method captures any little bits that might otherwise result during the trim. It also helps reduce dust which can be an enemy of screw trimmers. An alternate but equally effective solution is to enclose the entire trimmer in a paper bag (Yedlin 1948).

Removing several smaller bits with consecutive trims is better than one big piece in a single trim, as this gives better control with less chance of an unpredictable (and undesirable) break. Nibble away small bits (perhaps with tile nippers or pliers), starting at the specimen edges, working gradually closer to the section to be retained (Yedlin 1973a, 262). Get a feeling for how the matrix will break, the force needed, does the break occur along the line expected (or not), etc. If you have little experience trimming, practice on junk rock to get a feel for your trimming tools as well as the various ways in which a matrix may behave.

The Mindat message board (www.mindat.org) has numerous discussions about trimmers and trimming techniques; see for example Barwood (2016). Yedlin (1973a and 1973b) shows with illustrations a method to reduce a large crystal-bearing mass to micromount size and (presumably) to any other size as well. Wight (1993, 64–70) provides an additional, excellent discussion of micromount trimming.

When **executing a trim**, patience - the number one tool in the mineral cleaner's toolbox - is critical. Place the trimmer in shallow box or tub to collect trimmings. These trimmings should be retained for later examination (often under magnification). The catch tray also consolidates the trimming mess and speeds cleanup.

During the trim the specimen tends to break towards the thinner (weaker) side. Thus, when the chisels are placed closer to the display face than to the rear face, parts of the display face will frequently flake off first. This can be controlled to an extent by making a shallow saw cut (a kerf) where you want the chisels to grip. Placement and use of this cut is a technique which should be practiced before committing your best material to the whims of the chisels.

When the matrix breaks under trimming force substantial energy is transferred to the specimen. Fragments will fly out, resulting in further damage if not anticipated. *Only if sufficient room is available*, hold the entire specimen with the fingers (or at least the part to be saved), *protected with heavy gloves*. **The specimen should only be stabilized by hand if it is the room to do so is obviously sufficient, otherwise significant injury can result**. Use the protective shield (if the trimmer has one) to direct any flying rock fragments away from yourself. If the trimmer does not have a such a shield, place a supported sheet of protective material made of acrylic, metal or wood between yourself and the trimmer.

When selecting a spot for the chisels, look for two roughly parallel matrix faces. Surface bumps or shallow kerfs in the surface can also be used. If the surface is curved and hard, the chisels

will merely slide off instead of gripping. Chisels can more readily dig into and grasp a soft surface (such as limonite), so such specimens are less problematic.

When initiating the trim apply the minimal force necessary to get the job done, slowly increasing it until the matrix break occurs. Applying sudden, large force - with subsequent rapid transfer of energy to the specimen - can result in an unnecessarily violent matrix break and avoidable collateral damage to the specimen. For large specimens or specimens having tough matrix, it may take time for a crack to develop. In these cases, apply force until no more can be easily applied (in some cases the specimen will make noises) then wait maybe ten minutes or more until a crack appears or the specimen comes apart.

For removal of tiny bits along the matrix edge, use tile nippers or pliers as mentioned above. When a very precise trim is needed, use air abrasion.

Know when to quit! Avoid the temptation to over-trim, which is especially problematic with crumbly, friable or soft matrix. If in doubt that an additional trim will yield positive results recall Guiding Principle 4: "If unsure...don't."

After the trim give the specimen a quick dip in the ultrasonic cleaner to remove any dust which may have accumulated during the trim. Carefully examine the trimming residues (in the catch tray) under magnification. In these residues you might find (for example) possible micromount material. Carefully examine the specimen for any newly revealed crystals or pockets. This is especially important when trimming samples containing rare species.

When the specimen's catalog card contains a physical description (size, weight or photographs) remember to revise these after the trim is completed.

If the specimen has rust wait until after trimming before derusting, as the rust may have penetrated deep cracks or into a porous matrix, causing it to reappear on trimmed faces.

3.8 Sawing

Sawing is another matrix reduction technique, using different tools and techniques than used for traditional trimming. In general, the saw is used when a traditional trimmer cannot be used, for example to remove thick matrix, large chunks of matrix (Figure 3-14) or when the matrix is too tough or tends to break in unpredictable ways. As mentioned in the previous section, sawing is milder (transfers less potentially damaging energy to the specimen) and is (in general) more precise than pressure trimming. However, sawing leaves notches and flat faces which require extra labor to remove (Figure 3-15).

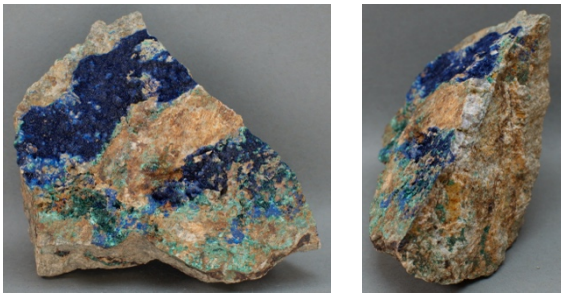


Figure 3-14. This 22 cm tall specimen is too large for the Zuber MP-5. For trimming the specimen must be sawn.

Figure 3-15. Obnoxious saw marks on the basalt matrix of an otherwise superb specimen.

Saws useful to the mineral collector include the trim saw (for shallow cuts and small specimens), the slab saw (for deep cuts and large specimens), the tile saw (for shallow cuts and small specimens) as well as the diamond-blade bandsaw. Trim and slab saws are designed to make precise cuts; these units typically cost several hundred to several thousand dollars when new. A tile saw makes less precise cuts (usually quite sufficient for rough mineral specimen trimming) with new unit prices up to a few hundred dollars and used units often available for a tenth of this.

Some lower end tile saws may not have enough power to cut the hardest materials. A tile saw - even a used unit - is suitable for most mineral development purposes. Some home improvement stores rent tile saws. Quality lapidary work, on the other hand, is best done with a trim saw or slab saw. When the amount of material to be removed is very small, trimming with vibratory impact tool may be a better choice than trimming with a saw. An angle grinder with a diamond blade can be useful for crude cuts (Werner 2024a).

These tools generally use a spinning diamond-coated disc to cut the material by abrasive action. Because a diamond blade lacks teeth like a wood saw blade has these tools are technically not saws, but regardless are often referred to as such (Figure 3-16).

Figure 3-16. A trim saw blade (left) is coated with diamonds and cuts by abrasive action whereas a wood saw blade (right) uses teeth.

When **selecting a saw** for mineral preparation work, several features must be considered. Key among these features is the blade. Select a new diamond blade, as a used blade may lack enough diamond grit to be very effective or it may be warped causing inaccurate cuts. Unless used frequently a new blade should last for many cuts and be a worthwhile investment. A smaller diameter blade makes shallower cuts than a larger diameter blade. The actual cut depth depends on the position of the center of the blade relative to the worktable surface. A blade with center below the table will make a cut whose depth is less than half of the blade's diameter. Select a blade with a continuous diamond rim (instead of a segmented rim) for greater efficiency, ease of cutting and improved finger safety. Blade thickness must also be considered. A thinner blade wastes less material per cut; this is an issue for lapidary work but generally not for mineral trimming. Inspect the blade frequently. If it wobbles side-to-side or doesn't cut efficiently then replace it.

Select a wet saw over a dry saw. A wet saw lubricates and cools the blade with water, simultaneously reducing dust. A dry saw may be a bit cheaper but lacks these important features. A wet saw should also have a guard to shield against water and cutting debris being thrown back at the operator. The saw's water reservoir should be large enough so that water refill isn't so frequent as to be annoying. Some lapidary saws use oil as a lubricant, which has some advantages over water but can also create quite a mess.

Some more expensive saws have variable speed, but this feature is unnecessary for routine mineral trimming work.

A small, handheld rotary tool (such as a Dremel) with a diamond blade can be useful, but even for the smallest cuts with this dry tool the dust hazard can be significant. If the amount of material to be removed is small, consider using a vibratory impact tool.

As with all procedures in this book **safety** is paramount. Sawing - even with a wet saw - throws rock fragments and dust into the air. *Impact-resistant safety glasses or a face shield are an absolute must.* A rock fragment in the eye can lead to sudden and instantaneous loss of vision. Even with safety glasses on, avoid lining up your eye with the blade to reduce the possibility of a thrown fragment impacting your face. A dust mask (N95 type) should be worn as well, even when a wet saw is used. Stories of cutters developing silicosis and other lung diseases are numerous, but a proper mask greatly reduces your risk. Working outdoors will further reduce the dust hazard.

The water mess created is also less of an issue outdoors than indoors. Some saws are quite noisy while operating, so ear protection may be necessary, especially during prolonged use.

A diamond abrasive blade lacks teeth (unlike a circular wood saw blade; Figure 3-18) and so will not readily remove a finger. However, it can cause give severe abrasions and so caution must be exercised. Common sense suggests that wearing some sort of puncture-proof gloves would provide protection. The consensus among saw users, however, is that such gloves create more of a hazard than they mitigate because they make the specimen harder to hold and may become caught between the blade and saw work surface.

A wet saw uses water and so should only be plugged into a ground fault circuit interrupter (GFCI or GFI) outlet. Keep the saw at least six feet from the outlet when operating. Allow the cord to droop somewhat to provide a 'drip loop' to direct any water along the cord to drip down to the ground instead of into the electrical socket.

Never cut a sample dry. This produces a cloud of potentially harmful dust as well as reducing the blade's useful life. Avoid an initial dry cut by wetting the specimen thoroughly before beginning the cut. Minimize or (much better yet) avoid cutting toxic, radioactive, or asbestiform minerals. Guiding Principle 4 applies here: "If unsure [about the material's composition] ... don't [saw] it."

The saw blade rotates in a set direction, either towards or away from you. Water and rock debris are thrown in the same direction the blade rotates. Orient the saw so this debris is thrown away from you, and not towards the electrical outlet.

When **planning the cut,** decide first if trimming is a better option than sawing. Avoid sawing friable specimens, even large ones, as friable specimens will generally just crumble unpredictably and make a mess.

Use a marking pen to draw lines where you anticipate making the cut(s). Multiple cuts are often needed when the specimen is too large for the blade size. You may need to combine sawing and trimming to complete the job.

In most instances one single cut will be used to remove excess material. An alternate method involves making a series of parallel, closely spaced cuts, perpendicular to the edge of the matrix to be removed. This 'sliced bread' matrix is then easily removed (GneissWare 2015).

Verify that the water reservoir is full before starting the saw. Top it off with clean water if needed.

Like trimming, matrix cracks and loose crystals which may be detached by the energy imparted to the specimen by the saw blade can often be stabilized to some extent by generous application of mineral tack, paraffin wax or a removable resin such as Paraloid B-72 (Zoic Palaeotech 2025a) or Duco cement. Swisher (2011) gives some useful hints. Like many other mineral preparation skills, use of a stabilizing agent requires some practice to perfect the technique.

Because a diamond blade cuts by friction, the specimen may become quite warm. Cutting wet helps reduce this, but damage due to thermal shock must be considered.

To execute the cut place the specimen on the working surface with the blade between you and the work ('cut from the other side of the saw' as they say) and slowly move the specimen

towards the blade. Pulling the specimen (instead of pushing it) provides for greater stability and safety. Don't hurry; cutting is not a race. Feed slowly and consistently. Avoid excessive force; let the blade do the work. If the blade binds, causing the specimen to fly out of your hands, the specimen will fly away from you and not towards you.

After a cutting session, the sump water contains suspended, very fine particles. Do not dispose of this water where this dust can be released by disturbance after it dries out (for example on grass to be walked on or mowed). Professional tile workers have devised some simple but effective methods for safe tile saw water disposal (Santos 2017). Change the sump water frequently, as dirty water reduces the blade's useful life. Some cutters recommend adding a blade lubricant; this is an option more than a requirement.

As usual for any preparation technique in this book, always practice with lesser quality material first before committing your better specimens to an irreversible procedure. Your practice specimens should be as similar in composition and size to the 'real' material as possible.

Saw marks are an inevitable result of sawing (Figure 3-16). They may appear as unnaturally flat surfaces or grooves and perhaps when the matrix is so tough that extraction by any method other than a diamond chain saw would destroy the specimen. Common examples include zeolite-bearing basalt from India or fluorite-bearing silicified limestone from the Rogerley Mine in England. Most collectors find visible saw marks mildly to severely objectionable, especially when visible during display. The best approach to avoid saw marks is to trim instead of saw, or in cases where sawing is necessary plan carefully to minimize these unsightly scars. There are numerous methods to diminish or remove saw scars completely with the best method depending upon factors such as the specimen matrix and tools on hand. Commonly used approaches to obliterate saw marks include air abrasion, a vibratory impact tool or grinding with a silicon carbide grinding wheel. When grinding, wear a dust mask and start with a course grit then move to finer grit as needed until the job is complete. Rand (1897) describes a rather elaborate but interesting method to remove small amounts of matrix at the base of a specimen by grinding instead of sawing.

Cutting wet may cause the steel saw blade to rust. Prevent rust by drying the saw and blade thoroughly and immediately after use, then apply a thin layer of a rust preventative such as WD-40 Multi-Use. For more on blade maintenance and replacement see Sima (2025).

Like most other mineral development techniques, sawing takes time and practice to perfect. Additional tips and tricks for this art can be found in Hall (2021) and Modisane (2025). If the specimen has rust wait until after sawing for derusting, as the rust may have penetrated deep cracks causing it to reappear on sawn faces. Sawing is also a useful mineral specimen development technique (Figures 3-13 and 3-17). Agates are frequently sawn and polished to reveal Nature's artistry within. Sawing is also useful for softer minerals such as calcite, whose breakage by a trimmer is very likely to leave a rough, unaesthetic surface.

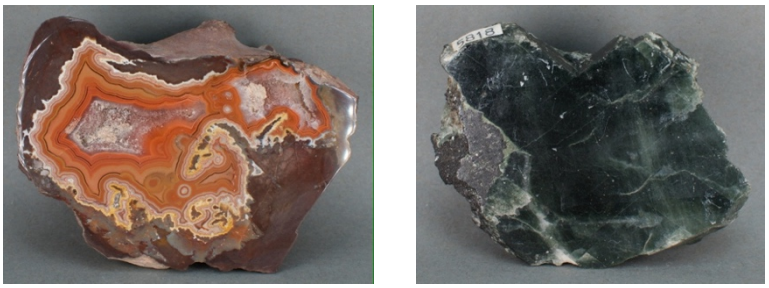


Figure 3-17. Sawing as a mineral specimen development technique. Left: A sawn and polished agate nodule. Right: This French Creek Mine, Pennsylvania calcite was sawn to reveal the dark green interior, a result of abundant inclusions of fibrous actinolite (byssolite).

3.9 Air Abrasion

Air abrasion (also called bead blasting) is a technique in which a fine-grained particulate abrasive material (the blasting medium) such as glass beads or $NaHCO_3$ powder is propelled at a surface by compressed gas to erode material in a controlled fashion. Sometimes also called sand blasting, but this name can be misleading, as abrasives other than sand are quite commonly employed for mineral specimen preparation. Air abrasion is useful for coating removal and trimming when sawing or mechanical trimming are not applicable or are too risky. Graham and Allington-Jones (2018) give a history of this technique.

Air abrasion is often beyond an amateur's budget, so only limited detail is included here. There is a significant body of information covering dental and industrial uses but much less for mineral specimen work, although most of the fossil preparation techniques are equally applicable to minerals. Zoic Palaeotech (2025b) and Ratkevich (1998) are worth studying before investing in air abrasion equipment.

Among many applications are removal of tourmaline crystal coatings or excavation of staurolite crystals from a schist matrix (Lauf and Clifford 2018). Famous late 19th-century Philadelphia mineral dealer A. E. Foote used air abrasion to remove excess fine-grained lepidolite matrix from tourmaline/lepidolite samples from the Stewart Mine in California (Sinkankas 1972, 234; Figure 3-18). Preparation of these specimens by any other method available to collectors then or now would be almost impossible.

Figure 3-18. Tourmaline in lepidolite, of the type prepared with air abrasion by A. E. Foote.

Air abrasion involves directing a stream of compressed gas carrying the abrasive particles at supersonic speeds toward the surface to be cleaned. The abrasive particles impact the surface of the specimen, removing unwanted material and exposing the underlying mineral structure. The nozzle is moved over the surface of the specimen in a controlled manner to ensure that the entire surface is evenly abraded. The abrasive action generates some heat, but the gas stream quickly carries this away, so thermal shock is not an issue. The result is a mild, shock-free cutting action. Another advantage of air abrasion is that it produces a clean surface finish that is free of scratches and other surface defects. This is particularly important for display specimens or those to be analyzed by optical or electron microscopy, as surface defects can interfere with the analysis. Air abrasion can also be used to prepare specimens of almost any size; compare this with size limits for most other mechanical mineral specimen preparation techniques.

Significant practice - perhaps more than any other method in this book - is required to master the technique. Many collectors have had little if any need for this technique; in this case it is more economically sensible to send the specimen to a specialist for preparation than to invest the money for the equipment and the time to master it.

The basic setup includes a compressed gas source, pressure regulator, gas filter/drier, nozzle, blasting cabinet, dust collector and abrasive source (Figure 3-19). This equipment is moderately expensive (typically costing $1000 or more although some collectors have had success with homemade units).

Figure 3-20. A commercially available air abrasion cabinet with gloves, three abrasive canisters, foot pedal and dust collector. The compressed gas source, pressure regulator and gas line filter are not shown. Alternate designs, including homemade setups, are quite common.

The compressed gas source is typically an air compressor (capable of ~90 psi), but noise can be an issue. Compressed gas from a metal cylinder can be a useful alternative but is usually less economical than an air compressor. If bottled gas is used, choose compressed air instead of carbon dioxide or nitrogen, as these latter choices are more expensive and can lead to asphyxiation in a closed space. A compressed gas cylinder requires a pressure regulator specific for the type of gas used; this is an additional equipment expense. A separate regulator is usually not needed with an air compressor as this control is usually part of the compressor. Abrasion usually occupies both hands (one to hold the sample and the other to manipulate the nozzle) so a foot pedal to control the gas flow can be useful.

Water vapor in the gas line can cause the abrasive to clump and clog the nozzle. A gas dryer trap (a desiccant; required even in the driest of regions such as the Arizona desert) and filter installed between the compressed gas source and the nozzle can mitigate this problem. This device can also remove oil, fine particulates (which can also cause clogs) and other pollutants in the gas stream. This regulated and filtered compressed gas source can also be used to power pneumatic vibratory impact tools.

A variety of nozzles are available. The nozzle is typically made of steel or tungsten carbide and is used to direct the abrasive material onto the specimen. The shape and diameter of the orifice are selected based on the abrasive used as well as the nature of the cleaning job. It may be useful to have several different nozzles on hand.

Material abraded away from the specimen becomes a very fine dust. Mixed with spent abrasive, this dust can be a significant health hazard. Therefore, the work must be carried out in an enclosed, air-tight cabinet with a transparent port for viewing. Heavy rubber gloves, built into the front or side of the cabinet, allow the specimen to be manipulated safely during work. The dust must be trapped in an appropriate dust collector (dust extractor). Although some workers avoid the cabinet and dust collector by working outdoors, the dust hazard is still quite significant. ***A mask or respirator alone is insufficient to mitigate this significant hazard.*** For an excellent discussion of dust extractors see Zoic Palaeotech (2025c).

Common abrasives (in order of increasing Mohs hardness) include plastic beads, $NaHCO_3$ (2.5–3), crushed walnut shells (2.5–3), dolomite (3.5–4), iron powder (4), glass beads (5.5–6) and aluminum oxide (alumina; 9). Other abrasives include (but are not limited to) ground corncobs, garnet powder, steel shot or grit, silicon carbide, pumice, coal slag and ground peach pits.

At first you might think that the abrasive can be any material that is harder than the material to be removed yet softer than the material to be retained. (It is not possible to remove a harder mineral and retain a softer mineral with this technique.) However, this is not always the case. Erosion by abrasion is caused by the particle impact and not by scratching. Recall that Mohs hardness is a measure of one material's ability to scratch another. Hardness is therefore not a perfect measure of abrasiveness, but instead just a practical correlation. In short, just because a mineral has a Mohs hardness greater than the abrasive does not necessarily mean that the abrasive is safe to use on this mineral. For example, Titamgim (1988) reports that chalk dust (hardness 3) abrades periclase (hardness 5.5) and that calcite and baryte (both hardness 3) abrade fluorite (hardness 4). In addition, minerals having elasticity (some micas) may cause the particles to bounce off without abrasion, a case where a hard abrasive may not be effective to remove a soft mineral (Hardinger 2023a).

Abrasive particles are typically 25–250 microns (μm) in size, depending upon the abrasive's composition. Large size particles are more abrasive (provide greater impact force) and remove material faster than smaller particles of the same material, but the former leave a more uneven surface (Graham and Allington-Jones 2018). Sharp particles (such as crushed glass) are more abrasive than smooth particles of the same material (such as glass beads). In one report,

$NaHCO_3$ (a soft abrasive with sharp particles) eroded ferberite, Mohs hardness 4–4.5 (Hardinger 2023a).

With these thoughts in mind, the abrasive must be chosen with care. A collector once said, "I've used crushed glass with a microblaster to successfully clean fluorite" to which another collector responded, "that will only be successful if you don't mind an etched, matte surface to the fluorite. Crushed glass blasting media is significantly harder than the fluorite." For the inexperienced worker, the best abrasive is chosen by starting with the softest abrasive available then gradually trying a harder abrasive until the desired effect is achieved.

In addition to hardness, other factors which influence abrasive choice include cost, particle shape (angular or smooth), reusability and possibility of nozzle clogging. Gas pressure and the angles between the nozzle and object being abraded also influence the abrasion process. For more on abrasives see Raptorblaster (2025), Zoic Palaeotech (2025b) and Graham and Allington-Jones (2018).

When a significant amount of material is to be removed, it is common to start with a coarse abrasive for rapid removal followed by a finer particle size for detail work and to produce a smoother finish.

If the specimen is rusty wait until after air abrasion before derusting, as the rust may have penetrated deep cracks, allowing it to reappear on abraded faces.

When air abrasion is unavailable, crystals in a soft, decomposed or poorly cohesive matrix can be exposed by carefully carving the matrix with a small, sharp knife, toothpick, fingernail or similar tool. A textile gun or vibratory impact tool may also be useful. In these cases, crystals can be easily dislodged if the specimen is carved incautiously, or the crystals are undercut. Avoid the temptation to flake off large chunks of matrix, but instead, remove only small bits at a time. (Recall that patience is the number one mineral cleaning tool!) Finish the job with very brief sonication - usually just a few seconds - to remove tool marks. Examples of materials suitable for carving include pyrite in marl (Ampliación a Victoria Mine, Spain) and grey danburite in dolomite-smectite (Alto Chapare Mining District, Bolivia). In general carving with a sharp tool or textile gun is more economical (but less precise) than air abrasion. Recall that coating removal is not always desirable (Figure 1-6).

That air abrasion can be used to carve and shape rock suggests this technique might also be used to modify natural mineral specimens to produce unnatural shapes. In a recent example, air abrasion was used to carve natural Bulgarian galena crystals resulting in unnatural arches and hollowed cubes (Figure 3-22). The presence of hemispherical impact craters and relict abrasive (glass beads and aluminum silicate crystals) revealed these 'artworks' to be manmade (Simonoff and Kearns 2010, Akhavan 2012 and Simonoff 2011). Before being discovered as fakes, they appeared (for a brief period) on several dealer's websites and commanded quite high prices. Fluorite 'balls', as singles, clusters and even arches, often on matrix, are another air abrasion-created fake seen in recent years (Figure 3-20). Other examples of air abrasion-created fakes surely exist. *Caveat emptor*!

Figure 3-20. Left: Air abrasion was used to carve a natural Bulgarian galena specimen, forming 'artistic' arches and hollow crystals. Right: This fluorite ball 'donut' was created from massive fluorite by air abrasion, then glued onto an amethyst matrix. Pretty, but fake!

Air abrasion requires patience and skill to master. Rarely will an amateur produce professional results by just 'diving in' without a good understanding of the technique, equipment and materials involved. Lots of information is available in print (and even more so) online; perform internet searches and read extensively before investing in this technique, especially with a precious specimen. As always, if the specimen is sufficiently precious and you are unsure of your skill have the work done by a professional mineral preparation lab.

3.10 Vibratory Impact Tools

Vibratory impact tools have a tip (also called a stylus or nib) rapidly oscillating in and out and are well-known for fossil preparation. The vibratory action is often driven by compressed air and so the tool is frequently called an **air scribe**. Other names include air chisel, air pen, air incisor, air engraver, pneumatic chisel, pneumatic stylus or pneumatic hammer. The same pressure-regulated and filtered compressed gas source used for air abrasion can also be used to power most vibratory impact tools. Although application of these tools to fossil specimen preparation is well-known (Converse 1984, Ratkevich 1998, Zoic Palaeotech 2025d) descriptions of their use for mineral specimen preparation are surprisingly uncommon and mostly lack specific details. Buřival (2018) mentions air scribe and engraver use for mineral specimen preparation but provides no 'how to' details. Behling (2011) discusses an example (but without much procedural detail) of air scribe use to prepare Kagem Mine emerald specimens.

Can vibratory impact tools be useful for matrix removal and related tasks in mineral specimen preparation work? This is indeed the case.

A quality air scribe plus the compressed gas source, pressure regulator and gas filter/dryer may be too expensive for the casual or budget-limited collector. Electrically driven versions, less expensive and not requiring a compressed gas source but otherwise roughly comparable to pneumatic versions are available. Premier among these is the Dremel 290 engraver (Figure 3-21).

Figure 3-21. Left: Pneumatic air scribe in use for fossil preparation. Right: The Dremel 290 electrical vibratory impact tool.

For those who like using vintage equipment, the Burgess Vibro-tool mentioned by King (1983, 77) can be purchased used and overall has a good reputation, but the motors tend to burn out when used when used nonstop for 20–30 minutes. Note this is an impact engraver and not the more widely available rotary engraver (which is useless for mineral preparation work). The Dremel 290 plus a set of Zoic Palaeotech fossil preparation tips (Figure 3-22) is an affordable entry into vibratory impact tools for mineral specimen preparation; the set costs less than $60 at the time of this writing. (Expect to pay several times this much for an air scribe by itself, without the compressor. Compare also to the price of an air abrasion setup.) If shopping for a different brand or model, get a vibratory tool and not a rotary tool; although a bit cheaper and much more widely available, a rotary engraver (or any tool sold with grinding, drilling or cutting bits) is of limited value for mineral work.

Figure 3-22. Zoic Palaeotech fossil preparation tips.

Other vibratory engraver brands or models having very similar appearance to the Dremel 290 are available. These have not been explored for mineral preparation, but the striking similarity between these alternates and the Dremel 290 suggests they may have been made in the same factory and thus are quite likely to have similar function, features and quality.

For prolonged use an air scribe is more comfortable than a Dremel 290 due to the former device's stylus shape. In addition, the Dremel 290 can become uncomfortably warm whereas the air scribe stylus remains at room temperature or even becomes cool (due to internal compressed air expansion; the Joule-Thomson effect). Additional advantages of a vibratory impact tool over

air abrasion include a smaller workspace investment and reduced materials cost (abrasive and in some cases compressed gas).

The working end of the tool is a tip, oscillating towards and away from the tool at hundreds to thousands of strokes per minute. Material is removed by fracturing and not by grinding. This tip is typically made of tungsten carbide, a tough and hard material. (Other materials may be used for special cases; see below.) Tips are available in a pointed or chisel shape (Figure 3-22). The tip shape choice depends upon the job at hand. For fossil preparation, Zoic Palaeotech (2025e) recommends the following: The short tip is best for matrix removal and maximizes available power. The longer tip has extended reach and is best for finishing work but delivers less force than a shorter tip. The chisel tip is useful for matrix smoothing and matrix removal (soft rocks). The short tip is more powerful than the long tip because less kinetic energy is lost along its length due to flexing caused by impact with the sample (Kate Acheson-Dumbravă, Zoic Palaeotech, personal communication). For mineral specimen work the longer tip may be needed to reach into deeper recesses, despite the kinetic energy loss.

Despite their hard material composition, the tips eventually become chipped and dull, requiring replacement. Use on harder matrix shortens the tip lifetime more quickly than soft matrix.

Use the Zoic Palaeotech tips instead of the tips supplied by Dremel because "the standard Dremel® 290 is supplied with a stylus in the box, but you'll find that this is *not* suitable for fossil preparation. It's too fat, too small and the tungsten carbide is of a metalworking grade and so wears to practically nothing in no time. We recommend using purpose built fossil preparation styli to get the most out of your Dremel. It seems counterintuitive, but the very fine tungsten carbide needles...focus what power the Dremel does have leading to more power transmission than a wider, chunkier stylus" (Zoic Palaeotech 2025f). The same tip choices apply equally well to mineral specimen work.

Specimen preparation using a vibratory impact tool creates dust and flying debris. ***Always wear safety glasses.*** Wear an appropriate dust mask and have adequate ventilation (work outdoors if possible). The tool's loud noise can be an irritating hearing hazard, so ear protection is recommended.

The rapid vibratory action of the tool's tip imparts significant energy to the sample which can cause a thin matrix to break and existing cracks to become larger. Loose crystals may become dislodged. These vibrational issues can generally be avoided with air abrasion.

Start work by inserting the selected tip into the tool's tip holder. Tighten the set screw so that the tip is held firmly in place. The dial on the side of the tool adjusts the stroke length and therefore the depth and power of penetration. Start at the lowest setting, increasing if necessary to achieve the desired result. Bring the oscillating tip to the work; varying the angle until the desired matrix removal is achieved. Don't rush; move the tip about slowly. The process can be slow but very precise. Where possible aim the tip away from any crystals to be excavated. This reduces the chance of damage should the tip slip and contact the crystal. Avoid the temptation to push hard; apply minimum force necessary and let the tip do the work. Retain enough matrix to hold the

crystal firmly in place; avoid the temptation to over prepare the specimen (to remove too much matrix), as this may cause dislodging of the crystal being excavated. A vibratory impact tool imparts some vibrational energy to the sample so air abrasion may be a more suitable preparation tool when the crystal to be excavated is cracked or cleaves easily (calcite, topaz, etc.; see www.mincleandev.com for mineral cleavage properties).

The tool works nicely on fractured quartz by working the tip along and into existing cracks. However, in some cases an unnaturally rough surface may result. It can also be used to create a shallow kerf for gripping by nippers or the chisels of a pressure trimmer.

As always practice on lesser quality material, preferably the same mineral species and locality before committing your better specimens. Experiment with the different tip shapes to get a feeling for their effects.

Vibrational energy can also be transmitted to the fingers and hand, causing 'vibration white finger' with tingling or numbness in the finger accompanied by whitened skin (Healthline 2022). If you feel these symptoms take frequent breaks and consult a doctor if they persist. Take a break every hour or so to allow your hand and wrist to recover.

The weight of the tool and air hose or electrical cord can cause wrist fatigue. Use a wrist support such as the workbench edge if needed. (A cordless/rechargeable version of the Dremel 290 would be ideal in this regard but such a tool does not appear to be available yet.)

After completing the work, the specimen may have residual tool marks, emphasized by fine white dust residues. These marks can often be removed or significantly attenuated by brief sonication, especially when the matrix is soft. Other cases may require brief chemical treatment for smoothing such as acid when the matrix is (for example) calcite or natrolite. If unacceptable tool marks persist air abrasion may be needed.

The Dremel 290 is an inexpensive tool which can be quickly mastered and can provide nice results. For example, a bent rutile crystal in a grainy quartz and feldspar matrix was successfully excavated in just a few minutes, without damage to the rutile (Figure 3-23). Similarly, a damaged and unaesthetic quartz/muscovite cap was removed from an undisplayable Shizhuyuan Mine, Hunan, China specimen to reveal a lustrous and well-terminated ferberite crystal beneath (Figure 3-24).

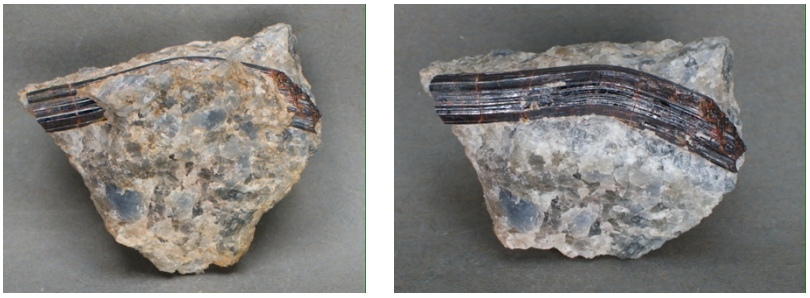


Figure 3-23. This bent rutile crystal in a grainy quartz/feldspar matrix (left) required just 15 minutes with the Dremel 290 for greater exposure. Brief sonication removed residual dust. Derusting with dithionite treatment completed the work (right).

Figure 3-24. The Dremel 290 made quick work of this specimen's ugly hat, revealing a well-formed and nicely terminated ferberite crystal beneath.

Additional, successful examples not illustrated here include exposing neptunite from enclosing natrolite (California State Gem Mine, San Benito County, California) thus avoiding the usual tedious acid treatment methods for such specimens and corundum crystals from a biotite gneiss matrix (Bozeman Corundum Co. Mine, Gallatin County, Montana).

Despite its low cost, ease of use and broad application for mineral specimen preparation the Dremel 290/Zoic Palaeotech tip set is not a panacea; it cannot replace air abrasion in all cases. This tool provides optimum results when the matrix is soft and/or fragmented. For example, a genthelvite crystal cluster (Huanggang Fe-Sn deposit, Inner Mongolia, China) was fully enrobed in an unidentified, microcrystalline coating (probably quartz) which could only be partly removed by the Dremel 290 (Figure 3-25). Air abrasion is unsuitable because it will be difficult to remove the harder quartz from the softer genthelvite. However chemical treatment finished the job. The seemingly excess matrix at the front of the photos was not removed because the specimen's obverse face is covered with magnetite; this mineral association was deemed to be more important than aesthetics in this case. More details on this example can be found in Chapter 6.

Figure 3-25. Complete removal of the quartz coating on this genthelvite cluster could not be achieved with the Dremel 290/Zoic Palaeotech tip combination.

Commercially available vibratory impact tool tips are made from tungsten carbide, a hard (Mohs 9 to 9 1/2; Mindat 2025) but somewhat brittle material. These tips do not have an infinite operating life, but their replacement is not a significant challenge to the amateur mineral preparator's budget. That the tungsten carbide tip is hard begs the question about collateral damage.

With the Dremel 290 set to maximum stroke displacement, the short (maximum delivered force) Zoic Palaeotech tip damages all minerals tried - quartz, tourmaline, microcline, spinel, topaz and even corundum (Mohs hardness 9). In one experiment, however, the short carbide tip scratched massive, uncracked quartz but did not effectively remove it. For experiments with tips of softer metals, a length of 3 mm diameter rod was cut to length and ground or filed to have the same profile as the Zoic Palaeotech tip. (A narrower diameter rod does not fit snuggly into the Dremel's tip holder and is thus too wobbly to be usable.) Results were as expected, based on the tip material's Mohs hardness. A steel tip (Mohs hardness 4 to 4.5) was found to scratch fluorite but not borosilicate glass or quartz. Tips of brass or copper (both Mohs hardness 3) or aluminum (hardness 2.75) left a metallic mark on fluorite and did not scratch it but easily scratched calcite and gypsum. Thus, these softer metal tips may be useful to remove soft matrix (calcite, limonite, etc.) while at the same time preserving some soft minerals (fluorite). For example, a brass tip is effective to remove the soft marl matrix of Ampliación a Victoria Mine, Spain pyrite specimens or to excavate dolomite variety teruelite crystals from Nabo Ravine, Spain. In another example, an aluminum tip was used to further excavate Ojuela Mine, Mexico adamites from their soft limonite matrix with less chance of damage than if the Zoic Palaeotech tungsten carbide tip was used. Residual tool marks were efficiently removed by brief sonication. Tips made of these soft metals dull easily but are inexpensive and easily manufactured in quantity.

3.11 General Notes on Chemical Methods

Most of the methods described in the remainder of this chapter use chemicals of some sort. Some of these procedures employ hazardous chemicals. Before beginning work it is important to understand how to manipulate these chemicals safely. Some of the procedures also include details about how the chemistry operates. For the most part you can skip these details but understanding them can increase your satisfaction as well as possibly helping you to modify these procedures or even develop new procedures of your own.

Sections 3.11 through 3.14 (especially Section 3.14 - Some Elementary Chemistry) include sufficient background information and detail to allow procedures in this chapter to be easily and comfortably performed by an amateur having little to no formal training in either theory or laboratory aspects of mineralogy and chemistry.

Read and thoroughly understand the safety and other considerations presented in Chapter 2 (especially Section 2.1) before conducting any procedure in this chapter.

Before starting any chemical procedure:

- Review Before Cleaning or Developing a Specimen (Section 2.3) first. Also review Section 3.12 (Basic Lab Equipment and Manipulations) and Section 3.13 (Working Safely with Chemicals).

- There is greater risk using chemical treatments to clean rarer species compared to more common species, as the chemical compatibility (www.mincleandev.com) of the former are generally less well known. Proceed with caution and (as always) experiment on lower quality material before committing your best specimens to an untried chemical procedure.

- Read the entire procedure before beginning any work to avoid surprises such as significant safety issues, need for specific chemicals, waste disposal, compatibility with the minerals being cleaned, etc.

- When planning a chemical purchase carefully consider the quantity to be purchased. How much is used each time? How often is it used? Purchasing a large excess may be cheaper on a per-gram or per-mL basis but simultaneously may create a waste disposal issue later. If you only need a small amount per use or only use the chemical infrequently consider purchasing just the smallest size which fits your mineral cleaning needs.

- Use only pure chemicals, avoiding commercial cleaning products which contain the same chemical. Unusual exceptions, such as Iron OUT, are noted below. These products contain additives which can interfere with the mineral cleaning process and might even cause damage. More than one collector has been fooled by dye residues from such products, believing some brightly colored, rare mineral has been revealed by cleaning. In addition, pure chemicals are generally cheaper than name-brand cleaning products which contain the same chemical. When considering any commercial cleaning product for a chemical cleaning process review the SDS and ask yourself if the risk of exposing your precious specimen to all these additives is worth the risk.

- Always exhaust all reasonable mechanical cleaning procedures before resorting to chemical procedures. Most mechanical procedures can be interrupted before catastrophic damage occurs to the specimen whereas damage caused by a chemical procedure is often irreversible.

- Before attempting any chemical cleaning method: (1) read the general notes discussing the problem to be solved, such as derusting; (2) read the advice for specific minerals present (or suspected to be present; Chapter 4) and (3) consult the mineral properties (hardness and cleavage) and chemical compatibility tables at www.mincleandev.com. Water and humidity sensitivity is discussed in Allington-Jones (2017, 4). Additional information on specific procedures and minerals may be elsewhere in this book; consult the Index. This information is particularly important when working with a mineral or a procedure which is unfamiliar to you. As always, experiment with lower quality material before committing your best samples to an untested procedure. Note also that stability towards mechanical

procedures or chemical reagents can vary even for samples of what appears to be the same mineral species. For example, albite variety cleavelandite may be stable to some procedures, but weathered cleavelandite on specimens from the same locality may be 'rotten' and easily destroyed. It is unwise to assume that minerals with similar chemical formulas have similar chemical properties. For example, opal ($SiO_2 \cdot nH_2O$) has much poorer chemical resistance than quartz (SiO_2).

- Tap water is acceptable for any aqueous procedure unless otherwise specified. When in doubt (especially if your tap water is very hard - has high concentrations of calcium, magnesium or iron) use distilled water. Rainwater is recommended by Duthaler and Weiß (2024) as a distilled water substitute, but rainwater contains dissolved CO_2, sulfur oxides and nitrogen oxides and so is typically slightly acidic. Rainwater should therefore be avoided as a distilled water substitute. In addition, rainwater may be sufficiently scarce (Southern California, Arizona, Nevada, etc.) as to make the issue moot.

- If the procedure involves an organic solvent (usually acetone or rubbing alcohol) and a plastic container is to be used, first verify that the plastic resists the solvent (Section 3.12). Better is to err on the side of caution and avoid plastics altogether when using organic solvents. Many articles on mineral cleaning - especially by authors outside of North America - recommend gasoline as a mineral cleaning agent. While this fluid is more readily available and perhaps (not so much in California) less expensive than many more esoteric organic solvents, its use should be avoided. Gasoline is highly flammable, toxic and carcinogenic.

- Remove as much biological contamination (plant residues) as possible before chemical treatment. Needle point tweezers are especially useful.

- Chemical solutions can easily penetrate cracks and porous matrix, creating problems after drying without appropriate rinsing. It is often said that this can be avoided by presoaking the specimen in clean water before a procedure to fill these pores. *This is obviously nonsense!* If pure water can penetrate, then so can chemical solutions. Waxing and oiling as an attempt to seal these pores against chemical incursion generally at best slows attack as chemicals can still seep under edges and coatings usually not fully waterproof.

- Sometimes a portion of a specimen needs to be protected against chemical treatment. For this purpose, a removable coating may provide some level of resistance to chemical attack. Paraffin wax is more robust to handling whereas beeswax is more easily removed. To apply paraffin wax, melt it on a hot plate (not a flame; paraffin wax vapors are flammable) then use a small brush to paint the liquid wax on the specimen as desired. (Consider the possibility of thermal shock.) A thick coating is better than a thin coating. To remove the

paraffin wax coating the specimen is immersed in room temperature water (not hot...thermal shock) with a few drops of dishwashing detergent and slowly heated until the wax has all melted and floated to the surface. (The dish soap helps release wax from the specimen.) Allow the specimen and water to cool together (again avoiding thermal shock). After drying inspect for any residual wax which may require an additional hot water (or textile gun) treatment. To avoid possible specimen-to-specimen contamination, the wax is not reused. Compared to paraffin wax, beeswax is easier to apply and easier to remove but is more likely to be damaged or flake away with handling. Other coatings are possible but their resistance to various acids (or any other chemical treatment) must always be considered. Paraloid B-72 is popular in the fossil community because it is easily applied and easily removed, however its use for mineral cleaning has not been well explored (Zoic Palaeotech 2025a). Duco cement is another poorly explored possibility.

During any chemical procedure:

- For any chemical procedure, minimize exposure time to reduce the chance of damage. Remove the specimen when the process appears complete. If later you judge that the procedure was prematurely terminated the specimen can be subjected to another cycle of that procedure.

- When removing a specimen from a cleaning solution, wear appropriate chemically resistant gloves. Gloves are preferred over tweezers or tongs, as gloved fingers have less change of damaging or dropping the specimen or crushing fragile crystals. Holding the specimen in a produce net or cheesecloth during sonication or chemical solution treatment is another possibility. Verify the chemical stability of the net or cheesecloth beforehand by soaking overnight it in the solution to be used.

- It is sometimes necessary to repeat a chemical treatment several times to achieve an optimal result, especially derusting with dithionite.

- Avoid heating for too long - including heating to dryness - by plugging the heating device (stirrer-hot plate or crockpot) into an electrical timer, which in turn is plugged into the outlet. *This is a very economical way to significantly reduce the very real hazards which may be caused by an electrical heating device*.

- After any aqueous procedure, drying is easily achieved by blotting with a soft, absorbent lint free cloth or paper towel. Immediate blotting minimizes water spots which are most easily visible on highly reflective surfaces. If water spots persist rinse with distilled water. Under longwave ultraviolet light (black light) cotton fibers will usually fluoresce a bright blue-white color. This is particularly frustrating when trying to photograph fluorescence.

Use cloth if possible as this is a more environmentally friendly option than disposable paper products. Drying in the warmth of direct sunlight is acceptable except when the specimen is at risk for thermal shock damage or has photosensitive minerals.

After any chemical procedure:

- It is often necessary to follow a chemical treatment with a mechanical cleaning method.

- Unless disposable, immediately clean all equipment used in a chemical cleaning procedure. In some cases, such as development of benitoite, residues which are allowed to sit will quickly become intractable.

- Tightly close and put away all chemical containers immediately after use. Containers holding water-sensitive chemicals must be sealed against moisture by stretching black electrical tape simultaneously over the lid and bottle (Figure 3-26). Parafilm is another excellent, but rather expensive, bottle sealing option.

Figure 3-26. Sealing a chemical bottle with taut electrical tape protects against moisture.

- Be a responsible mineral collector and dispose of chemical waste only according to the information given below. There is no general chemical waste disposal procedure; improper disposal can result in anything from a minor nuisance to a major hazardous situation. Do not accumulate waste; immediate disposal is safer than accumulation. Odoriferous solutions are best disposed outdoors. When in doubt about waste disposal consult an experienced collector friend. *If you cannot dispose of a procedure's waste responsibly don't engage in that procedure*. When a large quantity of unused chemical needs to be disposed, consider instead giving it to another collector. As always, wear safety glasses and gloves while disposing of chemical waste.

  Category I: Solutions of acetic acid, formic acid, citric acid, ascorbic acid, tartaric acid, oxalic acid and sulfamic acid and their salts as well as EDTA, NaOH, KOH (with or without TKPP), H_2O_2, acetone, rubbing alcohol, $HONH_2$ and NH_3 are disposed by *slowly* flushing down the drain with *plenty of water*.

Category II: Solutions of HCl, H_3PO_4, HNO_3 and H_2SO_4 are strongly acidic and so must be *carefully* neutralized before disposal by careful addition solid $NaHCO_3$ with stirring. This will fizz as carbon dioxide gas is released. When no more gas is evolved upon bicarbonate addition the solution can be flushed down the drain with plenty of water. Alternately, the waste solution can be slowly poured onto an excess of scrap calcite, aragonite or dolomite. Limestone, garden lime (which is usually crushed dolomite rock) or crushed seashells can also be used. Some effervescence (mild to vigorous) may occur. After standing 24 hours to allow the neutralization reaction to be completed the liquid can be flushed down the drain with plenty of water. The undissolved solids can be saved for the next batch of waste or disposed in your landfill (nonrecyclable) trash.

Category III: A spent dithionite solution (Iron OUT, pure sodium dithionite, Jacquard Hydro, Waller's solution and Bridge's solution; all with or without added EDTA) are disposed by flushing down the drain with plenty of water, preferably outdoors due to the persistent odor. (A common household application of Iron OUT is to derust showers and toilets.)

Category IV: Used NH_4HF_2 solutions *must not be disposed by flushing down the drain*. Not only is pipe damage possible but also some municipalities strictly forbid introducing fluoride into the wastewater stream. Instead, an excess of scrap calcite, aragonite or dolomite is added to the waste solution. Limestone, garden lime or crushed seashells can also be used. Allow to stand for at least 24 hours. All the fluoride will precipitate as nonhazardous CaF_2 (fluorite) and/or MgF_2. When effervescence has ceased flush the supernatant liquid down the drain with plenty of water. Allow the solids to evaporate to dryness, then place the container with solids into a trash bag and dispose in your landfill (nonrecyclable) trash bin.

3.12 Basic Lab Equipment and Manipulations

Every chemical cleaning method will require some equipment and supplies, discussed in the following paragraphs. Some items are used only in certain procedures and so the description and use of these items are covered in those procedures.

The availability of equipment and chemicals for mineral work has changed over the decades. Fifty years ago, a wide range of materials - especially chemicals - were more readily available to the amateur, as there were less concerns about safety and legal issues. Numerous items could be ordered from a catalog and shipped to your front door. Drug and hardware stores also carried a range of chemicals now considered too dangerous for the general public. As these issues became more significant materials became less available to the amateur but still available to professional and academic institutions. In addition, 'home science' became less about actual science and more about magic and pretty colors. The rise of the World Wide Web has had a

profound impact: A wide range of chemicals and laboratory equipment - some of it significantly hazardous - can now be purchased from numerous online sources, including Amazon, eBay and a range of specialty suppliers. This availability explosion has greatly expanded the range of mineral cleaning and development methods available to the amateur.

Save money and storage space by acquiring equipment and chemicals only as needed. Or if you are more of the impatient type who doesn't like to wait for an order to arrive when you have a project to complete, use the following discussion as a guide to equip your workspace.

Depending upon their purpose containers can be made of plastic, glass, or metal. Plastic containers have poor heat resistance and so should only be used for work at room temperature. These containers tend to become brittle over time when left outside in strong sunlight. For methods requiring heated solutions glass or metal may be suitable, depending upon the chemicals involved. Glass containers may be made of regular glass or of borosilicate glass such as Pyrex or Kimax; borosilicate is much less prone to cracking due to thermal shock from heating or rapid cooling. Metal containers are only useful in limited circumstances specifically mentioned in certain procedures.

The type of plastic can often be determined by the number inside the familiar *universal recycling symbol* (a triangle composed of three chasing arrows and a central number, usually embossed on the base of the vessel; Figure 3-27). Newer versions of this symbol also include a letter code to further indicate the plastic type. For best chemical resistance use vessels made of polyethylene (PE, HDPE or LDPE) or polypropylene (PP). (Plastic vessels for laboratory use having the Nalgene brand are made of HDPE. However, Nalgene products produced for the consumer market such as water bottle are not HDPE and often not suitable for chemical work.) Polyethylene terephthalate (PET or PETE) - the plastic used to make disposable water bottles - also has excellent chemical resistance. Polytetrafluoroethylene (PTFE; Teflon) is superior to polyethylene or polypropylene for chemical procedures, but also more expensive. PTFE is recyclable but has no specific universal recycling symbol code number. For more on chemical resistance of various plastics see Calpaclab (2025). Organic solvents such as acetone or rubbing alcohol may attack certain plastics, so it is best to use only glass containers with these solvents. Older vessels lacking a recycling symbol will have unknown chemical resistance and so should not be used for chemical processes.

High-density polyethylene Low-density polyethylene Polypropylene

Figure 3-27. Plastic composition may be determined by the number in the three chasing arrows.

Borosilicate glass contains boron trioxide in addition to silica. This results in a low coefficient of expansion and therefore good resistance to cracking or breaking when subjected to thermal shock. The most common borosilicate glass brands are Pyrex and Kimax. Most professional laboratory glassware is made of these materials. If the glass is not clearly marked as one of these brands it is most likely not borosilicate and therefore prone to breakage when subject to thermal shock. *In the mineral laboratory vessels to be heated must always be made of borosilicate glass*.

Measuring the volume of a liquid or weight (mass) of a solid is one of the most common and most basic laboratory operations. For methods in the following chapters, most measurements do not need to be very precise unless otherwise specified. Approximate liquid volumes can be determined using markings on the container. Unless otherwise specified containers for measuring liquids can be made of polyethylene, polypropylene, 'normal' (silica) glass or borosilicate glass.

Large volumes are best estimated using kitchen measuring cups, available in a variety of sizes up to one liter or more (Figure 3-28). Medicine dispensing cups (up to about 30 mL) or laundry detergent cups are adequate for small volumes. (These are also useful for weighing solids; see below). For more precise measurements of 10 mL and more use a graduated cylinder (Figure 3-28). Very small volumes - a few drops to a few mL - are most easily measured using a disposable plastic syringe (without a needle) or graduated dropper.

Figure 3-28. Equipment to measure liquids include polypropylene medicine cups (left) and polypropylene kitchen measuring cups (center). The graduated cylinder (right) contains 18 mL.

Larger vessels, usually used for immersing specimens in a chemical solution, should also be made of polyethylene or polypropylene. In most cases an open vessel is adequate but closed vessels are occasionally needed. When an open vessel is acceptable a shallow tub is easier to work with than a taller, narrower container. Volumes from 100 mL to about 25 liters will be used depending upon the number and sizes of specimens to be cleaned. Many types of containers are useful, including food and paint mixing containers. A handle is convenient when the vessel is large because a handle facilities agitation and transport. (Recall that a gallon of water - about four liters - weighs 3.8 kilograms. Now add some rocks...).

More literature sources than can easily be cited here fail to include specific weights of chemicals or volumes of liquids in their mineral cleaning recipes, whereas recipes given in this work do. While precise measurements are often not critical, such measurements help avoid

chemical waste and are important to reproducibility. Some sources (such as Duthaler and Weiß 2024) suggest estimating weights of solids with kitchen measuring spoons. This is not a new idea, as toy chemistry sets having been using this weight estimation technique since the 1930's. It is best to measure accurately when possible and to avoid "just dump some in." Weighing and taking notes leads to more reproducible results and more clues when a procedure doesn't work right and/or you are experimenting with a new procedure.

Always weigh instead of estimate if you can. For this a balance or scale is necessary. A vintage pan balance can lend a satisfying feel to your work, but these are nowhere near as convenient as a modern electronic digital scale (Figure 3-29). Digital scales are widely available and inexpensive with some units available for $20 or less at Amazon and eBay. Used but perfectly useful balances and scales are frequently listed at www.shopgoodwill.com. Select a unit having at least 100-gram capacity and a minimum of 0.1-gram accuracy. Avoid food scales and postal scales as these are not accurate or sensitive enough. If you anticipate using specific gravity to identify mineral specimens or gemstones select a unit which can also be used for this purpose, such as the single pan balance in Figure 3-29.

Figure 3-29. For weighing solids, a single pan balance (left), a double pan balance (center) or an inexpensive digital scale (right) is needed.

To use a digital scale do not place chemicals directly on the pan as some chemicals are corrosive. Instead, place a small container (medicine cup, small beaker, etc.) or a piece of paper folded into quarters on the pan then press the 'tare' button. This resets the scale's display to subtract the weight of the container or paper, so you can now read the weight of the powder directly. Use a small spoon or spatula to slowly add powder until the desired weight is reached. If another chemical is to be weighed use a fresh container and reset the tare. When weighing is complete wipe the scale immediately.

A common complaint with inexpensive digital scales is that the reading may 'wander around' somewhat, especially in the last decimal place and when weighing small amounts (perhaps one gram or less). Sometimes this is a result of poor balance engineering but more often is a result of air currents or static electricity. Air currents can be blocked by placing the balance inside a box, open on the front. Static electricity can often be discharged by wiping with a lightly damp (not sopping) cotton rag then allowing a few seconds for complete drying before weighing again. If the balance reading wanders when the mass being measured is light weigh into a heavier container.

Additional equipment which might be useful includes various sizes of borosilicate beakers (Figure 3-30). Sometimes chemicals are supplied in large chunks so a mortar and pestle is necessary to grind the chemical to a fine powder. (Figure 3-30; the mortar is the bowl.) Porcelain performs better than glass for this purpose. Metal or plastic spoons are also useful. If you choose disposable plastic spoons, please be kind to Mother Earth and reuse them instead of discarding into a landfill after just one use.

Figure 3-30. Left: A 150 mL Pyrex beaker. Right: A porcelain mortar and pestle.

Every cook knows that chemical reactions are accelerated by heating. The same applies to chemical reactions, so every mineral cleaning lab needs a heat source. An electric hot plate is preferred over gas as the former is easier to control and creates less of a fire hazard. Select a hot plate with variable temperature, but do not depend on temperature markings on the knob as these are notoriously unreliable. The hot plate surface should be ceramic instead of metal, as metal may be corroded by cleaning solutions. Avoid an induction hotplate. Carefully consider the possibility of damage due to thermal shock when a hot cleaning solution is used.

When necessary to remove a vessel from the heat source, ideally you should wait for the heat source and vessel to thoroughly cool before handling the vessel. *Important reminder: Just because a vessel doesn't look hot doesn't mean that it isn't hot! When in doubt, use hand protection. Fabric potholders and oven mitts are not chemically resistant and provide no protection against chemical exposure! Silicone potholders combine heat protection with chemical resistance.*

After use and cooling, wipe the heating unit clean. Every cook knows that stovetop resides become harder to clean if they are allowed to accumulate.

When a procedure calls for heating for a specific time or when you want to avoid heating to dryness, a countdown timer which cuts off the electricity to the heater is very useful. Select a unit which has an ample power rating (watts) for the needs of your heater. *Forgetting a heated solution could cause serious toxic fumes and/or a fire hazard not to mention destruction of a favorite mineral specimen.*

A thermometer is needed to monitor a heated solution's temperature. Select a long glass thermometer having a range of approximately -10–110 ºC (widely lower or higher ranges are not useful), filled with alcohol (red liquid). An oral thermometer is too small to be of use. A mercury thermometer is also suitable but presents the problem of a mercury spill cleanup if broken (NYSDH 2025). Be careful of a liquid-filled thermometer's bulb (reservoir) as the glass is quite

thin and fragile. For hot alkali the thermometer must be metal; an analog or digital food thermometer with a metal probe suffices. Avoid a metal thermometer for any other hot chemical solutions as these may attack the metal.

Chemical reactions occurring at the interface between a liquid and solid - as is the case when using a chemical solution to clean a mineral - work faster if the solution is stirred. Stirring accelerates the amount of fresh solution passing by the solid, so the reaction rate is not dependent on diffusion alone (which is slower). Solids dissolve faster with stirring. Brief stirring can easily be achieved with a plastic spoon or glass stirring rod but what if overnight stirring is needed? In this case magnetic stirring (Figure 3-31) is ideal. A magnetic stirrer is a simple device: In its base is a magnet mounted on a motor with variable speed. The stirring bar (another magnet, this one smaller and encased in Teflon or similar chemically resistant plastic) is placed in the vessel to be stirred. The two magnetic fields align and as the motor spins the magnet in the vessel spins with it. Magnetic stirrers have been available for industrial and academic laboratories for decades, but with the rise of the World Wide Web have only recently become available and sufficiently inexpensive for the amateur mineral collector. A magnetic stirrer with built-in hot plate is ideal.

Figure 3-31. A magnetic stirrer hot plate in action. Note the vortex above the spinning stir bar.

A magnetic stirrer is easy to use. If the magnet motor speed is too slow the stir bar may not move at all. If the speed is too fast or the vessel not centered over the motor the stir bar may dance around chaotically. Overly vigorous stirring doesn't make the cleaning process occur more rapidly than mild stirring and often causes the solution to splash out of the vessel and make a mess. If vigorous stirring is required, cover the vessel with a suitable lid such as a watch glass or Petri dish. Magnetic stirring is ideal for glass and plastic vessels but fails when the vessel is steel. When the vessel is too small to accommodate both the stirring bar and mineral to be cleaned, consider suspending the specimen in the solution above the stirring bar. The built-in thermometer holder is handy for this purpose.

Chemical procedures in large vessels can also benefit from agitation, but a typical magnetic stirrer simply doesn't have enough power to move a large volume of solution. In this case agitation can be achieved with a gentle air bubble flow from an aquarium pump placed outside the vessel. Don't immerse the pump in the solution or use the pump to circulate the solution. Both circumstances will most likely rapidly destroy the pump (which is usually not chemically resistant). Bubbling air will cause water to slowly evaporate so mark the solution level at the of

the process and occasionally add more water as needed. Gently swirling the vessel every few hours - perhaps by twirling by the handle - is also an effective agitation method. Large scale procedures can require more time without agitation, but rarely fail when stirring is not used.

Some chemical cleaning procedures involve monitoring the acidity or alkalinity (the pH) of a solution. Litmus paper can determine if a solution is acidic or basic. Blue or neutral litmus paper turns red when dipped into an acidic solution. Neutral or red litmus paper turns blue when the solution is alkaline. Litmus paper is quite inexpensive but does not give a numerical measure of pH. Universal indicator paper (Figure 3-32) works like litmus paper except that it produces a broader range of colors and can be used to estimate the pH with accuracy of about one pH unit. Electronic pH meters (Figure 3-32), sold mostly for gardening and swimming pool maintenance, are now widely available, inexpensive and accurate to 0.1 pH units. If you anticipate employing a wide range of mineral cleaning procedures (or even researching new procedures yourself) get some universal indicator paper as well as a pH meter. Experiment with your pH paper and meter by measuring the pH of some common solutions and compare with Table 3-2. Instructions for inexpensive pH meters general fail to mention that the instrument will be more stable and have a longer operational lifetime if during storage the electrode is immersed in pH electrode storage solution instead of plain water.

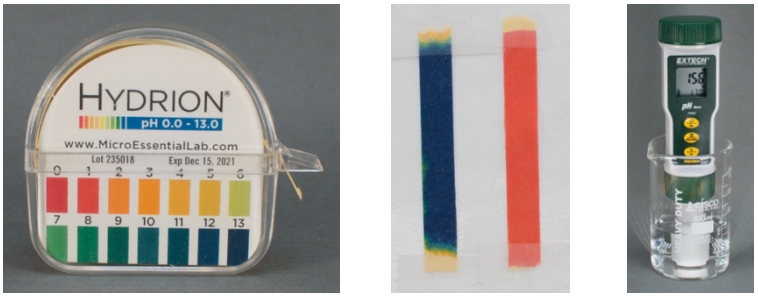


Figure 3-32. Left: Universal indicator paper. Note the pH-indicating color scale. Middle: Universal indicator paper, indicating pH ~12 (strongly basic; dark blue) and pH ~1 (strongly acidic; dark red). Right: An inexpensive pH meter indicating a pH of 1.56.

Like dishes in the kitchen, labware must be cleaned. In most cases this is as simple as a thorough rinse followed by wiping with a dry rag or air drying. On rare occasions stubborn residues can be removed with the textile gun or the ultrasonic cleaner. Don't use your kitchen dishwasher!

Finally, keep notes about procedures you use for the first time or for anything unusual during a procedure which has become routine to you. Include amounts of chemicals used, times, temperatures, colors, smells, etc. These notes might help you figure out why a procedure went wrong or perhaps why it worked unexpectedly well. A digital copy of your lab notes will generally be more useful and last longer than a paper copy. Photos of specimens before and after work are a useful addition to the lab notebook because memory alone often isn't good enough.

3.13 Working Safely with Chemicals

All chemicals present some hazards and must be treated appropriately. With common sense and a little basic knowledge (which you will learn here) chances of a chemical injury are reduced.

Before using a chemical for the first time, learn its specific handling procedures and safety hazards by reading its *Safety Data Sheet* (SDS; formerly called *Material Safety Data Sheet*, MSDS). These are readily available online (often at the supplier's or manufacturer's web site) and include information such as health and safety hazards as well as product ingredients. Keep a file of SDS sheets for all chemicals in your workspace. To learn how to read an SDS see OSHA (2012) and MIT (2025).

Chemicals must be stored in clearly labeled, sealed polyethylene or polypropylene bottles (Figures 3-27 and 3-28) with solids in wide mouth containers and liquids in narrow mouth containers. To avoid hazards caused by breakage glass bottles should be used only when plastic is unsuitable. Where possible use the original container with original label. For chemical storage a locked cabinet and/or fireproof cabinet is preferred. Note that metal cabinets often attacked by strong acid vapors even if bottles appear tightly closed.

Chemical storage should ideally be segregated by reactivity: Strong acids should be stored separately from strong bases. Water-sensitive chemicals should be stored separately from water solutions. Chemical containers should sit in chemically resistant pans in the event of drips or leaks. This segregation is especially important in seismically active locations.

Avoid storing large quantities. Buy only what you reasonably anticipate needing. If only small amounts are needed but only large amounts available share excess with other collectors or ask them for their excess instead of buying.

When pouring a liquid immediately wipe the opening and sides of the container to clean up all drips which may have occurred. Dispose of the used wipe the same as the chemical itself. Have dry kitty litter on hand for easy cleanup and disposal of spilled liquids.

To prepare a dilute solution of a strong acid, ***always wear safety glasses and gloves***. Always *slowly* pour the acid to the water with stirring and never add water to the acid. Mixing strong acid and water produces heat (is exothermic) so the latter sequence could cause violent boiling with the acid solution spattering dangerously. To avoid thermal shock, wait until after the diluted acid has cooled to room temperature before adding any minerals to be treated. Place all vessels involved in the dilution in a plastic basin to safely contain any spills. For more on the general properties, handling and disposal of strong acids see Sinkankas (1972, 235).

Don't mixed chemicals to (for example) improve an existing procedure or invent your own. The results can be anywhere from somewhat obnoxious to downright toxic. For example, you may be familiar with the common warnings about mixing NH_3 and bleach, a reaction which produces highly toxic chloramine gases. One might consider mixing sodium dithionite with strong acid to achieve faster derusting, but this produces toxic sulfur dioxide gas (SO_2) which has a choking, burning sulfur smell.

All chemical cleaning procedures generate chemical waste whose disposal is covered in Section 3.11.

More detail on handling and storing chemicals is easily available on the World Wide Web; see for example EHS (2025). Gorman (2005) is another useful (albeit somewhat simplistic) resource.

3.14 Some Elementary Chemistry

To understand and execute the chemical cleaning procedures that follow no chemical knowledge is needed, but it can be helpful. Thus, some elementary chemistry concepts are presented in this section. Feel free to skip this material if you already have an adequate chemistry background.

All matter is composed of *atoms*, particles so small that it would take one million carbon atoms laid side-by-side to equal the width of a human hair. Every atom has an even tinier *nucleus* composed of one or more *protons*, particles which carry a positive electrical charge. (The nucleus also contains neutrons, electrically neutral particles, which are not important for our purposes here.) Orbiting the positively charged nucleus like planets around a star are negatively charged *electrons*. (This solar system model is a great simplification of the true quantum mechanical complexities of an atom, but despite the simplicity, it is sufficiently useful for our introductory purposes.) An atom seeks to maintain electrical neutrality with the number of protons and the number of electrons is equal.

A *chemical element* is a substance that cannot be broken down into other substances by chemical reactions. Familiar elements include oxygen and iron. Air is not an element because it is a mixture of gaseous elements, mostly nitrogen, oxygen and argon. Rust is not an element because it can be broken down into iron and oxygen. The identity and chemical properties of an element are determined by the number of protons in the nucleus. For example, the nucleus of an oxygen atom always contains eight protons whereas in the nucleus of an iron atom we find 26 protons. The number of protons is also called the *atomic number*.

Each element's name is abbreviated with its *chemical symbol*, having one or two letters. Some of these abbreviations are derived from familiar names, such as O for oxygen while others are derived from ancient (often Latin) names, such as Fe (ferrum) for iron. These symbols are widely used in chemistry and mineralogy. Table 3-1 lists some chemical elements commonly found in minerals as well as each element's atomic number (At. No.). There are 94 naturally occurring elements, only about half of which occur frequently enough to be in minerals likely to be encountered by the amateur collector.

In 1869 Russian chemist Dmitri Mendeleev organized the elements known at the time into a *periodic table*, based on trends on chemical and physical properties. Many different periodic table arrangements have been designed since then. Figure 3-33 depicts the most common arrangement.

Table 3-1. Some chemical elements commonly found in minerals.

Name	Symbol	At. No.	Name	Symbol	At. No.
Hydrogen	H	1	Copper (cuprum)	Cu	29
Lithium	Li	3	Zinc	Zn	30
Beryllium	Be	4	Arsenic	As	33
Boron	B	5	Strontium	Sr	38
Carbon	C	6	Zirconium	Zr	40
Nitrogen	N	7	Niobium	Nb	41
Oxygen	O	8	Molybdenum	Mo	42
Fluorine	F	9	Silver (argentum)	Ag	47
Sodium (natrium)	Na	11	Cadmium	Cd	48
Magnesium	Mg	12	Tin (stannum)	Sn	50
Aluminum	Al	13	Antimony (stibium)	Sb	51
Silicon	Si	14	Cesium	Cs	55
Phosphorus	P	15	Barium	Ba	56
Sulfur	S	16	Lanthanum	La	57
Chlorine	Cl	17	Cerium	Ce	58
Potassium (kalium)	K	19	Tantalum	Ta	73
Calcium	Ca	20	Tungsten (wolfram)	W	74
Titanium	Ti	22	Platinum	Pt	78
Vanadium	V	23	Gold (aurum)	Au	79
Chromium	Cr	24	Mercury (hydrargyrum)	Hg	80
Manganese	Mn	25	Lead (plumbum)	Pb	82
Iron (ferrum)	Fe	26	Bismuth	Bi	83
Cobalt	Co	27	Thorium	Th	90
Nickel	Ni	28	Uranium	U	92

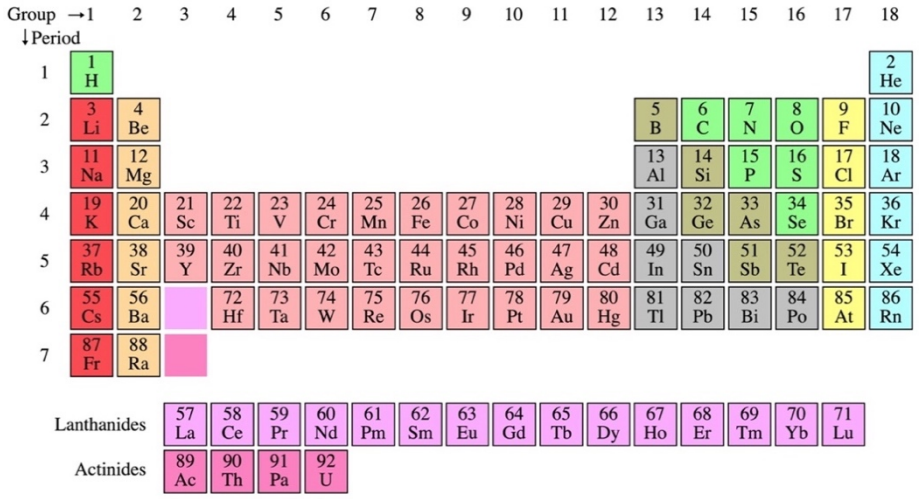


Figure 3-33. A periodic table including all elements up to atomic number 92.

The periodic table has great importance in chemistry including showing relationships and trends among the elements. For example, adjacent elements in the same period (row) such as manganese and iron have some similar chemical and physical properties. The same is true for elements in the same group (column) such as copper and silver. These similarities and differences in properties are key to understanding many aspects of basic chemistry and mineralogy.

Some minerals are composed of only one atom type, such as copper, gold or diamond (which is just carbon). When a mineral contains two or more different elements it is a *chemical compound*. (This is another necessary but useful simplification. We are ignoring alloys and some other mineral classes for the sake of convenience.) The ratio of the atoms in a particular mineral are always the same (another simplification). These ratios can be represented by a *chemical formula* which lists all the different atoms with subscripts to indicate how many of each atom. For example, orpiment contains two atoms of arsenic for every three atoms of sulfur, so its chemical formula is As_2S_3. Pyrite has a 1:2 ratio of iron to sulfur; its formula is FeS_2. (A subscript of 1 is omitted.) Halite (table salt) has an equal number of sodium and chlorine atoms, NaCl. The subscripts are almost always integers but can be fractional numbers in some cases.

In mineral formulas, the abbreviation REE means 'rare earth element' which includes any elements from lanthanum (La) to lutetium (Lu). These elements have very similar chemical properties and often occur together in minerals.

Chemical formulas for minerals can be quite complex. For example, elbaite tourmaline is $Na(Li_{1.5}Al_{1.5})Al_6(Si_6O_{18})(BO_3)_3(OH)_3(OH)$. A set of atoms in parenthesis, such as (BO_3) often indicates these atoms are attached to each other as a group. (A set of atoms does not always have to be in parenthesis to be considered a group.) Elbaite has a borate group (BO_3), a silicate group (Si_6O_{18}) and a hydroxyl group (OH). Minerals with the same group can sometimes (but not always!) have similar properties. For example, many minerals having a carbonate group (CO_3) will produce carbon dioxide (CO_2) gas bubbles when treated with strong acid. Calcite, a calcium carbonate - $CaCO_3$ - is the most obvious case. Rhodochrosite, a manganese carbonate - $MnCO_3$ - also has a carbonate group and so we predict that rhodochrosite may also react with strong acids to release CO_2. There are dozens of other atom groups, some very common (such as silicates) and others rather rare. For a good discussion on writing formulas for minerals see Rosenzweig (1996).

When the formula contains a set of atoms within parenthesis and these atoms are present as a repeated unit, and the total number of atoms in the molecule indicated by the subscript outside the right parenthesis. For example, in the formula for sodium acetate - $Na(C_2H_3O_2)_2$ - there is one Na atom for each $C_2H_3O_2$ group, and the entire formula can also be written as $NaC_4H_6O_4$.

When a substance contains water as part of its crystal structure, this is indicated by "$\cdot nH_2O$," where n is the number of water molecules (except when n = 1, which, like a formula subscript of 1 is assumed). A substance having one water molecule is a monohydrate ($Na_2CO_3\cdot H_2O$ is sodium carbonate monohydrate), two water molecules a dihydrate ($C_2H_2O_4\cdot 2H_2O$ is oxalic acid dihydrate), etc.

Chemical formulas are also very useful to give a compact representation of a *chemical reaction*, a process in which one or more substances are decomposed while other new substances

are formed. For example, in words we might write "calcite ($CaCO_3$) reacts with hydrochloric acid (HCl) to produce calcium chloride ($CaCl_2$), carbon dioxide (CO_2) and water (H_2O)." Writing reactions as words quickly becomes cumbersome and doesn't easily accommodate all the information that can be included when chemical formulas are used to write a *chemical equation*. The chemical equation for the reaction of calcite with hydrochloric acid is:

$$CaCO_3 + HCl \rightarrow CaCl_2 + CO_2 + H_2O \qquad \textbf{Equation 3-1}$$

The arrow designates "things on the left (called the *reactants*) react to become things on the right (called the *products*)." Because atoms cannot be created or destroyed (or converted into another element) in a chemical reaction the total number of atoms of a particular element in the products must be the same as the total number of atoms of the same element in the reactants. When a chemical equation is written in a way which meets this condition it is *balanced*. Equation 3-1 is not balanced because there are two chlorine atoms in the products but only one in the reactants. Adding numbers in front of the formulas can balance the equation (one calcium, one carbon, three oxygens, two hydrogens and two chlorine atoms on both sides of Equation 3-2):

$$CaCO_3 + 2\,HCl \rightarrow CaCl_2 + CO_2 + H_2O \qquad \textbf{Equation 3-2}$$

Balanced equations are important in many areas of chemistry but lucky for us they are usually not needed to understand the basic reactions involved in mineral specimen cleaning. Therefore, we will usually not make the effort to write balanced equations.

An atom having an electron count different than the proton count is called an *ion*. If a neutral atom (having an equal number of electrons and protons) loses one or more electrons it gains a positive electrical charge and is called a *cation*. If a neutral atom gains one or more electrons the resulting ion has a negative electrical charge and is called an *anion*. For example, when a sodium atom (Na) loses an electron (abbreviated in equation 3-3 as e^-) it becomes Na^+ (a sodium cation). When this electron is gained by a chlorine atom (Cl) the chlorine becomes Cl^- (a chloride anion). In the same way we denote an atomic charge with a superscripted plus or minus sign a superscripted zero can be used to denote a neutral atom.

$$Na^0 \rightarrow Na^+ + e^- \quad \text{and} \quad Cl^0 + e^- \rightarrow Cl^- \qquad \textbf{Equation 3-3}$$

For the sake of simplicity, the superscripted zero is often not shown and an atom without a superscripted charge is assumed to be neutral. Applying this simplification to Equation 3-3 gives Equation 3-4:

$$Na \rightarrow Na^+ + e^- \quad \text{and} \quad Cl + e^- \rightarrow Cl^- \qquad \textbf{Equation 3-4}$$

In Equation 3-4 note that the total electrical charge of the reactants and of the products is conserved, because electrons cannot just be created or destroyed; they must go to, or come from, somewhere. The net effect in this example is to transfer an electron from a sodium atom to a chlorine atom. Equation 3-4 illustrates electron transfer between single atoms, but it can occur also occur between two groups, or an atom and a group, or even whole molecules. Furthermore, the transfer is not limited to a single electron; transfers of two or even three electrons are common.

When one or more electrons are lost the atom (or group or molecule) has been *oxidized* and the charge becomes more positive. When one or more electrons are gained, *reduction* has occurred, and the charge becomes more negative. In Equation 3-3 Na has been oxidized to Na^+ and Cl has been reduced to Cl^-.

Because electrons cannot just appear or disappear, this means that oxidation must always be accompanied by reduction. A reaction having both reduction and oxidation is called a *redox reaction*. Derusting with dithionite is an example of a mineral cleaning redox reaction.

Ionic charges can be just about any positive or negative whole number but because of the way electrons are sorted in their orbits charges of more than eight are restricted only to certain uncommon groups. For example, in Equation 3-5, derusting with dithionite - $S_2O_4^{2-}$ (an anion having six atoms and a minus two charge) involves reduction of Fe^{3+} (the ferric cation) to Fe^{2+} (the ferrous cation). Ions of the same element but having different charges will often be referred to by similar but unidentical names. The iron atom in Equation 3-5 is reduced and so dithionite must be oxidized. However, equation 3-5 is not balanced (the dithionite oxidation products are not shown). Unbalanced equations are often used to illustrate a principle without showing all details of the reaction.

$$Fe^{3+} + S_2O_4^{2-} \rightarrow Fe^{2+} \qquad \textbf{Equation 3-5}$$

Recall that opposite electrical charges attract. This attraction is the basis for one kind of bonding between atoms in molecules called *ionic bonding*. Equation 3-6 shows a sodium cation and a chloride anion coming together by mutual attraction to form sodium chloride whose formula is NaCl (halite, also familiar as table salt). Because this compound is formed by the attraction of oppositely charged ions, we say NaCl is an *ionic compound*.

$$Na^+ + Cl^- \rightarrow Na^+Cl^- \qquad \textbf{Equation 3-6}$$

A *covalent bond* is formed by sharing one or more electron pairs between atoms. Covalent bonding exists in (for example) carbon dioxide (CO_2) and silicate groups (SiO_4^{4-}). Ionic bonding is more common between atoms from opposite ends of the periodic table (such as Na, group 1 and Cl, group 17) whereas covalent bonding dominates when periodic table positions are closer (Si and O are both from group 16 and in adjacent periods). In our simplistic, introductory approach we treat all bonding as if it is ionic (a convenient, although not very accurate simplification).

Chelation (sequestration) is a special case of bonding where a metal cation is bonded to another molecule (called a *ligand*) in two or more spots. The word 'chelation' is derived from a Greek word meaning 'claw.' The ligand surrounds the cation like a crab holding prey with both claws simultaneously (Figure 3-34). In mineral cleaning chelation is employed to keep certain metal cations (especially Fe^{2+}) dissolved in solution so they do not redeposit on the specimen being cleaned. Ethylenediaminetetraacetic acid (EDTA) and citric acid (or the salts of these compounds) are two commonly encountered chelating ligands.

Figure 3-34. An AI interpretation of chelation.

So far, we have focused on transfer of electrons. Transfer of hydrogen cations (H^+) is also important. A species which donates H^+ is called an *acid*, whereas a species which accepts H^+ is called a *base*. ("H^+" is another widely used simplification; "H_3O^+" is also commonly used and is more accurate but is still an imperfect representation of reality.) For example, in Equation 3-7 HCl (hydrogen chloride; called hydrochloric acid when dissolved in water) gives H^+ to HO^- (part of the ionic compound NaOH, also called lye). In this reaction HCl is an acid and HO^- is a base. The products are HOH (water) and NaCl.

$$HCl + Na^+ OH^- \rightarrow HOH + Na^+ Cl^- \qquad \textbf{Equation 3-7}$$

Other acids familiar acids include sulfuric acid (H_2SO_4) and acetic acid (CH_3CO_2H; in vinegar). Sodium carbonate (Na_2CO_3; washing soda or soda ash) is a base. Some molecules can be either acids or bases, depending on what other substances are present in the reaction. Like redox reactions, acid-base reactions are also a common aspect of chemical mineral cleaning procedures.

The concentration of acid or base in a reaction is often crucial. This is quantified by *pH*. When pH < 7 the solution is acidic, pH > 7 is basic (or alkaline) and pH = 7 is neutral. The pH scale (1–14) is derived from a mathematical equation so that each pH step corresponds to a ten-fold change in acid or base concentration. Table 3-2 lists the approximate pH ranges of some common solutions. A solution's pH is measured with pH paper, litmus paper (whose color changes with pH) or an electronic pH meter. Practice using pH paper or a pH meter with the materials in Table 3-2.

In some cases, it is useful to maintain pH within a specific, narrow range; this is achieved with a *pH buffer*. Iron OUT powder (a common mineral derusting agent) contains sodium bicarbonate ($NaHCO_3$) as a buffer.

More information on any topic discussed in our brief, whirlwind chemistry course can be found at Wikipedia. Armed with a little basic chemistry knowledge, we are ready to explore some chemical methods to clean and develop mineral specimens.

Table 3-2. pH of some common solutions.

Solution	Approximate pH range	
Battery acid (H_2SO_4)	< 1	Strongly acidic
Orange juice (ascorbic acid)	3.3–4.2	
Vinegar (acetic acid)	4–5	
Black coffee	5	
Milk	6.5–6.8	Weakly acidic
Pure water (H_2O)	7*	Neutral
Sea water	7.5–8.4	Weakly basic
Ammonia (NH_3)	11.0–11.5	
Household bleach (NaOCl)	12.5	
Lye drain cleaner (NaOH)	14	Strongly basic

*Usually slightly acidic (pH 6–7) due to dissolved CO_2.

3.15 Derusting

Perhaps the single most common mineral cleaning issue faced by the amateur collector is brown, earthy crusts of iron (usually Fe^{3+}) hydroxides/oxides ('iron stains' or 'rust'; sometimes also called limonite). Rust is usually a complex mixture of ill-defined species which may include lepidocrocite - $Fe^{3+}OOH$, goethite - $Fe^{3+}OOH$, ferrihydrite - $Fe^{3+}{}_{10}O_{14}(OH)_2$, akaganeite - $Fe^{3+}{}_{10}O_{14}(OH)_2(Fe^{3+},Ni^{2+})_8(OH,O)_{16}Cl_{1.25}\cdot nH_2O$, jarosite - $KFe^{3+}{}_3(SO_4)_2(OH)_6$, hisingerite - $Fe^{3+}{}_2(Si_2O_5)(OH)_4\cdot 2H_2O$ and miscellaneous hydrated iron oxides such as $Fe_2O_3\bullet nH_2O$ as well as iron phosphates or arsenates (Macchia 2016 *et al.* and Ralph 2023). Geologically, rust may be formed by decomposition of iron-containing minerals within the same pocket or by intrusion of iron-rich water.

The amateur collector might be tempted to remove such coating by scraping but the results are only rarely (if ever) satisfactory. In addition, removal of rust - especially a thick coating - may leave a rough, pitted surface. This must be considered when planning rust removal. If the coating is to be removed, start with the textile gun to remove as much as possible, as the chemical methods described below generally only remove thin rust deposits. Gol (2004a and 2004b) provides a brief comparison of chemical derusting methods.

For minerals compatible and noncompatible with derusting chemicals mentioned in this section see Chapter 4 and www.mincleandev.com.

A. Sodium Dithionite

Rust contamination occurs on a wide range of mineral species so a broadly effective, yet mild method is needed to remove these crusts. Beginners often try strong acids such as HCl or H_3PO_4, but these are often ineffective and can make the situation even worse by damaging other minerals present. Iron OUT (powder), familiar to many amateur mineral collectors, is by far the mildest and most effective chemical available for derusting. Figure 3-35 illustrates an example of this chemical's effectiveness.

Figure 3-35. Iron OUT powder (left). Derusting orthoclase with Iron OUT solution, before (center) and after (left) overnight treatment.

The active derusting ingredient in Iron OUT (powder) is sodium dithionite ($Na_2S_2O_4$, also called sodium hydrosulfite, even though it lacks any hydrogen or sulfite ions). Duthaler and Weiß (2024, 56) provide a general overview of this chemical. Dithionite works by reducing Fe^{3+} to Fe^{2+} thus converting insoluble rust into more soluble iron species. It is especially effective against minerals with weak Fe–O bonds (Machia *et al.* 2016). The electrons to reduce Fe^{3+} are provided by oxidation of dithionite ion to bisulfite ion (HSO_3^-) as shown in Equation 3-8:

$$Fe^{3+}OOH + S_2O_4^{2-} + 4\,H^+ \rightarrow 2\,Fe^{2+} + 2\,HSO_3^- + 2\,H_2O \qquad \textbf{Equation 3-8}$$

Iron OUT is tolerated by a wide variety of mineral species. It is widely available (Amazon, hardware stores and home improvement stores) and is inexpensive enough for routine, large-scale use (about $20 for a two-kilogram bottle at the time of this writing).

There are several products available under the Iron OUT brand, so make sure you purchase Iron OUT *powder* (Figure 3-35). Originally the dithionite-containing Iron OUT product was called Super Iron OUT and the product called Iron OUT was a liquid formulated with oxalic acid. A few years ago, Super Iron OUT was renamed Iron OUT, but its ingredients remained the same. None of the other products currently under the Iron OUT brand contain dithionite.

The Iron OUT SDS reveals that in addition to 15–40% dithionite the product also contains sodium carbonate (Na_2CO_3), sodium metabisulfite ($Na_2S_2O_5$) and sodium sulfite (Na_2SO_3). These are likely unavoidable byproducts of dithionite manufacture which are not economically reasonable to remove and do not alter the product's derusting characteristics. Also present is citric acid which serves as a pH buffer and iron chelator.

Based on its ingredients list (Lab Alley 2025) Iron Away appears nearly identical to Iron OUT, but its use for mineral cleaning appears untested. Beware of a similarly named product called Iron-Away whose SDS (ChemBrite 2025) indicates it does not contain dithionite and is likely to damage a wide range of mineral species.

Iron OUT and other dithionite chemicals are only effective against thin rust coatings; thick coatings are not noticeably affected. Extended treatment is not useful because a water solution of dithionite loses its potency in 24 to 48 hours. Simply adding more dithionite is uneconomical because the dithionite decomposition products hasten the decomposition of dithionite itself. In fact, dithionite can be used to remove thin rust coatings in the presence of thick iron hydroxide/oxide masses such as Ojuela Mine limonite matrix. When the coating is thick or well-crystallized (such as goethite or its pseudomorphs after other minerals) clean the specimen with a textile gun, air abrasion or a vibratory impact tool before dithionite. A hot oxalic acid solution can also be effective but only a few minerals can be successfully subjected to this rather brutal derusting treatment.

Rust may also appear as black stains and can be treated with dithionite in the normal way. However, such black stains may instead be manganese hydroxides/oxides which cannot be removed with dithionite; other treatments are necessary.

If the specimen is to be trimmed, sawn or abraded, complete these procedures before derusting, as the rust may have penetrated deep cracks or a porous matrix, causing rust to be visible again on newly exposed specimen faces.

For mineral specimen derusting, Iron OUT is quite easy to use. Iron OUT powder and its water solutions produce mildly objectionable sulfur dioxide (SO_2) odors, so it is best to work outdoors. If the cleaning is conducted indoors a sealed container must be used. (A closed container is not necessary outdoors, but it can increase the solution's working lifetime.) *Wear gloves when adding specimens to or removing them from this solution as the disagreeable odor can be quite persistent on skin*. Dithionite can bleach some clothing dyes, so an apron or lab coat is recommended. The specimen to be cleaned is placed in an adequately large container (plastic is preferred but steel or glass are also useable) then fully submerged in room temperature tap water. (Distilled or deionized water is often recommended but rarely needed. Why use purified water when the water will just become heavily contaminated with dissolved iron? When in doubt, however, use distilled water.) Add 2–5 g of Iron OUT powder per liter of water. An exact weight is not needed but a large excess is more wasteful than beneficial. Dissolution may be somewhat slow.

When possible, the dithionite solution should be agitated by magnetic stirring. A circulating solution lifts reduced iron from the sample surface more efficiently than a static

solution. This is especially important with samples having a porous matrix as this reduces the possibility of yellow stains appearing after drying. The rate acceleration is evidenced by a more intense yellow to brown coloration (dissolved iron compounds) in stirred solutions versus those not stirred. Dithionite decomposition is accelerated by atmospheric oxygen, so agitation by air bubbling is not ideal.

Betts (2025a) recommends using hot water (perhaps to hasten dissolution), but this is detrimental as dithionite decomposes faster at a higher temperature and the powder dissolves quickly enough (aided by some patience...our primary mineral cleaning tool) at room temperature.

Dithionite powder decomposes slowly in contact with atmospheric water vapor (dithionite dust has been reported to ignite in some cases) so store in the original container in a cool, dry place. Further sealing with electrical tape (Figure 3-28) is a good idea. The powder's dust and sulfur dioxide fumes can provoke an asthmatic attack (American Lung Association 2023) so at-risk collectors should work outside and wear a suitable dust mask while handling this chemical.

Check the cleaning progress every few hours. In some cases, the rust color will fade completely after 3 hours while other times 24 hours or longer are needed. Treatment longer than 48 hours is ineffective because the dissolved dithionite completely decomposes during this time (Equation 3-9). The time issue is addressed in more detail below.

$$2\ S_2O_4^{2-} + H_2O \rightarrow S_2O_3^{2-} + 2\ HSO_3^- \qquad \textbf{Equation 3-9}$$

Rust stains may fade and appear to be removed after just a few hours only to reappear when even just partially dried because some reduced iron remains on (or below) the specimen's surface. It is better therefore to continue immersion overnight even when stains have disappeared after an hour or two. Used in conjunction with dithionite, EDTA (below) can often obviate this issue.

The solution may have a yellow to dark brown color at this point due to a high concentration of dissolved iron (especially if the rust layer is thick or the specimen is large) but this is not a problem. Instead, it suggests that additional dithionite treatment may be needed.

When the rust has been decolorized or 24 to 48 hours have passed the specimen is removed from the spent dithionite solution (gloves!), rinsed thoroughly with fresh water and allowed to dry. Sonication can be useful to remove the last traces of dissolved iron especially when the specimen has cracks or a porous matrix.

An impatient collector may be tempted to speed up dithionite derusting by heating the solution. However, this does not help as heat causes the dithionite to decompose faster without any significant acceleration of its cleaning effect.

Sometimes a yellow color reappears on the specimen after drying for hours or even days and most frequently with specimens having cracks or a porous matrix. This can occur because some of the iron was reduced and decolorized but not dissolved. The color reappears when chemical structure changes during dehydration or residual Fe^{2+} is oxidized back to Fe^{3+} by atmospheric oxygen. When HCl has been used for derusting staining may also occur due to

conversion of rust to $FeCl_3$. This $FeCl_3$ is then hydrolyzed by water to form $Fe(OH)_3$ which a appears as a yellow when dry (Equation 3-10):

$$\text{Rust} + HCl \rightarrow FeCl_3$$
$$FeCl_3 + H_2O \rightarrow Fe(OH)_3$$

Equation 3-10

The simplest method to remove the yellow staining is to repeat the dithionite cleaning procedure, with an emphasis on thorough rinsing and prolonged soaking (perhaps with sonication) after removal from the dithionite solution. Keeping the rinse water slightly acidic by adding a few drops of concentrated HCl or 85% H_3PO_4 reduces the production of $Fe(OH)_3$ deposits. Iron salts that are precipitated under these conditions will be colorless phosphates or chlorides (Duthaler and Weiß 2024, 51). Especially problematic is porous 'bonespar' microcline (Figure 3-36). Uncommonly, the yellow may fade after thoroughly drying for a few days. If this fails, brief exposure to 12% H_2O_2 or bleach may solve the problem. As always, verify that these reagents are compatible with the minerals present.

When repeating a cleaning procedure to remove yellow stains the stains can appear on specimens in the same batch which were not stained before as the iron from one stained specimen can dissolve then be deposited on other specimens in the same batch.

Figure 3-36. This porous 'bonespar' microcline required extra precautions during cleaning to avoid formation of yellow iron stains upon drying.

If, after repeating dithionite treatment, the yellow persists additional measures are needed to remove residual iron by adding a chelating agent such as EDTA, except when EDTA is contraindicated; Chapter 4 and www.mincleandev.com. (Several EDTA varieties are available. In this book, 'EDTA' refers to the disodium salt dihydrate.) The added chelator not only helps keep iron in solution but also helps Fe^{2+} resist oxidation back to Fe^{3+}. Try including one or two grams of EDTA per liter (amount not critical) with the Iron OUT bath in the post-Iron OUT rinse water. Sonication immediately after removal from the Iron OUT bath (with or without EDTA) can also be helpful. Unlike Iron OUT, EDTA may not dissolve quickly, even with stirring. This is not an issue, however, as the undissolved powder eventually dissolves over time.

In one case, a large porous feldspar specimen required multiple cleaning cycles (Iron OUT/EDTA solution overnight, followed by an overnight soak in clean water containing EDTA

and at least a day of drying) over six weeks before yellow no longer reappeared after a week's drying. To obviate the aggravation caused by repeated yellow stain removal always use EDTA in the Iron OUT solution and always sonicate in EDTA solution before final drying. When EDTA treatment fails, soaking in a solution of 5% HCl in water (one part concentrated HCl added to six parts water) followed by soaking in distilled water and thorough drying (overnight or longer) may do the trick. Textile gun treatment after the dithionite bath but before the final rinse is also helpful in some cases. In rare instances where these procedures fail Pearl (1982, 33) suggests extended a soak in concentrated HCl follow by extended soaks in clean water.

In some instances, green stains will appear after dithionite treatment, thorough rinsing and soaking (with or without sonication or EDTA). These stains are probably due to Fe^{2+} which has not been removed and tend to occur when the rust coating was thick and/or the matrix is porous. The stains often fade after a day or two of drying, due to atmospheric oxidation of green Fe^{2+} compounds to colorless Fe^{3+} compounds. When green stains persist after a day of drying repeat dithionite/EDTA treatment followed by extended soaking/sonication with EDTA. Duthaler and Weiß (2024, 61) report that when the green stains linger for days or longer their disappearance can be accelerated with H_2O_2 or bleach.

Minerals may be attacked by EDTA because this molecule chelates a wide range of metal cations having +1 to +4 oxidation state, including Fe^{3+}, Fe^{2+}, Ca^{2+} and Ba^{2+} (Chempendix 2025). Damage can range from imperceptible to minor delustering to major etching. For example, a glossy baryte crystal became somewhat dull when treated overnight with a solution containing 5 grams per liter disodium EDTA dihydrate. (Citrate did not attack the baryte; see below.) Consider carefully the need to use EDTA in conjunction with dithionite and consult www.mincleandev.com before proceeding. Keep exposure time as short as possible. As directed by Guiding Principle 5 always test on lower quality material first.

In place of EDTA some preparators recommend citric acid, sodium citrate (which is already present in Iron OUT) or ammonium citrate (King 1983, 57) but these do not appear to be any more effective or more widely tolerated than EDTA. Other ligands for chelation which have been explored include thioglycolate (but see Section 3.32), cysteine and methionine (Macchia *et al.* 2016).

A slimy deposit of undissolved iron compounds and/or elemental sulfur may appear during dithionite treatment. This is easily removed by water jet treatment or sonication. Some previous workers have suggested dissolving this sulfur precipitate in toluene, but this is a bad idea. Water and toluene do not mix so the specimen must be thoroughly dry for toluene treatment to work. Toluene is highly flammable, toxic and possibly a neurotoxin (Section 3.32). And the best reason of all: Water is much cheaper than toluene.

Collectors often ask how long does a dithionite solution last. Dithionite rapidly decomposes in air (oxygen) while in solution even in a closed container (King 1983, 57). The solution remains effective for 24 to 48 hours at most, depending upon temperature, concentration and other variables. There is no point in storing a dithionite solution for later use; a fresh solution must be prepared and used immediately each time dithionite treatment is needed. Adding fresh Iron OUT

(or any other dithionite product) to an aged solution is fruitless, because dithionite decomposition products already present accelerate decomposition of the additional dithionite. (Decomposition products tend to low the solution pH. The rate of dithionite decomposition is inversely proportional to pH, with a faster rate at lower pH.) A dithionite-containing powder is much less sensitive to oxygen than a dithionite solution but should be stored in a well-sealed (air- and water-tight) container as a precaution.

Dithionite may cause ink of all types - especially iron-based inks - to fade. Because provenance such as labeling should generally always be preserved avoid dithionite treatment when labeling is present.

Iron OUT is versatile but not without some problems. For example, there are some mineral incompatibilities (discussed below). Because of this some alternate dithionite-containing derusting products have been explored. 'Pure' sodium dithionite (i.e., lacking the extra chemicals found in Iron OUT) is useful, but is unfortunately also unavailable to the amateur in the United States because it cannot be shipped. **Jacquard Hydro** is a mixture of about 70–90% sodium dithionite and 10–30% Na_2CO_3 (Jacquard Products 2018). Jacquard Hydro solutions are frequently hazy, but this does not inhibit the reagent's derusting capacity.

Waller's solution (Waller 1980) is another dithionite-containing rust removal recipe widely recommended by mineral collectors (see for example Betts 2025a and Currier 2014). In one liter of water this solution contains 8.5 g $NaHCO_3$ (as a buffer to maintain the optimal pH ~ 7.3), 71 grams sodium citrate (to chelate Fe^{2+}) and 20 grams of sodium dithionite (to reduce Fe^{3+} to Fe^{2+}). When making Waller's solution use 'pure' dithionite not Iron OUT or Jacquard Hydro as these have additional ingredients which may etch carbonates or interfere with pH buffering (see below). Optimal ingredient ratios have been explored by Duthaler and Gloor (2015).

Some variations of the Waller's solution ingredient ratios have been suggested including increasing the amount of bicarbonate when calcite and other acid-sensitive minerals are present. A problem not addressed in any of these ratios is what kind of sodium citrate should be used? Not even Waller himself (Waller 1980) is clear on this. Citric acid has three acidic groups, so sodium citrate might have a 1:1 Na:citrate ratio (the monosodium or monobasic salt), a 2:1 ratio (the disodium or dibasic salt) or a 3:1 ratio (the trisodium or tribasic salt). In addition, any of these can be anhydrous (no water molecules as part of the compound) or a hydrate (one or more water molecules). This issue is potentially critical to the Waller's solution buffering capability and pH, as such properties depend on the precise ratios of substances present (in this case the dithionite, citrate and bicarbonate anions) which in turn will be different in the various citrate salts. So which sodium citrate should be used? Waller references Jackson (1958), who specifies use of tribasic sodium citrate dihydrate, $Na_3C_6H_5O_7 \cdot 2H_2O$.

Brochier (1990) gives an alternate Waller recipe but lacks detail: "Dissolve citric acid in water. Add [sodium] bicarbonate until there is no more effervescence or add NH_3 until a strong smell of the solution is present. Then add the dithionite." What water volume and chemical masses are used? Brochier states that oxalic acid can be used instead of citric acid, but (again) without details. (It is assumed to be the same recipe as with citric acid.)

Note that tribasic sodium citrate, and not citric acid, is used in Waller's solution. In this role citric acid is said to cause dithionite decomposition, resulting in a finely divided sulfur precipitate on the specimens being cleaned (Gol 2004b). The **Bridge's modification of Waller's solution** (King 1983, 57) uses 'ammonium citrate' (not specified but assumed to be the anhydrous dibasic salt; 20 grams per liter) in the same solution with the dithionite (2 grams per liter).

Whether Iron OUT or Jacquard Hydro is the best alternative depends upon the problem at hand. Iron OUT is not readily available in all countries, whereas these alternate products or their components might be. 'Pure' sodium dithionite is available for example from Lab Alley (www.laballey.com) and Jacquard Hydro from Amazon. When hunting for sodium dithionite, also try the alternate name, sodium hydrosulfite, but do not purchase sodium dithionate, bisulfite or bisulfate.

An additional consideration is the acidity increase (drop in pH) over time. Control experiments with dithionite decomposition products suggest the pH drop is due to production of $NaHSO_3$ product as shown in Equations 3-8 and 3-9. In one set of experiments, a fresh Iron OUT solution had a pH of 7.8 (slightly alkaline) immediately after preparation. This pH dropped during derusting to 6.1 (weakly acidic) after three hours and to 2.9 (moderately acidic) overnight. Iron OUT is often claimed to be buffered by the citric acid present, but this data suggests such buffering is only poorly effective (the solution's buffering capacity has been consumed). Similar pH profiles were observed with Iron OUT/EDTA, 'pure' dithionite or Jacquard Hydro. However, Waller's solution maintained an almost constant pH over 24 hours, starting at pH 7.2 and rising slightly to pH 8.0. Therefore, Iron OUT or Jacquard Hydro should only be used with caution (or not at all) with acid-sensitive minerals (Chapter 4 and www.mincleandev.com) or when acid sensitivity is unknown or in doubt, whereas these minerals are less likely to be damaged by Waller's (and perhaps Bridge's) solution. Some collectors also recommend adding extra $NaHCO_3$, NaOH or KOH to help maintain an alkaline pH during cleaning. However, the rate and capacity for Fe^{3+} reduction by dithionite decreases as the pH increases (Mehra and Jackson 1960, 317) and so derusting may be only poorly effective (if at all) at higher pH. As usual, always experiment with less quality material before committing your best material to an unexplored procedure.

Calcite etching during dithionite treatment remains a somewhat controversial subject due to conflicting reports. In many cases these reports are not based on reasonable experimentation and should therefore be ignored. Lustrous calcite quickly becomes frosty when treated with a water solution of citric acid, an ingredient present at 1–5 % concentration in Iron OUT (Summit Brands 2024) but absent from pure dithionite or Jacquard Hydro. Control experiments reveal that citric acid and EDTA (at typical derusting procedure concentrations) both etch calcite within ten minutes but trisodium citrate does not. Calcite is inconsistently resistant to etching when treated with unbuffered sodium dithionite, Jacquard Hydro, Waller's solution and Bridge's solution. Waller's solution does not etch calcite as long as the pH remains neutral to slightly basic (pH > 7). When in doubt minimize contact time and use Jacquard Hydro, Waller's solution or Bridge's solution instead of any other dithionite recipe, especially for calcite, aragonite and other carbonates. Treating calcite (and to a lesser extent other carbonates as well) with any dithionite procedure

should be avoided, if possible, especially if the calcite has good luster. Hansen (1984) briefly discusses applying paraffin wax over areas of the specimen to be protected from dithionite attack. This technique is promising but does not appear to have been explored in depth.

Jacquard Hydro lacks a chelator so calcite etch not an issue, but undissolved Fe^{2+} may remain, reappearing as brown or yellow stains after drying. In some cases, following Jacquard Hydro treatment with a water jet tool or sonication will remove this residual Fe^{2+}. Repeat the Jacquard Hydro/water jet cycle several times if needed. When the matrix is decomposed iron sulfides (pyrite, marcasite, pyrrhotite, etc.) preventing re-emergence of iron hydroxide/oxides stains can be difficult to impossible.

Scattered reports on accelerating derusting suggest only modest or inconclusive results. For iron extraction from a soil sample, Mehra and Jackson (1960) held a buffered dithionite solution at 80 ºC for 15 minutes (this would also accelerate mineral cleaning) but as Waller (1980) reminds us, heating should be avoided (where possible) for mineral cleaning due to the risk of thermal shock and other damage. Hansen (1984) also reports using Waller's solution at 75ºC for accelerated cleaning but implies that sulfur dioxide evolution was unacceptable. Betts (2025a) recommends using hot water (perhaps to hasten dissolution), but this is detrimental; dithionite decomposes faster at higher temperature and the powder dissolves quickly enough at room temperature. Warming accelerates the rate at which a dithionite solution decomposes but it is unknown if cleaning is accelerated enough to be worthwhile. In the same 1980 paper Waller reports that "using an ultrasonic cleaner to agitate the solution shortens treatment time somewhat...". Betts (2025a) also suggests sonication to accelerate cleaning with dithionite but gives no details. Experiments reveal that acceleration by sonication is unreliable and unpredictable was effective in only few cases using an Iron OUT/EDTA solution on various minerals and fossils.

Not all rust stains can be removed with dithionite. For example, the calcite and aquamarine in Figure 3-37 were unaffected by any derusting chemicals because in both cases the rust is included within the crystal (below the surface) and thus unreachable by the dithionite solution. Similarly, a quartz with galena specimen was inert to Iron OUT/EDTA as the rust was completely included within the quartz (Figure 3-37).

It has been recommended that dithionite treatment be avoided with minerals found in an ore oxidation zone (Duthaler and Weiß 2024, 62). This is reasonable advice, although not always necessary; some oxidation zone specimens are readily improved by dithionite treatment without damage. However, when in doubt always err on the side of caution and experiment on lower quality specimens first. Copper minerals appear to be especially susceptible to dithionite damage. Figures 3-39 through 3-42 illustrate changes observed when some copper minerals were treated with Iron OUT. In each case the color change was not removed by sonication. With malachite, azurite and boleite a fine, red-brown metallic precipitate (probably copper metal) was deposited.

Figure 3-37. These calcite (left), aquamarine (center) and quartz with galena (right) specimens were not improved by dithionite treatment because the rusty material is below the surface.

Waller's solution cleaning of a fluorite and rusty quartz specimen (Figure 3-38) was only partially successful, because the rust is thick and (in some spots) included within the quartz. More aggressive derusting with hot oxalic acid is not appropriate in this case because the fluorite will be damaged.

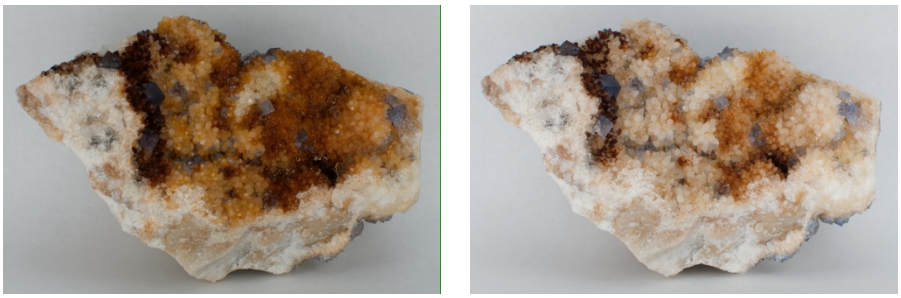


Figure 3-38. Treating this quartz and fluorite specimen with Waller's solution (left before, right after) was only partially successful because the rust is (in some places) thick, and both on and within the quartz.

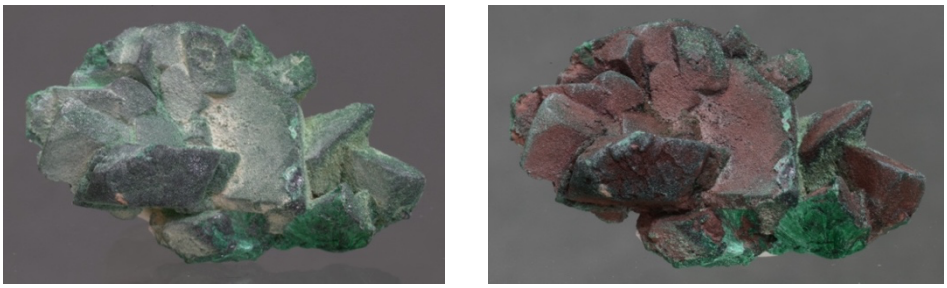


Figure 3-39. Malachite - $Cu_2(CO_3)(OH)_2$ - turned brown after ten minutes exposure. After removal from the Iron OUT solution the green color was restored after one week.

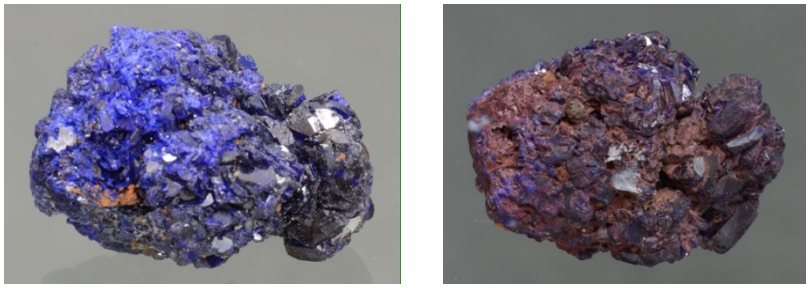


Figure 3-40. Azurite - $Cu_3(CO_3)_2(OH)_2$ - turned irreversibly dark after twenty minutes.

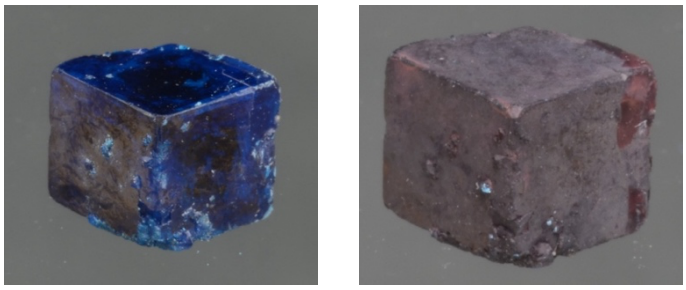


Figure 3-41. Boleite - $KPb_{26}Ag_9Cu_{24}(OH)_{48}Cl_{62}$ - turned brown after ten minutes exposure. After removal from the Iron OUT solution the darkening only faded slightly in one week.

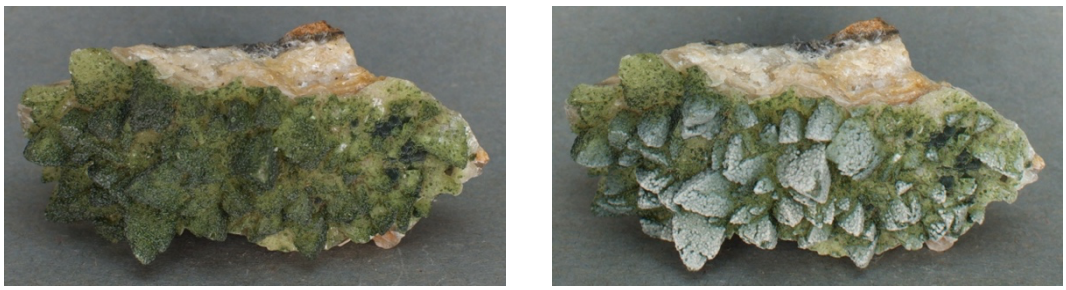


Figure 3-42. Duftite - $PbCu(AsO_4)(OH)$ - on calcite suffered a partial change from green to pale grey when treated with Iron OUT.

Iron OUT/EDTA brightened some sulfide minerals including galena, pyrite, pyrrhotite, sphalerite and chalcopyrite, but chalcocite was rapidly reduced producing a reddish surface deposit of metallic copper. For more information on dithionite compatibility see Chapter 4 and www.mincleandev.com.

B. Oxalic Acid

Oxalic acid ($C_2H_2O_4$) is an organic diacid with two carboxylic acid (CO_2H) groups. Its most common mineral cleaning use is for dissolving iron hydroxide/oxide crusts (rust). Dithionite is also frequently used for this purpose but unlike dithionite, oxalic acid will attack (weaken) and even fully dissolve both thin and thick rust deposits. Despite being more aggressive than dithionite,

oxalic acid is broadly useful for derusting. Oxalic acid is a moderately strong acid and will therefore attack acid sensitive minerals (especially those containing calcium) such as calcite or apatite (Chapter 4 and www.mincleandev.com), especially when hot. Quartz, feldspars and other minerals highly stable to acids can be cleaned of even thick rust crusts by hot oxalic acid solution.

In keeping with General Principle 7 derusting should be attempted with dithionite before oxalic acid is used, as dithionite is a milder and more selective treatment. An exception is when all minerals present (or suspected to be present) are tolerant to oxalic acid, in which case the latter, more aggressive method can be used. Sometimes several dithionite treatment cycles can achieve the same cleaning as one hot oxalic acid treatment. However, if after three dithionite cycles no further improvement is seen switch to a more aggressive treatment. When a thick coating is to be removed in the presence of oxalic acid-intolerant minerals repeating dithionite treatment for ten or even more cycles may be effective.

Iron hydroxide/oxide crusts are dissolved by converting insoluble iron hydroxides/oxides (represented here as Fe_2O_3) into soluble iron oxalate - $Fe_2(C_2O4)_3$. Contrary to numerous other reports Fe^{3+} is not reduced to Fe^{2+} during this process (equation 3-11):

$$Fe_2O_3 + 3\ C_2H_2O_4 \rightarrow Fe_2(C_2O4)_3 + 3\ H_2O \qquad \textbf{Equation 3-11}$$

As the reaction proceeds, the solution often turns yellow due to dissolved $Fe_2(C_2O_4)_3$ (Figure 3-43).

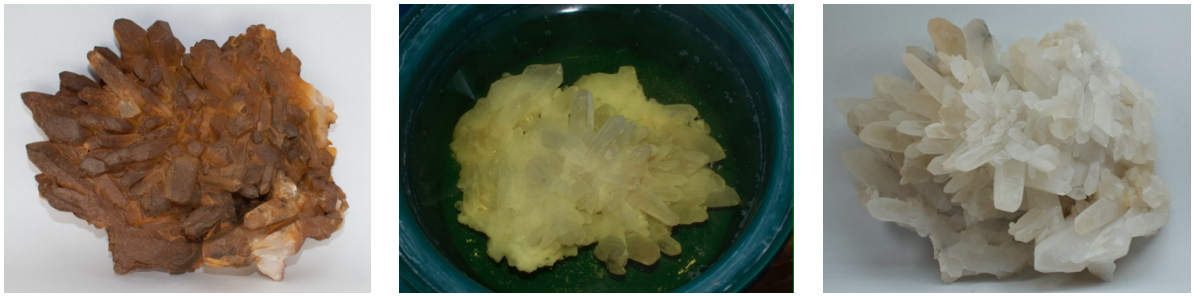


Figure 3-43. Cleaning rusty quartz (left) with hot oxalic acid. The solution is colored yellow by dissolved $Fe_2(C_2O_4)_3$ (center). After cooling and thorough rinsing the quartz is rust-free (right). The lightly frosted crystal faces were present before oxalic acid treatment.

Oxalic acid dihydrate ($C_2H_4O_4 \cdot 2H_2O$) is an inexpensive, widely available, white crystalline powder. Hardware stores may sell this chemical as 'wood bleach.' Numerous household cleaning products containing oxalic acid are also available under a wide variety of brands, but these products should be avoided as they often contain other ingredients which may interfere with mineral cleaning and/or damage the minerals you are trying to clean. These products are also typically less economical than pure oxalic acid powder (~$15 per pound at the time of this writing).

Oxalic acid is toxic; wear gloves and safety glasses when handling it. Avoid skin and eye contact. Although the use of oxalic acid at room temperature is frequently recommended such

treatment typically takes weeks or even months and offers no significant advantages over a hot oxalic acid solution. *Never boil an oxalic acid solution to dryness* as heat causes decomposition of solid oxalic acid into carbon monoxide (CO) and formic acid (HCO_2H). Formic acid further decomposes into carbon dioxide and water (equation 3-12). Carbon monoxide is familiar to many collectors as the highly toxic, colorless, tasteless and odorless gas responsible for 420 household deaths each year (CDC 2024). *Oxalic acid solutions should only be heated with excellent ventilation or (better yet) outdoors.* Plugging the heat source into an *automatic shutoff timer is an excellent idea*. If heated indoors, a carbon monoxide alarm is a useful and inexpensive safeguard.

$$C_2H_2O_4 \rightarrow HCO_2H + CO \rightarrow CO_2 + H_2O + CO \qquad \textbf{Equation 3-12}$$

Use of hot oxalic acid is straightforward. A crockpot having a glass (Pyrex) or glazed earthenware pot is best; hot oxalic acid solutions attack aluminum and some stainless-steel alloys (Hdchemicals 2023 and Sekine, Yuasa and Yajima 1997). Published information on the resistance of cast iron to oxalic acid is inconsistent so cast iron containers are best avoided. Containers made of wood (watch for leaks!) have also been recommended but are far from the best choice. Adjustable temperature and a timer are desirable (but not necessary) crockpot features. *Do not use this same crockpot for food*. The crockpot must have a suitable lid to minimize evaporation which might otherwise be problematic when the crockpot is heated for hours at a time. The lidless 'double boiler' setup recommended by Sinkankas (1970, 290) is not without potentially serious problems. If you anticipate using hot oxalic acid frequently a crockpot is an excellent investment. A used crockpot is ideal.

Before treating with oxalic acid remove as much loose debris from the specimen with the textile gun as possible. If the rust crust appears to be thin try dithionite treatment before submitting the specimen to more brutal, less selective oxalic acid treatment. Guiding Principle 7 tells us to always try the mildest possible method first. The quartz specimen of Figure 3-43 was not significantly changed by preliminary treatments with a textile gun or with Iron OUT/EDTA, so hot oxalic acid treatment was necessary for complete derusting.

The specimen to be cleaned is placed in the crockpot and more than covered with tap water, but do not fill to the top. Recall that water expands somewhat as it heats, so allow adequate space for this. (Distilled water is often recommended because tap water can contain enough calcium to cause precipitation of poorly soluble calcium oxalate, but this precipitate is trivial to remove with a textile gun.) Oxalic acid is then added; about 10 grams per liter of water is adequate. Higher concentrations are often recommended but are usually just wasteful. For example, Gol (2004b) recommends 50–75 grams per liter - an absurd waste, unless the solution is to be re-used frequently (which is not advised). If you are cleaning very similar material on a large scale - for example a hundred Arkansas quartz specimens at once - and rust seems to constantly persist after a single oxalic acid treatment - then higher concentration may be in order. The oxalic acid usually does not all dissolve immediately but will do so as the temperature increases. Stirring is not necessary, as

agitation will be provided by convection currents in the warming solution. Add the lid (any well-fitting lid except metal; even plastic works here) but do not lock it down to avoid pressure buildup.

The crockpot is heated for 3–8 hours, reducing heat when the solution boils. Check the water level every now and then and add more *hot* water only if the specimen is no longer fully submerged. (Replenishing evaporated water with fresh cold water may cause thermal shock. Or better yet cool to room temperature, replenish the water and resume heating.) The solution often turns yellow due to dissolved iron oxalate (Figure 3-43), but this is not a problem. Heating for more than eight hours is of little value as after this time all the oxalic acid will have been converted to iron oxalate (and visible rust will remain) or all the rust will have been dissolved (and the specimen will look clean). Stop heating and allow the specimen and solution to cool together to room temperature (reduces thermal shock risk). Remove the room temperature specimen (gloves!), rinse thoroughly (textile gun is useful for this and may remove any residual rust which was weakened but not dissolved) then allow to dry for at least 24 hours. Sonication and/or a little EDTA in the rinse water will help prevent yellow stains from appearing. The yellow stain issue is discussed in more detail in Section 3.15A.

Although heating an oxalic acid solution to boiling is contraindicated by some authors, it appears to cause no damage and is even beneficial as the moving water can more effectively loosen stubborn clay.

Some sources suggest that is better to remove the specimen from the hot solution (without cooling down) and immediately transfer to fresh, hot water to cool because this will minimize iron compounds being drawn back into cracks (and leaving yellow stains when dry). This recommendation is dangerous because it creates several chances of thermal shock (and subsequent damage risk), when the specimen is removed from the hot solution and exposed to the cooler air, and again when the now-cooler specimen is immersed in hot water. Better to deal with (generally treatable) yellow stains than to risk permanent damage.

After oxalic acid treatment, King (1983, 58) recommends a one-hour soak in distilled water to rinse out residual acid followed by a pH test with blue litmus paper. If the test paper turns red (indicating acid remains) the soak is repeated with fresh water. If the paper remains blue all the acid has been removed. However, litmus paper may not be sensitive enough for the last traces of acid; testing the rinse bath with pH paper or better a pH meter before and after immersion is recommended. Adding $NaHCO_3$ or other base is frequently recommended for this soak however King advises against it as the iron compounds which comprise the yellow stains are more soluble in neutral to acidic medium than in alkaline medium.

Some sources advocate an extended soak (days to weeks or longer) in oxalic acid and that heating must be avoided. In one extreme case, noted California collector Bob Bartsch is said to have left Colorado amazonites in oxalic acid solution for twenty years (!) with an acid change every few months (Hardinger 2023b). Although patience is a critical tool of the proper mineral preparator, this is absurd! Taking thermal shock into consideration, most (if not all) minerals which survive oxalic acid at room temperature will also escape unscathed after a few hours in a hot oxalic

acid bath. Colorado amazonite was found to clean up quite well without damage after just a few hours in a hot oxalic acid bath.

Small volumes of oxalic acid solutions can be flushed down the drain with plenty of water. The EPA indicates that such disposal presents no threat to sewage systems as microbes degrade the oxalic acid within 24 hours (EPA 1992). The pre-disposal neutralization recommended by some authors is therefore not necessary.

After treatment a white coating or precipitate of insoluble calcium oxalate is said in many reports to be common, especially in very hard water. It is also commonly stated that oxalic acid should be used only with distilled water to prevent these precipitates. This is generally untrue. If the calcium concentration in hard water is high enough to cause a calcium oxalate precipitate, then such a precipitate would be formed when oxalic acid is added to the water at the start of the cleaning procedure, even in the absence of any mineral specimens. In fact, the calcium oxalate precipitate might form only when (a) the solution volume is reduced significantly by evaporation, or (b) acid-sensitive calcium minerals present are attacked by oxalic acid or (c) the oxalic acid solution has been reused too many times. If the precipitate does form, it is generally easily removed (after cooling) by sonication or textile gun treatment.

If eight hours have elapsed and the specimen is not clean, drain the *cooled* solution and prepare a fresh oxalic acid solution. Adding more oxalic acid to the same solution increases the likelihood of yellow staining after drying. Some specimens have limonite coatings that cannot be removed even with strong oxalic acid. In such cases use "fresh 'fuming' [undiluted] hydrochloric [muriatic] acid" (Kandutsch 1983).

Yellow staining upon drying after oxalic acid treatment is resolved by the same methods used for dithionite. If yellow persists repeat treatment with hot oxalic acid solution.

It has been said that the yellow color of the oxalic acid solution and stains left on drying are due to some mysterious interaction of light with the oxalic acid. This is simply not true as the yellow color is due to compounds having Fe^{3+} and/or Fe^{2+} with a range of ligands (oxalate, water, hydroxide, oxide, etc.). It is therefore not necessary (and even utterly pointless) to avoid light when cleaning with oxalic acid.

Care must be taken with thermally sensitive specimens or those with pre-existing cracks. In these cases, it is best to use either mechanical cleaning methods such as air abrasion or chemical methods at room temperature such as dithionite. Soaking in oxalic acid solution at room temperature (instead of hot) is often recommended. This takes days to weeks (instead of hours) and only rarely (if ever) will result in less specimen damage, especially to acid-sensitive mineral species (Chapter 4 and www.mincleandev.com). A room temperature soak can be particularly frustrating if, even after weeks of soaking, derusting is incomplete.

Betts (2025a) suggests that oxalic acid treatment can be accelerated by sonication in a heated ultrasonic cleaner bath. For this place the specimen and oxalic acid solution in a closed, glass container, place this container in the cleaner basket and heat while sonicating. The process might take as little as thirty minutes for completion.

Re-use of oxalic acid solutions are sometimes advised but such reuse creates more problems than advantages. With continued reuse the iron concentration rises and with it the chance of yellow stains upon drying. In addition, as the oxalic acid is consumed the solution becomes less effective at derusting. Given oxalic acid's low cost and the waste of time to remove avoidable yellow stains, it makes more sense to discard the oxalic acid solution after each use and prepare a fresh solution for the next batch of minerals to be cleaned.

King (1983, 58) and Gol (2004b) mention including aluminum (foil or pan) or granulated zinc metal in the oxalic acid solution to reduce Fe^{3+} to Fe^{2+} and prevent yellowing. Experiments failed to reproduce this assertion.

Not all cases of apparent rust can be removed with oxalic acid. For example, oxalic acid is frequently used to clean rusty feldspar specimens. However, the microcline shown in Figure 3-44 was not changed when treated with hot oxalic acid solution because the red brown material is included below the crystal surface.

Figure 3-44. This microcline crystal was unchanged when treated with hot oxalic acid solution because the rust is included below the crystal surface.

Other than derusting, oxalic acid and its salts are only rarely used (or even useful) in mineral cleaning. In one example, Brochier (1990) states that ammonium oxalate "is an excellent rust remover" used by itself or with dithionite, but no details are given. However, experiments with hot aqueous ammonium oxalate failed to give any evidence of derusting. Herborner (unpublished results) reports "An alternating use of alkaline cleaning solutions and oxalic acid is promising" but no details are given.

Many silicates and minerals with high chemical stability can be successfully cleaned with hot oxalic acid. For example, rusty Himalaya Mine (California) specimens having tourmaline, microcline, quartz and lepidolite are successfully cleaned by a three-hour bath in hot oxalic acid solution, followed by appropriate cooling and sonication. For minerals compatible and noncompatible with oxalic treatment see Chapter 4 and www.mincleandev.com.

In closing this section, it is amusing to note that rubbing with a raw potato (with or without dish soap and some salt) is said to be effective for derusting, presumably due to oxalic acid present in this starchy root food. Unlike most other methods presented in this manual, the author has not verified the efficacy of this procedure.

C. Weak Acids

When dithionite and oxalic acid are either ineffective or inappropriate, other derusting reagents must be tried. Examples from the literature are briefly discussed below. However, these alternatives are generally only poorly effective.

Derusting is a common household problem, and so numerous commercial derusting products such as Rust Away and CLR Calcium, Lime and Rust Remover can be found. These products have very little value (and no real advantages) for mineral cleaning any but the most chemically robust minerals such as quartz. Not only are these products more expensive than Iron OUT or pure oxalic acid powder many (if not all) include ingredients harmful to minerals. For example, CLR Multi-Use contains lactic acid (among other things, according to the bottle's ingredients list) which can cause deposition of a thick calcium lactate crust when used to derust or etch calcite. Rust Away includes citric acid and NH_4HF_2 (Proschoice 2020). Check the product's SDS for ingredients that will obviously cause a problem. If you do choose to experiment with one of these products for mineral cleaning, as always try on lesser quality material (of the same mineral species and if possible, from the same locality) before ruining your better specimens.

Citric acid ($C_6H_8O_7$) has also been used for derusting but without specific details. In this capacity it behaves much like oxalic acid but is somewhat less effective (Duthaler and Weiß 2024, 53). Experimentation revealed that a hot solution prepared from 10 grams anhydrous citric acid in one liter of tap water does derust to a limited extent, but not as quickly or thoroughly as dithionite or hot oxalic acid solution. This citric acid solution has a pH of 2.9 and so like oxalic acid is inappropriate for acid-sensitive minerals. Post-drying yellow stains can be an issue; these are treated the same as with dithionite or oxalic acid. As with oxalic acid, calcium citrate deposits may form, but are easily removed. Some workers (Gol 2004b) suggest absurdly high (and quite wasteful) citric acid concentrations (300–500 grams per liter) are necessary for effective derusting.

Trisodium citrate (*not citric acid!*) is a component of Waller's solution as well as Bridge's modification of Waller's solution (King 1983, 57). However, this chemical is not an effective derusting agent by itself, even when hot. Diammonium citrate is likewise ineffective.

For derusting carbonates King (1983, 57) suggests applying a paste of made of sodium dihydrogen citrate and glycerine. Multiple applications may be needed. For delicate specimens, immerse in one part sodium dihydrogen citrate to six parts water followed by flushing with aqueous sodium bisulfate ($NaHSO_4$). Details are sketchy. Both procedures will cause some calcite etching so contact time must be brief.

Tartaric acid ($C_4H_6O_6$) is stated in several sources to be another suitable replacement for oxalic acid. Like citric acid, tartaric acid offers no derusting advantages over sodium dithionite or oxalic acid. A hot water solution of tartaric acid (no more than 50 grams per liter) is said to avoid yellows stains caused by other derusting agents (Gol 2004b, 48–50; King 1983, 58 and Sinkankas 1972, 237) but this lacks chemical sense because calcium oxalate and calcium tartrate are both colorless whereas iron oxalates and tartrates are colored.

Potassium sodium tartrate (Rochelle salt) is also reported to derust, but this effect could not be reproduced, even when the solution is hot. Duthaler and Weiß (2024, 53) suggest that sorrel salt (potassium hydrogen oxalate) is an even poorer choice for derusting due to its limited availability, higher cost and greater aggressiveness towards silicates.

Ascorbic acid ($C_6H_8O_6$) behaves similarly to other organic acids mentioned in this section, even though it lacks a CO_2H unit. This readily available, nontoxic white powder is better known as vitamin C. The most common salts are sodium ascorbate and calcium ascorbate. Its use as a mineral derusting agent has been mentioned briefly but not well explored. In some experiments the performance of these compounds was poor and inconsistent.

We might conclude that the presence of an CO_2H (carboxyl) or CO_2^{2-} (carboxylate) group in a molecule imparts some derusting ability. **EDTA** (ethylenediaminetetraacetic acid; usually as the disodium salt dihydrate) has two carboxyl groups and two carboxylate groups in its molecular structure. For mineral cleaning, its main purpose is to chelate iron and keep it in solution as well as to resist oxidation of Fe^{2+} back to Fe^{3+}. However, control experiments reveal that an EDTA solution has no derusting power by itself, even when hot.

Sulfamic acid, used mostly for removing carbonates was not found to have any derusting properties (despite mineral cleaning literature reports to the contrary and manufacturer's claims) and therefore need not be considered for derusting.

D. Strong Acids

Strong acids - particularly **hydrochloric acid** (HCl) - are frequently recommended for derusting but in fact are of little actual value for this purpose. *Muriatic acid* is an impure, concentrated HCl; these reagents can be interchanged for most mineral cleaning and development purposes. The range of mineral species which tolerate such harsh treatment is limited (Chapter 4 and www.mincleandev.com) so this derusting method should only be applied to the most chemically resistant minerals.

Published instructions for derusting with HCl often amount to little more than "throw rock in acid then rinse." For example, Pearl (1982, 33) says only that the specimen should be soaked in cold, concentrated HCl for several days or boiled (!) in concentrated acid for several minutes until clean. Some authors even suggest using HCl for cleaning without specifying precisely what cleaning problem is to be addressed! Betts (2025a) gives the most useful operating procedure: If used to remove rust check progress daily; rinse thoroughly, treat with the textile gun and repeat immersion as needed.

Muriatic acid has a yellow color due to Fe–Cl compounds. Dilution replaces chloride with water to produce colorless Fe–H_2O compounds. This iron impurity manifests as an increased probability of post-treatment yellow stains (which are treated by the same procedure used for dithionite derusting, Section 3.15A). Gol (2004a) suggests removing post-HCl yellow stains by soaking in a solution containing 50–200 grams of tartaric acid per liter. Although the suggested tartaric acid concentration appears wasteful the solution can be reused.

Strong HCl solutions release noxious hydrogen chloride gas. Precautions must be taken to avoid breathing these fumes. Treat specimens in closed containers and open these closed containers under water in a large bucket while wearing gloves and safety glasses.

Concentrated (85%) or diluted **phosphoric acid** (H_3PO_4; also called orthophosphoric acid) has also received scattered recommendations for derusting, but (again) usually lacking useful detail. Like HCl this chemical is not well tolerated by many minerals (Chapter 4 and www.mincleandev.com) and offers no significant advantages (and a greater number of disadvantages) for derusting compared to dithionite or oxalic acid. Daniel Gol Minerals (danielgol.com) offers (among other mineral cleaning chemicals) "Acide Cristocline." Its exact composition is secret, but it appears to be little more than just H_3PO_4. The product is only available in France (R. Duthaler, personal communication).

Other strong acids likely to be encountered by the amateur mineral cleaner when scouring the available literature include sulfuric acid (H_2SO_4), nitric acid (HNO_3), aqua regia (a mixture of HCl and HNO_3) and hydrofluoric acid (HF). *All of these are dangerous materials* (Section 3.32) - ***especially HF*** - *and have no significant value in mineral derusting*. King (1983) notes "Although widely recommended . . . [derusting with HF] should NEVER be used." In general, HCl and H_3PO_4 are more useful for calcareous carbonate sinter removal than for derusting.

E. Miscellaneous Methods

Ammonium oxalate, either alone or in conjunction with dithionite has been mentioned but no operational details are provided (Brochier 1990). Knopman (1975) reports without details that ammonium oxalate, ammonium phosphate and ammonium fluoride "are considered the most effective agents for removing iron stains" from stone artwork. An ammonium oxalate solution is slightly acidic, so the apparent rust removal may occur not by Fe^{3+} reduction and dissolution but instead by surface etching. Unpublished control experiments show that this chemical does not derust quartz, even when hot.

Drosdoff and Truog (1935, 669) and King (1983, 58) present a method for derusting which simultaneously preserves apatite. Key to this procedure is treatment with a solution of hydrogen sulfide gas (H_2S) dissolved in water. This gas is toxic and has a very strongly disagreeable rotten eggs smell, so amateurs should avoid this procedure (Section 3.32).

Duthaler and Weiß (2024, 75) and Macchia, *et al.* (2016, 323) briefly discuss the use of thioglycolic acid, ammonium thioglycolate and related chemicals for rust removal. However, these compounds have strongly disagreeable odors and must only be used with very good ventilation (a chemical fume hood); working outdoors may not be good enough if you wish to avoid emergency responders appearing to investigate a gas leak. Thioglycolates have also been mentioned (but not discussed in detail) for derusting minerals but are probably not worthy of deeper exploration, as these substances are carcinogenic and mutagenic (NTP 2023) and thus should be avoided by the amateur mineral preparator (Section 3.32).

Lieber (1978, 117) states that rust can be removed by soaking in 10% alum solution. This suggestion was unrepeatable and makes no sense as a derusting procedure, as it lacks an agent to reduce Fe^{3+} to Fe^{2+} or to chelate these ions. Control experiments reveal this alum solution is modestly acidic and attacks several carbonate minerals, so the 'derusting' effect might instead be a surface etching phenomenon.

Pearl (1982, 29) gives these two recipes: "Rust can be removed from specimens by soaking them in the following mixture: 1 part sodium gluconate, 1 part sodium citrate, 1 part 36 percent NH_3 water and 7–10 parts water" and "Successive immersion in potassium permanganate (1/2 teaspoon in 1 pint water) overnight and in $NaHSO_4$ (1 teaspoon in 1 pint of water) for 30 minutes was suggested for cleaning quartz." Both recipes make no chemical sense and appear to be no more than mineralogical old wives' tales.

3.16 Removing Black Coatings

A black deposit on a mineral specimen might be composed of iron hydroxides/oxides (rust) or of manganese minerals such as 'wad', 'psilomelane', manganite, hausmannite, pyrolusite, romanèchite, hollandite and coronadite to name a few, or something else such as silver (Figure 3-46). Such dendrites are usually not removed because they are mineralogically and aesthetically interesting. The black coating may be part of the specimen's natural mineral paragenesis so its removal should be carefully considered.

Figure 3-45. Manganese hydroxide/oxide dendrites on limestone.

When such a coating is to be removed try mechanical cleaning methods such as a textile gun or sonication before chemical treatment. Air abrasion may also be suitable if available. The amateur collector might be tempted to remove such coating by scraping but the results are only rarely (if ever) satisfactory: The coating usually only incompletely removed, and the underlying surface may already be naturally pitted and scarred, or it may acquire damage from the brushing and scraping. When mechanical methods are unsuitable, try dithionite as the first chemical method. Oxalic acid should be tried if dithionite fails, and no incompatible minerals are present (Chapter 4 and www.mincleandev.com). If dithionite and oxalic acid both fail the coating is very likely manganese based (especially if it is jet-black and somewhat powdery) and therefore needs a different approach.

Hydrogen peroxide (H_2O_2) often reacts with manganese-based coatings producing mild to vigorous effervescence as oxygen gas (O_2) is released (Equation 3-13):

$$H_2O_2 + MnO_2 \rightarrow O_2 + H_2O + MnO_2 \qquad \textbf{Equation 3-13}$$

Cleaning with this reagent is probably a combination of a chemical reaction (manganese mineral dissolution) and the physical action of effervescence. Drugstore H_2O_2 (a 3% solution in water) is often strong enough to see this effect. At this concentration the chemical requires no special safety precautions to handle (have you ever cleaned a wound by rinsing with 3% H_2O_2?). If no effervescence is seen with 3% H_2O_2 it is likely that the encrustation is not a manganese hydroxide/oxide mineral. A 12% H_2O_2 solution (sometimes called '30 volume' or '40 volume' peroxide) is also commercially available and not very expensive but requires the usual safety precautions (gloves and safety glasses). Some references recommend using a 30% solution (sometime called perhydrol), but this chemical must be stored in the refrigerator (but not with food!) and causes *severe, frostbite-like burns immediately on contact with skin*. (Some internet sources suggest preparing 30% or stronger H_2O_2 by evaporating solutions of lesser concentration. *This is exceptionally dangerous and should never be attempted!*) In some cases, soaking the specimen to be cleaned in 3% or 12% H_2O_2 for a few hours to overnight is sufficient for cleaning. The peroxide bath can be considered depleted when bubbling ceases or cleaning is complete.

If some cleaning has occurred but the process is incomplete sonicate the specimen briefly to move any material which has been loosened, then treat with fresh peroxide solution.

Adding H_2O_2 by itself to the sample to be cleaned may result in mild to vigorous effervescence but without any cleaning. Pyrolusite (MnO_2) and some other manganese hydroxide/oxide minerals decompose H_2O_2 catalytically, meaning they react with H_2O_2 but are not chemically altered themselves (Equation 3-13).

H_2O_2 (3% or 12%) contains a little acid as a stabilizer so care must be exercised when using this chemical on acid sensitive minerals (Chapter 4 and www.mincleandev.com). However, the pH of an H_2O_2 solution rises rapidly from mildly acidic to mildly alkaline as it reacts with manganese hydroxide/oxide coatings, so the acid threat is usually minimal.

If the black coating resists H_2O_2 by itself the process can be assisted by acid (but only if the minerals present are acid-tolerant; Chapter 4 and www.mincleandev.com). Don't just add acid to the H_2O_2 solution already in use, as the peroxide may have already been consumed. Instead, pour off the decomposed H_2O_2 solution before trying acid-assisted H_2O_2. Start with a 1:1 mixture of 3% H_2O_2 and 5% acetic acid. If this is ineffective, try 12% H_2O_2 or 20% or even 30% acetic acid. Specimens which are not cleaned by a mixture of 12% H_2O_2 with 30% acetic acid are unlikely to be affected by higher concentrations of either peroxide or acid. Acids stronger than acetic acid (such as HCl) rarely offer any advantage here and decrease the range of mineral species which tolerate this treatment (Chapter 4 and www.mincleandev.com). By itself, H_2O_2 is tolerated by a wide range of mineral species. If acetic acid is added, then tolerance to this mild acid must also be

considered. Sulfamic acid has also been recommended but its alleged effectiveness could not be reproduced.

In some cases, treatment for 24 hours or longer is necessary, during which time the peroxide may decompose completely before cleaning is complete. It is then unclear if active peroxide remains (in which case peroxide treatment will not completely remove the black material) or if the peroxide has been full consumed. The presence of peroxide can be determined with starch-iodide paper, which turns from white to dark purple when dipped into a peroxide-containing solution. (Test this with your peroxide stock bottle.) If no color change is observed pour out the spent solution and add fresh peroxide (with or without acid) as needed.

"Accelerated hydrogen peroxide" is a commercially available, weak solution of H_2O_2 with added acid (often H_3PO_4). For example, the SDS of one product (Maunco 2004) indicates it contains 5–10% H_2O_2, 1–5% H_3PO_4 and other ingredients. While a premade solution of peroxide and acid may seem convenient, commercially available, acidified H_2O_2 products have not been tested for mineral cleaning purposes and should most likely be avoided.

After peroxide treatment (with or without added acid) the specimen is sonicated briefly (or soaked overnight) in clean water then allowed to thoroughly air dry.

Here are several examples. A 1:1 mixture of 12% H_2O_2 and 5% HCl removed black stains from Hale Creek, California inesite in 30 minutes. Baryte from Carterville, Georgia required overnight treatment with the same solution. A mixture of 3% H_2O_2 and white vinegar is recommended for specimens of calcite/franklinite/willemite/etc.; a toothbrush scrub may also be needed, and attention must be paid to possible calcite etching (Mark Heintzelman, personal communication). Miller (1971) states that black manganese coatings on rhodochrosite "may be removed without damage to the spcimen [sic]" by immersing it in water, adding a few drops of HCl (concentration not specified but assumed to be muriatic acid) and a few milliliters of 3% H_2O_2. The solution will effervesce as the coating (and perhaps some of the rhodochrosite!) dissolves. Of course, an excess of acid must be avoided to prevent damage to the rhodochrosite. Figures 3-46 through 3-48 illustrate the processes described in this section.

Figure 3-46. This baryte and vanadinite specimen had a heavy coating of powdery, sooty manganese hydroxides/oxides (left). After a two-hour treatment with a 1:1 mixture of 12% H_2O_2 and 30% acetic acid the specimen was greatly improved (right). The baryte and vanadinite both survived without suffering a loss of luster.

Figure 3-47. Treatment of this Franklin, New Jersey ore sample (left) with just 3% H_2O_2 or just 5% acetic acid resulted in only modest improvement. However, immersion a 1:1 mixture of these reagents resulted in marked improvement after just one hour (right).

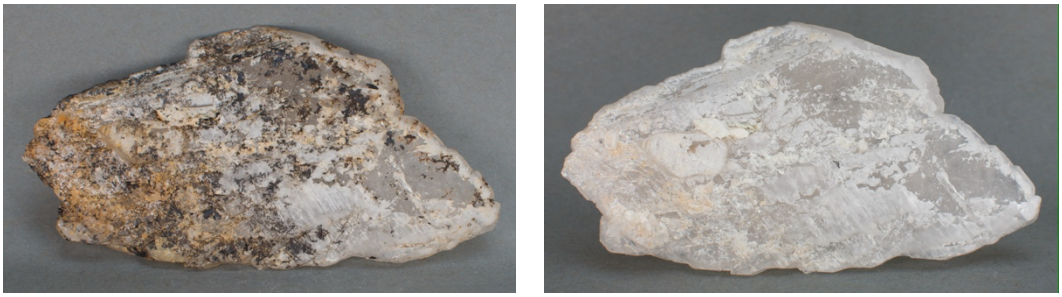


Figure 3-48. Not all dendrites require peroxide treatment. Textile gun cleaning was ineffective. An Iron OUT/EDTA solution removed both the rust and dendrites, so H_2O_2 treatment was not necessary in this case. Before (left) and after treatment (right).

Hydroxylamine ($HONH_2$) has been suggested as another reagent to remove manganese mineral coatings (Sinkankas 1970, 299; no procedural details are given). For example, Franklin, New Jersey franklinite and willemite samples were treated with a magnetically stirred tap water solution containing 5 grams hydroxylamine hydrochloride ($HONH_2 \cdot HCl$) per liter. Brown stains were removed in one hour to overnight. The solution was modestly acidic at the start (pH 3.9) and the pH rose but remained just slightly acidic during the treatment. A control experiment revealed that calcite suffered obvious etching during this treatment so use of this procedure with acid sensitive minerals (Chapter 4 and www.mincleandev.com) may be problematic. However, $HONH_2$ is still effective against manganese stains at alkaline pH without etching calcite. In one experiment, the pH of a solution containing 5.0 grams $HONH_2 \cdot HCl$ in one liter of water was adjusted to ~13 by addition of 6.7 grams KOH; this solution removed manganese stains overnight without etching calcite. Hydroxylamine sulfate ($HONH_2 \bullet H_2SO_4$) can be substituted for $HONH_2 \cdot HCl$ with equivalent results. However, cleaning with $HONH_2$ has only been reported for a few minerals (and these are generally minerals with high chemical stability) so they should only be used with caution on (for example) minerals of easily reducible cations such as copper and lead. As always, apply Guiding Principle 5 and experiment on lower quality material first before committing (and possibly irrevocably damaging) your better specimens.

Brannock (1970) suggests that a solution of either sodium bisulfite ($NaHSO_3$) or sodium metabisulfite ($Na_2S_2O_5$) will remove "thin stains of manganese oxides" but no details are given. The action of the two reagents is expected to be essentially identical, as metabisulfite hydrolyzes in water solution to form bisulfite (Equation 3-14):

$$S_2O_5^{2-} + H_2O \rightarrow 2\ HSO_3^- \qquad \textbf{Equation 3-14}$$

Gol (2004c) gives a recipe using metabisulfite. In one experiment a sample of calcite, franklinite and willemite having dark brown stains was cleaned with a one-hour immersion in a magnetically stirred solution of 63 grams $NaHSO_3$ per 100 mL distilled water. (Tap water should also work but was not tested.) The pH of this solution was 4.3, suggesting that cleaning may have been affected by calcite etching and not manganese hydroxides/oxides reduction. In a control experiment a lustrous calcite cleavage sample was subjected to the same solution for two hours after which time definite frosting was noted. In the presence of enough KOH to make the solution strongly alkaline (pH ~12), $NaHSO_3$ is equally effective at manganese hydroxide/oxide coating removal. Under these conditions bisulfite (HSO_3^-) is converted to sulfite (SO_3^{2-}; Equation 3-15):

$$HSO_3^- + HO^- \rightarrow SO_3^{2-} + H_2O \qquad \textbf{Equation 3-15}$$

Using Na_2SO_3 (sodium sulfite) instead of $NaHSO_3$ obviates the need for KOH and provides an alkaline solution that is as effective as $NaHSO_3$ for black coating removal. This promising method needs more exploration and should be applied with caution to acid-sensitive minerals. In addition, $NaHSO_3$/KOH and Na_2SO_3 solutions produce some noxious SO_2 gas so work outdoors only.

Gol (2004a, 31–34) and King (1983, 60) both suggest that either dilute or concentrated HCl can be used to dissolve manganese oxide (MnO_2; pyrolusite) but underlying minerals may be attacked. That the reaction of strong HCl and MnO_2 releases toxic chlorine gas and that milder methods for black coating removal exist make this a 'last-ditch' method.

3.17 Removing Silica and Silicate Coatings

As a group, silicates are the most abundant species in the mineral kingdom, so it is not surprising that their removal is sometimes necessary. Except for nesosilicates (such as olivine, garnets and zircon) all silicates have a crosslinked framework of SiO_4 units arranged in chains, sheets and other structures. These structures must be hydrolyzed (from Ancient Greek *hydro-* 'water' and *lysis* 'to unbind') to weaken or completely dissolve an undesired silicate coating. Such coatings are frequently called sinter (a mineral deposit with a porous or vesicular texture).

Before attempting to remove a silicate sinter coating, recall that this is part of the natural mineral paragenesis or assemblage. The potential increase in aesthetic value upon removal must be weighed against the loss in scientific value. In such cases apply Guiding Principle 4: If

unsure...don't, and Guiding Principle 11: A specimen's scientific or historical value generally outweighs its aesthetic or monetary value.

A. Hot Alkaline Reagents

Strong acids such as HCl or oxalic acid are of marginal value for silicate hydrolysis as many silicates resist their attack. That many other minerals can be attacked by strong acids renders this unselective treatment even more undesirable for mineral cleaning. Strongly alkaline reagents can also achieve silicate hydrolysis to some extent and with significantly better selectivity than typically seen with strong acids.

When treated with a hot, aqueous solution of strong alkali, it is believed that hydroxide ion (HO^-) replaces some silicon-oxygen-silicon bridges with silicon-hydroxyl bonds, partially disassembling the crosslinked silicate network (Equation 3-16). When enough silicon-oxygen-silicon bridges have been ruptured, the silicate network has been weakened to the point where it can be removed by mechanical means such as textile gun treatment or maybe even dissolve in the hot water solution.

$$\text{Si–O–Si (crosslinked)} + HO^- \rightarrow \text{Si–OH} + \text{HO–Si (crosslinks broken)} \qquad \textbf{Equation 3-16}$$

The hydroxide ion is commonly supplied by sodium hydroxide (NaOH; lye) or potassium hydroxide (KOH; caustic potash). These are both readily available, inexpensive solids which are easy to use and dispose. KOH and NaOH are interchangeable for hot alkali solution treatment; KOH is more expensive but also a bit more aggressive.

Potassium pyrophosphate ($K_4P_2O_7$; also called tetrapotassium pyrophosphate or TKPP) is added to enhance cleaning. Including TKPP is not essential, but its presence makes cleaning with hot alkali more efficient.

Premade NaOH or KOH solutions are also commercially available but are notably more expensive than preparing your own solutions from the corresponding solids. Avoid a commercial drain cleaner liquid containing KOH or NaOH such as Drano. Although such pre-made solutions saves time these products often contain additives harmful to minerals.

As with any chemical cleaning procedure, check Chapter 4 and the www.mincleandev.com compatibility data before treatment with hot alkali.

Alkaline reagents of any concentration can be corrosive to skin and eyes; *always wear gloves and safety glasses*. These hazards are greater at higher concentrations or higher temperatures.

The cleaning process is conducted in a stainless-steel pan with a lid that fits well (but allows steam to escape; Figure 3-49). Glass vessels and enameled pots (Zurn 2008) must be avoided because these are corroded by strongly alkaline solutions. Aluminum vessels must also be avoided because these can react *vigorously* with strong alkali to produce flammable hydrogen gas. Always avoid a plastic container when the solution is to be heated.

Figure 3-49. A stainless-steel pan with hot plate, digital food thermometer and metal probe suitable for silicate sinter removal by hot alkali treatment.

Heat is provided by an adjustable electric hot plate. Temperature regulation with a gas flame is more difficult than with an electric heater and should be avoided. Temperature is best monitored with a metal meat thermometer or digital food thermometer having a metal probe. *Do not use a glass thermometer as it will be attacked by the hot alkaline solution.* The temperature can be monitored by lifting the lid and testing at intervals, but this can be quite tedious. Instead, a hole is drilled in the lid and fitted with a rubber gromet allowing the thermometer stem (or probe) to be immersed in the solution. In this way the temperature is easily monitored without lifting the lid.

The specimen to be cleaned is placed in the pan and sufficient tap water added by measuring cup to more than cover the specimen without overfilling the pan. (Tap water can be used. Distilled water is often called for but not necessary. TKPP keeps calcium in solution and further obviates the need for distilled water.) Remove the specimen and set it aside. To the water add one gram of TKPP per 10 mL of water then 3 grams KOH per 100 mL water. (These numbers don't need to be precise but avoid just dumping in a random amount.) KOH readily absorbs both water and CO_2 from the air, so its storage container should be tightly closed and sealed with electrical tape immediately after use (Figure 3-27).

The solution will immediately become quite warm as the KOH dissolves (an exotherm occurs). Gently stir for a few minutes until the solids have dissolved. *Caution! Room temperature KOH solutions are highly corrosive - especially to the skin - and hot solutions even more so! Wear safety glass and gloves (as always!). Avoid breathing any mist created. Work in a well-ventilated space!*

To avoid thermal shock, allow the solution to cool to room temperature (perhaps overnight) before returning the sample to be cleaned to the pot. Cover the pot, and heat at 60–80ºC for a few hours, checking the cleaning progress every now and then. Eight hours is often adequate but resist the temptation to heat overnight as this can lead to accidental evaporation to dryness or other problems. Replenish the water level with hot water (not cold...thermal shock) as needed, or better to allow the setup to cool before adding water and reheating. When cleaning is complete or after no more than eight hours, stop heating and allow the setup to slowly cool to room temperature (don't hurry the process...thermal shock risk!).

Note the position of the temperature control dial to give the correct temperature range. This will save time in future runs by giving you a good starting position for the heater control knob to get the desired temperature range.

Remove the now-cooled specimen from the alkaline bath **while wearing gloves** and allow excess solution to drip off. Do not use tongs as the alkali makes the specimen rather slippery. Rinse thoroughly, treat with the textile gun then sonicate for 30 minutes. If cleaning is incomplete, prepare a fresh alkaline bath and repeat the process. (A fresh bath gives better results than a reused bath.) If satisfactory results haven't be achieved after three treatment cycles, consider alternating hot alkali treatment with a fluoride reagent bath (discussed below).

The used KOH/TKPP solution is disposed by flushing it down the drain with plenty of water.

When rust occasionally appears (or reappears) after treatment with hot alkali, derust with dithionite.

Stainless steel has excellent but imperfect resistance to attack by hot alkali, resulting over time in a pitted surface. Carefully inspect your pan prior to use with hot alkali. Leakage through cracks or pits is likely to have significant, catastrophic effects. If pits are seen, replace the pan.

The importance and versatility of the KOH/TKPP procedure is illustrated in the following examples. In Figure 3-50 a Colorado specimen was barely recognizable as quartz until after it was treated with KOH/TKPP solution for 5 hours at 60–80°C. This revealed several limonite after siderite pseudomorphs and left the specimen somewhat rusty. Iron OUT derusting removed the rust stains. Other, similar specimens from the same find were not affected when treated with either just a textile gun, hot distilled water, or just TKPP in hot distilled water.

Figure 3-50. Before KOH/TKPP treatment (left) and after (right).

In Figure 3-51 this cleavelandite was heavily coated with a white clay material which did not succumb to textile gun treatment. However, treatment with hot KOH/TKPP solution softened the clay to the point where much of it could now be removed with the textile gun. After repeating the hot alkali/textile gun cycle three times no further change was noted.

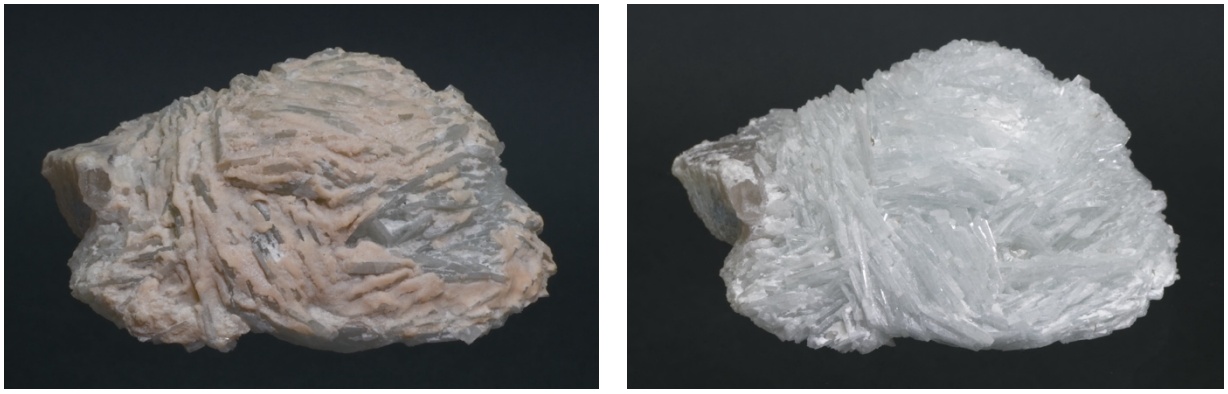


Figure 3-51. Before KOH/TKPP treatment (left) and after (right).

Treatment with hot KOH/TKPP is not a panacea; not every attempt was completely successful (Figure 3-52). This tourmaline was coated with a rusty crust which could not be removed with a water jet tool. Treatment with hot KOH/TKPP solution softened the clay to the point where much of it could be removed with a textile gun. After repeating the soaking/textile gun cycle three times no further change was noted. Cleaning efforts concluded with Iron OUT to remove the remaining rust. Air abrasion is likely necessary to remove the last of the coating.

Figure 3-52. Before KOH/TKPP treatment (left), and after (right).

Duthaler and Weiß (2024, 43) outline a similar procedure using NaOH instead of KOH/TKPP. NaOH is somewhat less expensive than KOH, but the KOH/TKPP recipe given here is often more effective, partly because KOH is a stronger base than NaOH. Solid NaOH sold as drain cleaner is of sufficient purity for mineral cleaning but should not contain any other additives such as aluminum shavings (damp NaOH reacts very vigorously with aluminum to produce a hot, highly corrosive alkaline solution plus hydrogen gas). Check the product SDS before use.

If you anticipate using this method frequently, time can be saved by preparing the NaOH or KOH/TKPP solutions in bulk (perhaps a few liters) ahead of time and storing them in plastic bottles (not glass or aluminum!). Prepare the bulk solution in a glass or steel vessel and allow to cool before transfer. Use of a glass vessel allows magnetic stirring, which greatly hastens

dissolution (but an hour or more might still be required). Brief contact of a glass container with the alkaline solution will not cause significant etching, but the vessel may deteriorate with prolonged use. Any containers holding water-sensitive chemicals must be tightly closed and preferably sealed against moisture (Figure 3-26).

Duthaler and Weiß (2024, 43) also recommend the laboratory glassware cleaning product Neodisher LM3 for this procedure. This cleaner is a water solution of KOH plus additives that do not enhance its ability to clean minerals. It does not offer any obvious advantages over the KOH/TKPP recipe and is somewhat difficult to obtain in the United States (occasionally available at Shannon Family Minerals, shannonsminerals.com).

Interestingly, some of the same mineral cleaning effects can be achieved by heating in full strength (undiluted) dishwashing detergent. Dawn Ultra brand was used in exploratory experiments, but because dish soap ingredients vary so widely between manufacturers (consult SDS data) it is unclear if other brands may work as well. A potential advantage of this approach is safety (hot dish soap should be less corrosive than NaOH or KOH) but cost is an issue. For example, hematite replacements of magnetite were partially excavated from a lizardite/hydrotalcite matrix using hot, undiluted Dawn Ultra dish detergent. In another example, lustrous quartz was cleaned of clinging montmorillonite clay without harming the quartz luster.

Treatment with hot alkaline solutions is especially effective to reduce or remove chalcedony, opal (albeit more slowly than chalcedony), clays, cookeite and related feldspar decomposition products from more chemically robust gem pegmatite minerals such as quartz, tourmaline, beryl and feldspars. It is likely that chalcedony and opal (as well as glass) are attacked in preference to quartz because chalcedony and opal have a more disorganized (less crosslinked) crystal structure compared to quartz.

Recall that removing chlorite and other coatings may leave the crystal with dull, pitted faces (and worse off than it was before so-called cleaning; review Guiding Principle 10). Check www.mincleandev.com to learn which minerals are compatible with hot alkali solutions.

Herborner (unpublished results) reports that alternating use of alkaline cleaning solutions and oxalic acid is promising but no details are given.

B. Fluoride Reagents

Anyone reading mineral cleaning literature will quickly learn that **hydrofluoric acid** (HF) is routinely recommended for silicate removal. It is "unreplaceable for the dissolution of silicate minerals, especially clays, cookeite, chlorite and other fine-grained minerals..." but "no description of this acid could possibly overemphasize the dangers it offers to the human organism" (Sinkankas 1972, 236). ***This chemical is much too dangerous for the unskilled and poorly equipped amateur to use***. It is difficult to obtain and requires careful disposal as well. Other procedures are often available to achieve the same cleaning effects, but with greater safety and ease. Therefore, the ***use of HF (or any product containing it) is very strongly discouraged***. Fluoroboric acid (HBF_4) is also a powerful reagent to dissolve silicates, but it is expensive, nearly as dangerous as HF and its

use is likewise ***strongly discouraged***. HF, HBF_4 and "accelerated" ammonium bifluoride (NH_4HF_2 plus a strong acid) are *exceptionally dangerous reagents* (Section 3.32). Duthaler and Weiß (2024, 92) indicate that sodium bifluoride (sodium hydrogen fluoride; $NaHF_2$) has about the same reactivity and safety concerns as NH_4HF_2 but provides no details. $NaHF_2$ is more difficult to obtain and more expensive than NH_4HF_2 but appears to offer no distinct advantages.

Ammonium bifluoride (also called ammonium hydrogen difluoride) is a milder, less expensive and far safer alternate for silicate removal. It is widely available for etching glass and may be familiar as the reagent to dissolve silica residues as the last step in preparing benitoite specimens (Chapter 4). It is speculated that NH_4HF_2 etches glass faster than quartz because the former has a more disorganized (less crosslinked) structure than quartz.

King (1983, 60) and Sinkankas (1970, 298) suggest using NH_4HF_2 to remove silica encrustations but without any operational details. NH_4HF_2 has a broader application as a silicate remover, however, when used in conjunction with hot alkali. ***Experiments have shown that alternating hot KOH/TKPP treatment with NH_4NH_2 treatment often provides more satisfactory results than using either reagent alone.***

Fluoride ion (F^-) hydrolysis of silicates is believed to proceed in a manner like hydroxide ion hydrolysis (Equation 3-16): F^- replaces the Si–O bonds, resulting in Si–F bonds which in turn react with water to form Si–OH bonds (Equation 3-17). The net result is degradation of the crosslinked silicate network.

$$\text{Si–O–Si} + F^- \rightarrow \text{Si–F} + \text{F–Si}$$

$$\text{Si–F} + \text{F–Si} + H_2O \rightarrow \text{Si–OH} + \text{HO–Si}$$

Equation 3-17

If treatment with hot alkali has not been completely satisfactory and if the specimen has good resistance to NH_4HF_2 (the reagent forms modestly acidic solutions; see Chapter 4 and www.mincleandev.com), a solution containing 2–4 grams NH_4HF_2 per liter of tap water is prepared in a plastic container. (Never glass or metal, as NH_4HF_2 attacks these materials.) Distilled water - although frequently recommended for mineral cleaning - is not necessary here. If tap water is used an inconsequential, slight haziness due to CaF_2 and/or MgF_2 precipitates is normal and is of no concern. Magnetic stirring is useful. Immerse the specimen into the solution (*gloves and safety glasses!*) and stir 3 to 24 hours. Remove the specimen (gloves!), rinse thoroughly, then treat with the textile gun or sonication. If cleaning is incomplete, additional treatment with hot alkali then NH_4HF_2 may be needed. If cleaning is incomplete after three HO^-/NH_4HF_2 cycles additional cycles are not likely to cause further improvement, and another cleaning method (usually air abrasion) may be needed to finish the job. Figures 3-53 and 3-54 illustrate successful and a not-so-successful treatments with NH_4HF_2.

Figure 3-53. The white encrustation on this dark blue tourmaline did not yield to the textile gun alone. Treatment with NH_4HF_2 solution for three hours followed by final cleaning with a textile gun was successful. Before (left) and after (right) treatment.

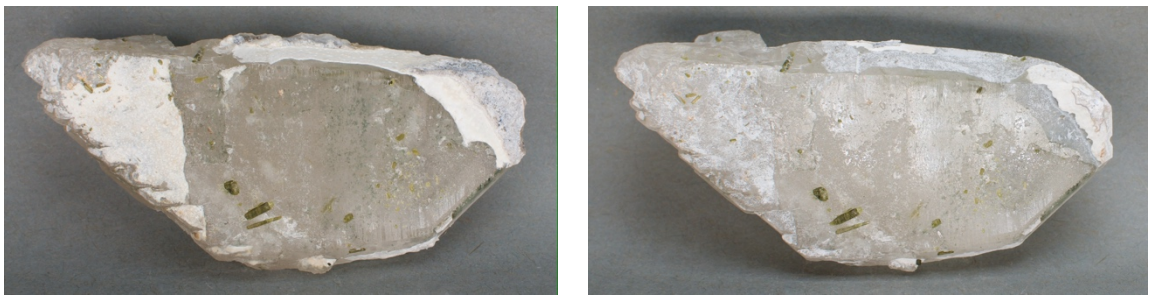


Figure 3-54. A quartz with epidote specimen, before (left) and after (right) three HO^-/NH_4HF_2 cycles. A white residue remains, which would require air abrasion for removal.

Four common gem pegmatite minerals - tourmaline, quartz, spodumene and beryl - were all found to survive three KOH-TKPP/NH_4HF_2 cycles without loss of luster or other damage.

Etching with NH_4HF_2 can be inhibited by painting the areas to be protected with a solution of beeswax in acetone, which is then removed with fresh acetone (Sinkankas 1970, 298).

NH_4HF_2 can also be used in conjunction with hot dish soap. For example (Figure 3-55) this quartz specimen with a pink montmorillonite coating was treated sequentially with undiluted Dawn Ultra (60–80ºC, eight hours), textile gun treatment, NH_4HF_2 solution (overnight) and a final textile gun cycle. Much of the overlying crust was removed without sacrificing any of the quartz luster. Additional treatment may have resulted in further cleaning but were deemed unwarranted for this low-quality specimen.

Air abrasion would more likely than not have achieved better and faster results with the specimens of Figures 3-44 and 3-45 but chemical treatment is a much less costly option.

NH_4HF_2 may brighten some sulfide minerals including pyrite, marcasite and arsenopyrite. For more details see individual mineral listings in Chapter 4.

Whether used alone or in conjunction with alkali, waste containing fluoride should be treated as a Category IV waste (Section 3.11).

Figure 3-56. Before cleaning (left) and after one Dawn Ultra/NH_4HF_2 cleaning cycle (right).

3.18 Removing Carbonate Coatings or Matrix

This section is about removing crusts, coatings and matrix composed of calcite and other carbonates. For advice on removing carbonates from specific minerals (dioptase, etc.) or cleaning calcite, aragonite and other specific carbonate minerals see Chapter 4.

Carbonate-rich coatings (also called calcareous sinter or caliche) are frequently encountered as a secondary coating on other minerals. These coating are usually composed of calcite, aragonite and dolomite and/or a mixture with other carbonates. Before considering removing a carbonate coating or matrix, recall that this is part of the natural mineral paragenesis or assemblage. The increase in aesthetic value against the loss in scientific value upon removal must be evaluated. Care must be taken when dissolving matrix which is partially to complete composed of a carbonate mineral, as this may be the only thing holding other minerals in place. Complete removal of the matrix may cause interesting crystals to detach or even disintegration of the entire specimen. Figure 3-56 shows an example.

Figure 3-56. The enclosing calcite on this grossular specimen was removed by acid treatment. However, this left cracks in the grossular crystals, potentially weaking the specimen.

A. Acid Treatment

Carbonate coatings and matrix are most frequently removed by acid treatment. Most carbonate minerals are prone to acid attack to some extent, depending upon the mineral species (such as calcite versus rhodochrosite), acid used (acetic acid versus HCl) and acid concentration (5% acetic acid versus glacial acetic acid). A stronger acid (typically HCl) removes the carbonate faster than a weaker acid (such as acetic acid) but is less selective. More minerals are attacked by HCl than by acetic acid (Chapter 4 and www.mincleandev.com). For a general study of selective carbonate removal by acids see Hardinger (2024a).

Before acid treatment, verify that the coating in question is a carbonate by placing a drop of concentrated HCl on an unimportant part of the specimen. A lack of vigorous gas evolution suggests that the sinter is not calcareous but instead maybe a silicate. Thoroughly rinse the specimen immediately after observing the results.

Acid attack usually does not occur at the same rate across the entire carbonate mass. Cracks and areas of interrupted crystal growth are attacked more vigorously. This results in an uneven, knobby 'karst-like' appearance when the carbonate (especially calcite) is not complete removed. To some extent this can be controlled by carefully experimenting with acid strength (try weaker acid first) and other variables (Duthaler and Weis 2024, 94).

Dilute strong acids (such as 5% HCl) or weak acids (such as acetic acid) generally provide a smoother, silkier final luster than concentrated and/or undiluted strong acids (undiluted HCl).

If the matrix contains an acid-sensitive carbonate or is porous or cracked, the specimen's integrity may be compromised to the point or disintegration (Figure 3-56). Residual matrix of acid-etched skarn minerals such as garnet, vesuvianite and diopside may be crumbly because acid can seep into the matrix (which is often cracked or partially to fully porous) and remove any calcite therein as well. Prolonged exposure to strong acid may cause some skarn minerals such as vesuvianite, grossular and epidote to become delustered and dull. A dolostone matrix is attacked more slowly than calcite, aragonite and most other carbonates. Use dilute acid and (importantly) patience. Carefully monitor the acid dissolution process and remove the specimen when the calcite removal is complete; over etching may cause the specimen to disintegrate.

Incomplete removal of a carbonate coating or matrix by acid treatment may result in an unnatural, curved or melted appearance (Figure 3-57). Such treatment may be necessary for scientific purposes but when the end goal is to produce an aesthetic specimen, other matrix removal techniques, such as air abrasion or a vibratory impact tool should be employed instead.

In some cases, a single method such as acid treatment may weaken but not completely remove a carbonate coating. In these instances, success may be had by alternating chemical treatment with a mechanical method such as a textile gun or sonication. Although calcite cleaves readily and is rather soft (Mohs hardness 3) its removal with a steel pick (such as a dental tool) is tedious, rarely complete and often not without some damage to the minerals you wish to expose.

Figure 3-57. Incomplete calcite removal with HCl caused an unnatural appearance.

To allow etching at selected areas on the specimen, an acid and water-resistant coating such as paraffin wax, beeswax, Paraloid B-72 or Duco cement can be applied. Recall that any coating is not a perfect barrier to chemical attack (especially at the edges of the coated area), but instead merely slows it down.

A general procedure for acid etching is as follows. Work with adequate ventilation, preferably outside. Acid fumes accumulating indoors - even to low levels - may cause your nearby steel tools to rust unexpectedly. The specimen is fully or partially immersed in the acid solution until the desired level of carbonate removal is achieved. The mineral's carbonate group (CO_3^{2-}) is converted to carbon dioxide (CO_2) which appears as gas bubbles (Equation 3-1). Care must be taken with strong acids and more reactive carbonates (calcite and aragonite) as the frothing can be quite vigorous. In these cases, a dilute solution of the strong acid (plus patience) should be used to maintain control. Bubbles breaking on the solution surface spray finely divided acid droplets, so use a loosely covered container (not a sealed container as the gas pressure must be relieved.) With weak acids and less reactive carbonates, bubbling may be quite slow, to the point of appearing as if nothing is happening. Bubbling ceases when either all carbonates have been removed or the acid is depleted. If a strong acid is used, as the acid is depleted avoid adding more strong acid except in cases where regeneration is known to be tolerated (Chapter 6). Regeneration can create several problems including increasing the chance of yellow stains on drying. Instead, drain the depleted acid and replace it with fresh acid. Acid etching can be quick - complete in an hour with a strong acid and reactive carbonate such as calcite - or may take days with a weaker acid and less reactive carbonate. Patience is (as always) our number one mineral cleaning tool. Monitor the progress frequently to minimize the possibility of acid damage to other minerals present.

When etching is judged to be complete or when further etching may do more harm than good the specimen is fully immersed for 24 hours in clean water containing a little $NaHCO_3$ to neutralize residual acid then allowed to dry thoroughly. The $NaHCO_3$ releases CO_2 - sometimes quite vigorously - as it reacts with residual acid. If this is observed, treat with a fresh $NaHCO_3$ solution until no more gas evolution is observed. Three or more $NaHCO_3$ bath treatments are frequently needed for optimum results because it may take days for the neutralization bath to fully seep into all cracks. Some authors recommend using NH_3 instead of $NaHCO_3$, but the former will not produce the useful gas bubble indication. Sonication assists removing any last traces of acid.

Textile gun treatment may also be useful at this point but recall that calcite cleaves easily and therefore the textile gun must be used with care.

Yellow stains, which are more common after treatment with HCl or when acid-sensitive iron minerals are present, may appear after drying and are treated as described in Section 3.15A.

For *important safety precautions* for diluting a strong acid see Section 3.13. Details concerning properties and uses of selected acids are given in the following paragraphs.

Hydrochloric acid (HCl) is inexpensive and widely available as *muriatic acid*, a somewhat impure form which is a 30–35% solution of hydrogen chloride gas in water. At full strength, Fe^{3+} impurities cause muriatic acid to have a pale-yellow color (due to Fe–Cl compounds) which fade upon dilution with water as Cl is replaced by H_2O. Fumes from undiluted HCl are highly irritating and quite corrosive; it should only be used outdoors. Undiluted HCl quickly causes skin burns. ***Gloves and safety glasses must be worn when handling HCl solutions of any concentration.*** All HCl solutions will corrode metal and so should only be prepared and stored in glass or chemically resistant plastic containers with tight-fitting lids. Even when the lid is tightly closed, fumes from an HCl solution can corrode any nearby metal or wood.

If HCl is to be used recall Guiding Principle 7: Always try the mildest possible method first. A diluted solution should be tried before an undiluted acid is employed. 'Dilute HCl' does not have a standard concentration that all chemists agree upon but instead means only the concentration is less than undiluted, concentrated HCl. A useful dilute HCl solution of about 5% concentration can be made by *slowly and carefully* pouring one part by volume concentrated HCl into six parts by volume of water.

Used HCl solutions of any concentration are treated as Category II waste (Section 3.11).

Phosphoric acid (H_3PO_4, also called orthophosphoric acid) is also an inexpensive, widely available strong acid. It will dissolve most carbonate sinter coatings but most of the calcium phosphate products have very low water solubilities, necessitating extra cleaning steps. H_3PO_4 is generally used only when minerals species intolerant to HCl but tolerant to H_3PO_4 (Chapter 4 and www.mincleandev.com) are present. Carbonated soft drinks (which contain H_3PO_4 and carbonic acid) are occasionally recommended as a mild method to etch calcite or carbonate sinter. Concentrated H_3PO_4 is a somewhat syrupy solution containing about 85% H_3PO_4 by weight but as always try a diluted solution first. Safety considerations and the procedure for safe dilution of strong acids is discussed in Section 3.13. Used H_3PO_4 solutions of any concentration are treated as Category II waste (Section 3.11).

Acetic acid (CH_3CO_2H), better known as vinegar, is available in various concentrations: 5% (grocery store vinegar) as well as 20% or 30% (cleaning vinegar). Glacial acetic acid is pure (100%) acetic acid. When purchasing 5% vinegar, select white (distilled) vinegar instead of brown (cider) vinegar, as the latter tends leave specimens with a stronger, more distinct vinegar smell after cleaning.

Vinegar in the 5–30% concentration range is inexpensive, easy to use and dispose and presents no major safety issues. Glacial acetic acid is less economical and requires more stringent safety measures (gloves and safety glasses required). Its odor is strong and pungent; it should only

be used with adequate ventilation (outdoors) and (as always) while wearing gloves and safety glasses. Glacial acetic acid vapors are flammable. Unlike 5–30% vinegar concentrations, glacial acetic acid crystallizes below 17 ºC so it cannot be used when cold. Glacial acetic acid can be used to prepare dilute acetic acid solutions (treat as a strong acid; Section 3.13) but purchasing 5–30% vinegar is much cheaper.

Acetic acid's main use - regardless of concentration - is selective dissolution of calcite and aragonite, forming calcium acetate - $Ca(CH_3CO_2)_2$ and carbon dioxide gas - CO_2 (Equation 3-18):

$$CaCO_3 + CH_3CO_2H \rightarrow Ca(CH_3CO_2)_2 + CO_2 \qquad \textbf{Equation 3-18}$$

For this purpose, acetic acid is very mild and tends to attack just calcite and aragonite more than other carbonates such as rhodochrosite ($MnCO_3$). Some carbonates may be attacked more slowly, resulting in frosted crystal faces but only negligible mass loss (Hardinger 2024a). Overall etching with vinegar can be rather slow, so liberal application of Guiding Principle 2 is needed.

To etch calcite or aragonite with vinegar, place the specimen is a vessel deep enough to allow complete immersion of the specimen. This vessel can be plastic, glass or metal. *As always*, while wearing gloves and safety glasses, slowly pour vinegar over the specimen. (We might think that 5% vinegar is perfectly harmless but do you really want to splash it in your eyes?) Effervescence may be intense at first. The reaction is complete when no more calcite/aragonite is seen, and bubbling has ceased. If bubbling has ceased but some material to be dissolved remains, there may be more calcite/aragonite present (drain the depleted vinegar, then add fresh vinegar) or the suspected calcite/aragonite may be something other than calcite or aragonite. When effervescence has ceased and no more suspected calcite/aragonite is present, rinse the specimen thoroughly in clean water (sonication helps significantly remove the last traces of acid from cracks and crevices) then allow to dry. If after thorough drying, yellow stains appear, dithionite treatment is appropriate. A post-etching sonication or a soak in water containing EDTA, $NaHCO_3$ or dilute NH_3 may be useful.

Acetic acid of higher concentration dissolves calcite faster than acetic acid of lower concentration. Recall that patience is our number one mineral cleaning tool; the higher costs of more concentrated solutions often outweigh the rate factor. However, when large amounts of calcite are to be dissolved from acetic acid-tolerant minerals such as fluorite use of 30% acetic acid is justified. After 2 to 3 days when the acetic acid is expended and any traces of effervescence have ceased, the acetic acid solution can be effectively regenerated by adding *no more than* 25 mL concentrated HCl per liter of acetic acid solution *with immediate stirring*. The acid can be regenerated this way two or three times before it becomes ineffective and should be replaced with fresh 30% acetic acid.

Acetic acid at 5% strength (vinegar) is a slow but effective reagent to remove calcite (and some other carbonates; see Hardinger 2024b) from fluoride and sulfides. Higher acetic acid concentrations, as well as other acids of any strength, may harm these minerals. Check Chapter 4

and www.mincleandev.com for compatibility. Stronger acids may require neutralization before disposal (Section 3.13).

In some cases, residual calcite/aragonite is inert to further acetic acid treatment, in which case complete removal may often be obtained with HCl or sulfamic acid.

The used vinegar and rinse water are not hazardous and can be flushed down the drain with plenty of water. Neutralization is not necessary.

Similar results can be obtained with **formic acid** (HCO_2H), but this reagent is more expensive than acetic acid. Like acetic acid, the odor of concentrated formic acid is strong and pungent, requiring adequate ventilation for its use. It generally offers no significant advantages which justify its greater cost, with one exception: Stoll (in Duthaler and Weiß 2024, 50) mentions that 5% formic acid at 5ºC might be useful to selectively remove calcite, but the procedure is of limited use as few amateur collectors have separate refrigerators for food storage and mineral specimen preparation. *Never store food and chemicals together!*

Lactic acid is a carboxylic acid with properties like acetic acid but is more expensive. It offers no cost-effective advantages for mineral specimen work.

Citric acid is a triacid (its molecular structure contains three CO_2H units) which is available in anhydrous form (no water of crystallization; $C_6H_8O_7$) or as a monohydrate ($C_6H_8O_7 \cdot H_2O$). It may also be encountered as one of three sodium salts: monobasic (monosodium citrate or sodium dihydrogen citrate; $C_6H_7O_7Na$), dibasic (disodium citrate or disodium hydrogen citrate; $C_6H_6O_7Na_2$) or tribasic (trisodium citrate; $C_6H_5O_7Na_3$). To add further confusion the tribasic salt is available in an anhydrous form (no water of crystallization) or as the dihydrate ($C_6H_5O_7Na_3 \cdot 2H_2O$). Many sellers of sodium citrate do not specify the number of sodium atoms or water molecules present, but trisodium citrate dihydrate is by far the most common form. Except as part of the Waller's solution recipe the number of sodium atoms or water molecules is unimportant. These compounds are all inexpensive, white, crystalline powders with low toxicity (some are commonly used as food additives, as antioxidants and to add tartness).

Like acetic and formic acids, a solution of about 10 grams citric acid per liter of water is useful as a mild (albeit somewhat slow) acid for calcite removal, and to selectively remove some carbonates in the presence of others (Hardinger 2024a). For example, Rohner (2000) suggests that lime removal products based on citric acid dissolve "carbonate deposits without attacking minerals like dolomite" but does not elaborate on which minerals compose these carbonate deposits. This is consistent with a recent study on selective dissolution of carbonates (Hardinger 2024a).

Citric acid and its solutions have no distinct odor and, in this way, may be preferable to acetic and formic acids. Waste solutions are treated as Category I waste and flushed down the drain with plenty of water.

Ascorbic acid (vitamin C) is reported to selectively dissolve carbonate minerals in the presence of sulfides, but no mention is made of which carbonates (Duthaler and Weiß 2024, 97).

Sulfamic acid (sometimes also called amidosulfonic acid; H_3NSO_3) is a white, water-soluble solid whose solutions are useful for removing carbonate sinter. This chemical is inexpensive, nonhazardous and readily available at hardware and home improvement stores (often

as a cement grout cleaner). However, any ingredients besides sulfamic acid in these products may interfere with mineral cleaning and may even damage specimens, so such products should be avoided. If sulfamic acid is needed, buy only the pure material, available from Amazon and home lab chemical suppliers. Sulfamic acid is a stronger than acetic or formic acids but weaker than HCl. Despite this, it is often a suitable replacement for HCl in mineral cleaning recipes. While sulfamic acid is more expensive than HCl, it lacks corrosive fumes and is thus safer and more pleasant to handle.

Duthaler and Weiß (2024, 97) report that when used at 5°C a solution of 5 grams sulfamic acid in 100 mL water selectively dissolves calcite in the presence of phosphates, magnesite and dolomite. That magnesium carbonates are more resistant to acid attack than calcite is consistent with a recent report on selective carbonate removal (Hardinger 2024a).

A dilute sulfamic acid solution (exact concentration not specified) was used to remove calcite from copper; it is presumably preferred for this purpose because it is less likely to damage copper compared to HCl and faster to etch than acetic acid (Rosemeyer 2023).

A sulfamic acid solution should be prepared as needed and not stored, as this solution slowly decomposes over time. For carbonate removal the exact sulfamic acid concentration is not critical; 5 grams per liter is adequate. This concentration does not need to be precise but avoid a wasteful 'just dump it in' philosophy. Used sulfamic acid solutions are treated as Category I waste and flushed down the drain with plenty of water.

Oxalic acid readily attacks many carbonates, especially when hot. However, it offers no advantages for calcite dissolution as the thick calcium oxalate deposits formed require additional effort for removal.

Commercial products for carbonate ('lime' or 'limescale') removal are plentiful, but in general should be avoided because they are usually more expensive than 'pure' chemicals (such as vinegar, HCl or sulfamic acid) and because they often include ingredients that may interfere with the mineral cleaning process or even damage specimens. Such products include Lime-A-Way and CLR Calcium, Lime and Rust Remover. The latter is frequently recommended to remove carbonate coatings. The active carbonate-removing ingredient in this product is lactic acid which can be quite effective at calcite removal but often leaves a thick deposit of calcium lactate, sometimes difficult to remove (Figure 3-58).

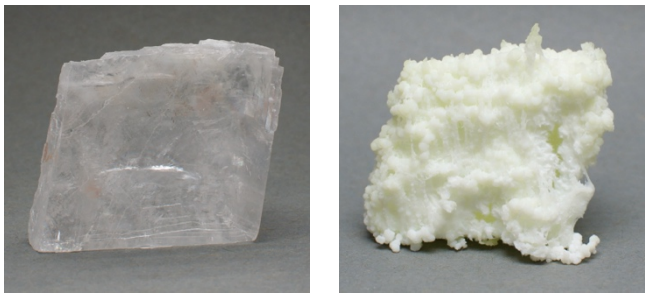


Figure 3-58. A calcite sample (left) was treated with CLR Multi-use resulting in a thick deposit of calcium lactate (right) which required additional cleaning steps to remove.

Like oxalic acid, **sulfuric acid** (H_2SO_4) is not ideal for carbonate removal as there are numerous better acid choices. Reaction with calcite produces gypsum ($CaSO_4 \cdot 2H_2O$) which has modest water solubility (2.7 grams per liter), so when large quantities of calcite are dissolved gypsum precipitates may coat the sample, necessitating additional steps to fully clean and develop the specimen. **Nitric acid** (HNO_3) is another strong acid (and strong oxidant) and not tolerated by a wide range of minerals but does have some specialized uses (see Chapter 4). Like HCl, many minerals are intolerant to these strong acids (Chapter 4 and www.mincleandev.com).

A solution of alum is said to dissolve calcite readily while leaving most other minerals (including dolomite) unaffected. Experiments show that a solution containing 40 g potassium alum - $KAl(SO_4)_2$ - per liter of water is slightly acidic and attacks calcite, aragonite, magnesite, smithsonite, malachite and azurite to some extent. Dolomite showed good but imperfect resistance. Thus, this reagent may have some selectivity for calcite over dolomite but not for other carbonates.

B. Other Methods

Duthaler and Weiß (2024, 94) describe a carbonate removal method which simulates the natural process by which dissolved CO_2 transports calcium, forming stalactites and stalactites in limestone caves. This somewhat operationally complex procedure uses a pressure vessel, magnetic stirring, soda water or dry ice and an ion exchange resin (to remove dissolved Ca^{2+}; not in direct contact with the mineral specimen) to etch calcite under mild conditions. (An ion exchange resin removes one ion from solution, such as Ca^{2+}, and replaces it with another ion such as Na^{+}. This technology is commonly used in some water softeners and fish tank water filters.) Duthaler fails to discuss this method's effect on other carbonates: Is it selective for calcite or will (for example) rhodochrosite - also known to be transported by dissolved CO_2 - also be etched? For a discussion of selective carbonate removal see Hardinger (2024a).

While exploring the details of this method as well a related ion-exchange resin gypsum removal procedure it was noted that calcite was etched *by direct contact* with the resin itself, without the need for dissolved CO_2 or a closed pressure vessel. In one experiment, a calcite crystal cleavage section suffered distinct etching and substantial mass loss when immersed overnight in a magnetically stirred mixture of 0.5 liter water (distilled or tap) and 0.2 liter mixed bed ion exchange resin. (Aquatic Life Mixed Bed Deionization Color-Changing resin was used; other mixed bed ion exchange resin brands were not explored but may also be useful. This brand of resin starts blue and turns brown as it becomes saturated with Ca^{2+}, a very useful feature.) In another experiment, 0.24 liter of resin in one liter of magnetically stirred distilled water removed 4.5 grams of calcite over 13 days. The etching mechanism is unclear; the solution pH remained mildly alkaline (pH 10–11, because the mixed bed resin replaces anions such as CO_3^{2-} with HO^{-}) during this time so an acidic process cannot be operating. Chemical reactions involving direct contact of two solids (in this case, calcite and the resin) are known but exceptionally rare. Figure 3-59 illustrates the results.

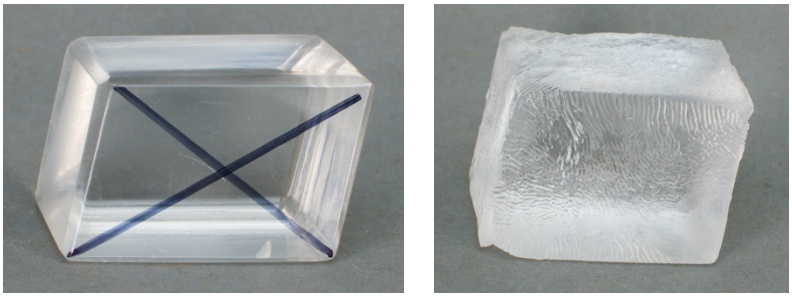


Figure 3-59. A polished calcite cleavage sample before (left) and after (right) etched by direct contact with mixed bed ion exchange resin. One face was marked "X" in case etching was difficult to ascertain.

Additional experiments revealed that (of the minerals tested) calcite, aragonite, ankerite, cerussite and magnesite were all attacked to some extent whereas rhodochrosite, azurite, malachite, smithsonite and siderite were inert to overnight treatment. While acids are cheaper than ion exchange resin, acids are less selective. The simplicity of this direct contact procedure makes it worthy of further exploration. As always, try lesser material before committing your best specimens to an unfamiliar and untried procedure. The author is eager to hear of your experiences.

3.19 Removing Gypsum

This section is about removing gypsum coatings and crusts. For advice on cleaning gypsum see Chapter 4.

Gypsum is another common mineral which can form crusts and coatings over previously deposited minerals. Its removal should be considered carefully as it is part of natural, geological processes and should therefore be retained but it may also be obscuring other minerals so its removal may enhance the aesthetic and monetary value of the specimen. Gypsum is soft (Mohs hardness 2) and easily cleaved, and so can be removed by picking and scraping (but this is often quite tedious and can easily result in damage to underlying minerals), air abrasion or a vibratory impact tool.

Alternately we can take advantage of gypsum's modest solubility in water (2.6 grams per liter at 25 ºC) and simply dissolve it, using equipment and materials most likely already present in your house. Some collectors place the sample in a large bucket of continuously flowing water. This is effective, but unconscionably wasteful. Better is to place the specimen in a stream or pond (in a container so it can be retrieved easily) or better still - a toilet's water tank! While this may sound quite disgusting, recall that this water is clean, and replaced each time the toilet is flushed. Even in very hard water (water containing high concentrations of dissolved calcium, magnesium and iron salts) gypsum is dissolved away at a convenient yet easily controlled rate. Just place the sample on the bottom of the toilet tank then check hourly or daily until the desired level of gypsum removal has been achieved. (Flushing sometimes causes violent draining and refilling of the tank, which may cause damage to a delicate specimen. Placing the specimen inside a container which is

then submerged in the tank will minimize this issue. Alternately, the ion exchange resin method mentioned below may be more suitable.) After perhaps the first hour you may notice that small bruises and scratches have disappeared, and the specimen takes on a slightly polished appearance. Longer exposure causes sharp edges to become rounded, and the specimen gets smaller. In one toilet tank experiment, 8 grams of gypsum was dissolved away in 24 hours; after one week 26 grams had been removed. A toilet's hard water may cause additional issues however: In one case (Chapter 6) gypsum was removed efficiently but a thin rust stain - requiring additional treatment with dithionite - has been deposited.

In the unusual case the toilet tank method for gypsum removal is not suitable (for example when the specimen is fragile) Duthaler and Weiß (2024, 100) describe a procedure which also takes advantage of gypsum's water solubility, but instead of using a large volume of running water, dissolved gypsum is removed from the gypsum/water solution with a mixed bed ion exchange resin (just like a water softener). Constant agitation is crucial for the process to proceed at a useful rate. Figure 3-60 illustrates this method. An improved version of this procedure is described below.

Figure 3-60. Rhodochrosite with gypsum before (left) and after (right) gypsum removal by the improved flowing water/resin procedure. Two weeks were required to remove about 15 grams.

Aquatic Life Mixed Bed Deionization Color-Changing resin is used. (Other mixed bed resin brands may also be useful but were not explored.) This resin removes dissolved Ca^{2+} and SO_4^{2-} ions as the solution passes through it, allowing more gypsum to dissolve. The net effect is to transfer gypsum from the specimen to the resin. At the start the resin has a dark blue color which turns brown as the resin becomes saturated (Figure 3-61). In one experiment, 0.2 liter of this resin was found absorb 7.4 grams of gypsum before turning completely brown.

Figure 3-61. Apparatus for gypsum removal via ion exchange resin.

Separating the specimen from the resin is important when calcite, aragonite and some other carbonates are present, as direct contact with the resin can etch these minerals.

The apparatus depicted in Figure 3-61 is assembled as follows. Into a tub having a few liters volume (and enough to fully submerge both the specimen and pump) is placed a submersible water pump (an aquarium pump is ideal). The resin holder tube was prepared by cutting off the ends of an inexpensive, plastic 100 mL graduated cylinder, but any similar material can be used. Translucency or transparency is important to monitor the resin's color change. (Ability to monitor the resin's color change before exhaustion is a useful improvement over the Duthaler and Weiß apparatus.) The tube ends should be smooth to prevent leaks. If the tube is plastic this is easily achieved by brief fire polishing. A larger diameter tube having greater resin capacity is more efficient when larger quantities of gypsum are to be removed. To one end of the tube is added a tight-fitting, one-hole rubber stopper followed by a cotton ball. The tube is then packed with the ion exchange resin and the other end closed with a cotton ball and one-hole rubber stopper. A hose nipple is added to one of the stoppers. The setup is completed by plumbing as shown in Figure 3-61. The stoppers can be further sealed by wrapping tightly with black electrical tape. Everything fits within the tub so that any water leaks are contained. Enough tap water to generously submerge both the specimen and pump is added. Distilled water is not necessary here; save money and use tap water. A closed tub minimizes water loss but is not necessary. If the water level drops to the point where the specimen or pump are exposed simply add more tap water to restore it.

At this point the pump is started. Progress is monitored by observing the resin color as well as residual gypsum on the specimen. Within as little as an hour the resin will begin to change from brown to blue, starting at the water inlet end. When the blue is completely discharged the resin is replaced.

Progress can also be monitored by noting the specimen's mass loss. Weigh dry at the start of the process and again every 24 hours or so. When the dry weight does not change over a 24-hour period and some blue resin remains the process is complete. The gypsum removal rate depends on several factors such as tubing diameter and pump speed but run times of several days are typical.

That the amount of resin capacity remaining and the approximate time before pH drop (see below) can been monitored is another improvement over the Duthaler and Weiß procedure. Replacing magnetic stirring with a less expensive water pump is another improvement as well.

When the process proceeds more than a few days, replace the water daily. This increases gypsum removal capacity and is more economical because water is cheaper than resin.

Resin in the tube not fully consumed by this procedure can be stored by replacing the one-hole rubber stoppers with tightly fitting solid stoppers of the same size. Seal the tube with electrical tape tightly wrapped around each tube end. Unused resin can be stored for several years before it decomposes enough to be useless, but it must be kept slightly moist and in a well-sealed container.

This method is highly selective for gypsum removal. Water-insoluble minerals remain behind. The toilet tank method described above obviates the need for special apparatus and chemicals (unless you don't have a flush toilet) but is substantially slower per gram of gypsum

removed due to infrequent water change in the toilet tank versus constant flow with the resin. Flushing the toilet can create rather violent turbulence in the tank so the resin method is preferred to remove gypsum from less robust specimens.

The toilet tank and resin procedures are obviously not applicable when other water-soluble minerals (such as halite) are present and need to be preserved. However, exercise care with the resin procedure when carbonates and other acid-sensitive minerals are present (Chapter 4 and www.mincleandev.com). In one experiment, the solution was moderately alkaline (pH 8.4) when the resin was fresh to only partially exhausted but when all the resin had turned brown the solution rapidly became moderately acidic (pH 2.8). The pH changes were approximately the same with the Duthaler and Weiß apparatus. When acid-sensitive minerals are present monitor the pH and replace the resin before it is completely saturated with Ca^{2+} (has all turned brown) to avoid the pH drop. As always, apply Guiding Principle 5 and try any new procedure on lesser quality specimens before committing your best material.

3.20 Removing Clay

Clay is another common mineral specimen contaminant, generally formed by weathering and other silicate rock and mineral decomposition processes. It is often encountered as soil residue or in a freshly opened crystal pocket. It can be hard and dry or soft and sticky (like peanut butter) but is often quite tenacious and tedious to remove. Clay consists of ultrafine mineral particles (often of micaceous minerals) cemented together by calcite, gypsum and other materials. A brown color indicates that iron hydroxide/oxide cements may be present. In some instances, chlorite encrustations can also be removed by the methods mentioned here.

Mechanical cleaning methods - which we always try before chemical methods - include picking, scraping or brushing with toothpicks, bamboo slivers or steel tools (but with risk of specimen damage, especially when crystals are hidden beneath the clay and/or the mineral being cleaned is soft - gypsum, calcite, etc.). King (1982, 42) warns that when clay residues are present between crystals it is better to soak (and loosen or completely remove the clay) before poking with tools as the later may force the crystals apart. Sonication is good for removing surface clay but often fails to clean deep cavities or to remove soft clays, although Rohner (2000) reports that sonication is effective to remove clay-like material from fossils. Water jet tools - especially a textile gun - are often the most efficient and most effective mechanical method, especially when combined with soaking/drying as discussed below. Air abrasion is a last-resort method but often highly effective for clay removal. Alternating mechanical cleaning with soaking and thorough drying (below) can also be useful.

Sinkankas (1970, 288) notes that tumbling may be applied to remove clay and better reveal a specimen's inner beauty. However, this technique is frowned upon by many serious collectors especially when precious crystal faces or the natural mineral paragenesis are destroyed. Tumbling is sometimes used on variscite, turquoise and peridot.

The chemical composition and tenacity of clays varies so widely that no single chemical method is effective against all clays. Suggested chemical (or 'wet') methods for clay removal in the mineral cleaning literature are legion. Some make chemical sense while others appear to be ineffective magical potions.

Sinkankas (1972, 232), Pearl (1982, 35) and King (1982, 42) suggest the following: When mechanical methods fail to remove all the clay an extended water soak (24 hours or more; avoid when water-sensitive minerals are present) will soften some clays and make their removal easier. Including a little liquid household dish detergent assists ingress of water. Allowing the specimen to dry thoroughly then soaking again is another effective (albeit time consuming) method to loosen clays (Buřival 2018). Similar soaking in acetic acid or dilute NH_3 may also be helpful. Water will dissolve gypsum cements and vinegar will dissolve calcite cements. However, Herborner (unpublished results) recommends avoiding NH_3 with anglesite, cuprite, linarite, malachite, turquoise, variscite and minerals from the ore oxidation zone. Duthaler and Weiß (2024, 66) recommend avoiding NH_3 altogether because it may attack a wide range of minerals and because milder methods are available. Review Chapter 4 and www.mincleandev.com for chemical compatibility before soaking. Rohner (2000) and Sury (1991, 10) recommend without details soaking in a 10% solution of urea in water for clay removal. Soaking also causes particles to swell, forcing them apart and resulting in less clay adhesion. If these methods fail, try soaking in dithionite overnight or room temperature oxalic acid for up to a week to disrupt iron-based cementing. Lightening of a clay's brown color is an indication these later methods may be working.

Petrov (in Morris 2022) reports without details that sodium hexametaphosphate - $Na_6(PO_3)_6$ - can be useful to remove difficult clays such as the sticky pocket clays found in pegmatite pockets. It is assumed that one alternates between soaking the specimen to be cleaned in a water solution of the reagent for hours or more with a mechanical cleaning method such as the textile gun.

Duthaler and Weiß (2024, 78) state that alternating between an oxalic acid soak and an "alkaline solution" (but do not specify what alkaline solution or the temperature; perhaps 10 grams of NaOH or KOH per liter of water can be used). Duthaler and Weiß (2000) also report effective clay removal by sonication in Neodisher LM3, a laboratory grade glassware cleaner, mostly unavailable outside of Europe. Because it lacks NH_3 Neodisher LM3 is said to be compatible with many ore oxidation zone minerals.

With any of these soaking regimens, repeated soak/clean/soak cycles may be needed for complete removal. If after three such cycles clay residue remains focus instead on other methods.

Methods based on cleaning by effervescence have also been suggested. For example, Herborner (unpublished results) recommends soaking in 3% H_2O_2. As the peroxide decomposes, oxygen bubbles are liberated forcing clay particles apart. The process is slow as peroxide decomposition may take days; the actual process here may be more a matter of water swelling of clay particles instead of the effervescence effect itself. A higher peroxide concentration produces more vigorous effervescence. Another chemically mild effervescence cleaning process is based on CO_2 evolution from the reaction of $NaHCO_3$ and citric acid. (More mature readers may recognize

this as the Alka-Seltzer "plop, plop, fizz, fizz" reaction.) In short, the specimen is immersed in a solution of $NaHCO_3$ to which small aliquots of a citric acid solution are added. Consult Duthaler and Weiß (2024, 33) for the details.

For the sake of completeness some recommended clay removal methods that are to be avoided are briefly mentioned here. Pearl (1982, 35) recommends "gentle boiling in a strong solution of sodium sulfide (Na_2S)." Not only will this stink strongly of rotten eggs (H_2S gas, which is extremely toxic) but the solution is also strongly alkaline (See Section 3.32). Some sources advocate the use of HF or HBF_4 for clay removal because these chemicals attack silicates and clay is silicate-based. However, the advantages of these reagents are far outweighed by the very significant health and safety dangers they present, and so these chemicals should never be used by an amateur (Section 3.32). NH_4HF_2 may be a mild alternative but appears unexplored for this application.

3.21 Removing Lichen, Moss, Roots and Other Biological Residues

Soil is the domain of plants so any specimen collected from that domain may be contaminated with biological residues such as lichen, moss and roots. Specimens from wet environments may be contaminated with algae. Unlike (for example) rust or carbonate coatings, biological residues are clearly not part of the natural geological processes which deposited a mineral. Therefore, their removal does not (or only exceptionally rarely) decrease a specimen's scientific value. As always consider mechanical methods for this cleaning issue before turning to chemical methods. A water jet tool such as a textile gun can be effective when the residues are not too entwined with the crystals. Tweezers (especially needle tip tweezers, Figure 2-3) can also be effective but rather tedious.

In some cases, complete residue removal by mechanical methods is ineffective so chemical methods must be applied. Duthaler and Weiß (2024, 76) present several recipes for this. Before application of mechanical methods, they suggest presoaking in an alkaline cleaning solution such as Neodisher LM3 (essentially unavailable outside of Europe). A solution containing 10 grams of NaOH or KOH per liter of tap water is also adequate. (NH_3 has also been recommended for this purpose but should be avoided due to the narrower range of compatible minerals.) This presoak causes plant parts to swell and soften and may also decolorize the residues by dissolving some pigment materials. After a 24-hour soak rinse thoroughly then continue cleaning with the textile gun and tweezers. The soak/rinse/mechanical cleaning cycle is repeated until the specimen is satisfactorily clean or no further progress is seen. Treatment with a hot alkaline solution may be needed when the plant residues are particularly intractable.

Household bleach (a water solution of sodium hypochlorite, NaOCl) has been recommended to both lighten and weaken biological residues by a soak one hour to several days. Wight (1993, 74) reports that bleach is recommended for algae removal. Bleach is a strong oxidant and strong alkali so check Chapter 4 and www.mincleandev.com compatibility tables before its application. Safety glasses and gloves must be worn. If the biological residues are bleached to

white but not removed, follow bleach treatment by cleaning with a water jet tool (Section 3.4). Liquid bleach contains sodium hypochlorite, whereas bleaching powder (better known as swimming pool shock treatment) is calcium hypochlorite - $Ca(OCl)_2$. The latter does not appear to have been explored as a mineral cleaning reagent, but its water solution should behave much like liquid bleach.

Some lead minerals are attacked by NaOCl (Figure 3-62); see Chapter 4 and www.mincleandev.com for chemical compatibilities. For example, anglesite gained a yellow to brown color; this was the origin of reddish Moroccan specimens in the 1980's (Weise 1984). Similarly, some samples of cerussite turned yellow (one minute), orange (five minutes) and finally are coated with a thin, golden-brown layer after 30 minutes. Interestingly this film could be removed by treatment with 3% H_2O_2 (another oxidant!) but this left a dull, pitted surface. Phosgenite behaved similarly, as did wulfenite; in the latter case the dark coating produced was easily flaked away. Linarite became black after a few hours. However not all lead-containing minerals were attacked by bleach. For example, vanadinite, pyromorphite, mimetite, galena, crocoite and plumbogummite were unaltered. Amazonite, whose blue green color is attributed to Pb^{+}/Pb^{3+} (Hofmeister and Rossman 1985), was also unaffected. It is likely that a wide range of other minerals may be damaged by bleach - especially those containing oxidizable cations - so when in doubt, avoid bleach treatment or at least experiment with lower quality specimens first.

Cerussite Phosgenite

Figure 3-62. Effect of bleach on lead minerals, before (left) and after (right).

Treatment with 6% H_2O_2 for 2–5 days is an alternate to bleach and is more widely tolerated. Strong alkali is another possibility. Alternately, the specimen is first wetted with an alkaline solution (undiluted Neodisher LM3, 10% Na_2CO_3 or 2–10% NaOH) then treated with 12% H_2O_2. The peroxide is applied with a separate dropper because contamination may cause rapid decomposition. Alkali is applied first because in acidic solution H_2O_2 has a strong oxidizing effect. After the peroxide has been applied the specimen is heated with an infrared lamp (not a flame or hot plate) resulting in rapid evolution of oxygen and plant residue decomposition. More peroxide is added dropwise until the results are satisfactory at which time the sample is thoroughly rinsed and dried. Figure 3-64 illustrates this alkaline peroxide process.

Heating in dilute H_2SO_4 has also been suggested (Duthaler and Weiß 2024, 77) but because many minerals will be incompatible with this treatment, it should only be a method of last resort.

For removing lichen and animal droppings (!) Wight (1993, 74) recommends a soak in diluted NH_3 (but does not give a specific concentration or soak time) followed by further work with mechanical methods.

Figure 3-63. These brittle root residues required both mechanical and chemical treatment for complete removal. Needle point tweezers were ineffective to remove all the roots. The specimen was then submerged in a solution of 10 g NaOH in 100 mL tap water, to which was added 100 mL 12% H_2O_2. Mild effervescence stopped after 10 minutes at which time cleaning was completed by brief sonication and thorough drying.

King (1982, 44) states: "If the surface on which they are growing is hard, the lichens, etc. are allowed to dry completely and then are vigorously brushed off using a small nylon handbrush. If the material is not too robust, the application of a dilute NH_3 solution, while the specimen is damp from the field, will help soften lichens and algae, which may then be removed by brushing under a flow of water. The use of concentrated acids in the removal of lichens and algae...is not recommended, though the careful and selective application of concentrated H_2SO_4 [or concentrated] HNO_3 may be used with good effect on some rock specimens."

Dithionite may be used to decolorize plant residues (Duthaler and Weiß 2024, 57) but organic material will remain requiring further work with water jet tools.

After his collection was damaged in a fire, Chamberlain (2008) reasoned that soot should be treated as an organic residue. Specimens were cleaned first by treatment with soap and water and then (if necessary) the same solution with a textile gun. If further cleaning was needed the specimen was soaked in Purple Power degreaser followed by textile gun treatment. Specimens which at this point "still looked like a piece of junk" were discarded (the KOH/alcohol bath treatment described in Section 3.22 may have been able to save some of these).

3.22 Removing Bitumen (Tar)

Some specimens are marred by a dark brown or black 'tar' coating which is not removed by H_2O_2 treatment. Such a coating is most likely to be found for example on sulfur (Russia or Sicily) or Illinois fluorite but can also be associated with Herkimer diamond quartz or some California fossils. The coating is derived from chemical reactions of petroleum over geological time and is categorized based on its properties. Bitumen (also called asphalt, asphaltum, kerogen,

pitch, pyrobitumen, petroleum, etc.) is a "sticky, black and highly viscous liquid or semi-solid to solid" with some solubility in organic solvents. Bitumen is not a single, well-defined mineral species but instead is a mixture of polymeric carbon-rich (organic) material ('tar'). Kerogen is similar in appearance to bitumen, but insoluble. Pyrobitumen is "brittle, infusible and relatively insoluble" (definitions from www.mindat.org). In this section 'bitumen' is taken to mean any of these coatings.

Regardless of its name or properties, collectors generally consider these coatings to be unsightly and therefore in need of removal. However, the collector should also consider leaving the coating in place as it is part of the specimen's natural geological history and whose removal reduces the specimen's scientific value. It is also possible that bitumen is the 'glue' keeping a crystal cluster together and that its removal will cause the specimen to disintegrate into its component pieces.

When bitumen is to be removed try mechanical cleaning methods before chemical methods. If a textile gun is used great caution is necessary as sulfur and fluorite both cleave easily. Air abrasion will be difficult because the coating and the underlying sulfur or fluorite are both soft, making selective removal difficult. In the unusual case where bitumen coats a mineral not prone to cleavage or much harder than the coating these mechanical methods may be suitable.

When using chemical methods to clean sulfur specimens Goo Gone Spray Gel is generally effective. This product consists mostly of petroleum distillates with lesser amounts of limonene and orange extract. (Goo Gone Automotive, Sticker Lifter and Pro Power have the same ingredients and should be equally effective but have not yet been tested for this application. Goo Gone Kitchen Degreaser is a different formulation which may also be effective but has not been tested.) This cleaner is flammable and so should be *used with good ventilation*, preferably outdoors. The SDS (Googone 2019) indicates that the product may be a skin irritant, so *nitrile or heavy rubber gloves and eye protection must be worn*.

There are numerous citrus-based cleaning products on the market which on the surface may appear to be viable substitutes for Goo Gone, such as Citra Solv. However, examining SDS information for some of these products shows their compositions vary rather widely. Hence their use as Goo Gone substitutes is questionable.

For cleaning the sulfur specimen is immersed in Goo Gone for 30 minutes then *gently* scrubbed with a toothbrush or other soft brush. If cleaning is incomplete the specimen is immersed for another 30 minutes. (Goo Gone causes minor mass loss after one hour and slight delustering of sulfur with on overnight exposure so keep exposure times as short as possible.) If cleaning is satisfactory residual Goo Gone is removed by gentle blotting with a lint free rag or paper towel. The last traces are removed by a liberal washing in 99% rubbing alcohol (lower concentrations are less effective) followed by immediate blotting. (Rapid evaporation of rubbing alcohol causes cooling which may lead to thermal shock which is especially problematic with sulfur.) Do not use acetone in which sulfur is slightly soluble as delustering will result. Alternately, Goo Gone residues can be removed by gentle cleaning with soapy, room temperature water (not warm...thermal shock). Brief sonication may also be useful to remove the last traces of both

bitumen and Goo Gone. The effectiveness of this procedure varies from specimen to specimen; some are cleaned in just one cycle whereas others require five or more cycles. Figure 3-64 shows an example.

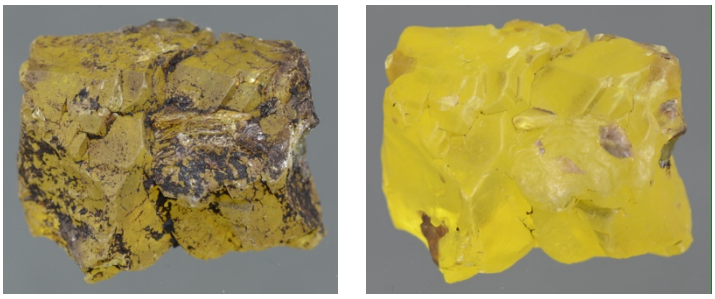


Figure 3-64. A Russian sulfur specimen before (left) and after (right) Goo Gone treatment.

As a final note on this topic, it is amusing to read of two enterprising collectors who have removed petroleum using mayonnaise and the canola oil therein (Mortimer 2024 and Young 2017).

Goo Gone, acetone, dichloromethane (Section 3.32) and Klean Strip Premium Paint Stripper are generally ineffective for removing bitumen from fluorite, probably because the bitumen on fluorite is of a different nature than the bitumen on sulfur. A different cleaning protocol is needed, namely an intensely alkaline bath. First, however, verify that the 'bitumen coating' is not just a dark color zone within the fluorite, near the specimen's surface (Figure 3-65).

Figure 3-65. This 'unremovable bitumen coating' is really a thin, dark blue zone near the specimen's surface. Illumination from the rear (left) can be helpful to spot this dark zone.

The alkaline bath is prepared in a polypropylene or polyethylene container (not polyethylene terephthalate or glass; Figure 3-27) which can be tightly closed. Magnetic stirring is helpful but not required. For each 200 mL of 99% rubbing alcohol needed to fully cover the specimen is added 26 g KOH. (Unlike dissolution in water, dissolution of KOH in alcohol does not produce much heat and thermal shock concern is minimal.) The solution turns light yellow immediately, fades in a few minutes and then intensifies over the next few days. If after a few days all the KOH has dissolved, add more. (Undissolved KOH does not interfere with cleaning.) NaOH can be used but is somewhat less effective. *Wear gloves and eye protection; this bath is strongly corrosive.* The specimen is added and the container closed to minimize evaporation. Every 24

hours the specimen is removed and cleaned with a textile gun or sonication. If cleaning is incomplete the specimen is returned to the bath. Multiple weeks are usually required achieve satisfactory bitumen removal. As the KOH precipitates and redissolved a fine sludge is formed. This is normal and does not inhibit cleaning. The bath is replaced every 1–2 weeks.

When cleaning is satisfactory the specimen is washed thoroughly in water and dried. Long exposure to the base bath is not an issue; control experiments have confirmed that fluorite it not etched, and no luster is lost even after several weeks of exposure. Control experiments reveal that fluorite retains its luster after at least ten days in the KOH/alcohol bath and that rubbing alcohol alone is ineffective for bitumen removal. Like using Goo Gone to remove bitumen from sulfur the bath's effectiveness for removing bitumen from fluorite varies widely between specimens. Sonication may accelerate this process but has not yet been explored. The used base bath can be disposed by flushing down the sink with plenty of water. Figure 3-66 shows a fluorite specimen cleaned by this alkaline bath procedure.

Figure 3-66. Left: A Cave-in-Rock, Illinois fluorite with bitumen before treatment. Right: The same specimen after 11 weeks of alkaline bath treatment. More details are given in Chapter 6.

As an alternate to prolonged base bath exposure, extending soaking in acetone - even with prolonged (several hours) sonication - had no effect. Miller (2010) reports that a prolonged soak (days) in a 1:5 Lestoil to water solution also removes bitumen from fluorite as well as baryte.

Internet searches reveal that numerous other solvents have been suggested for bitumen removal but that none are particularly effective. These should not be 'first choice' solvents because they are too hazardous (toxic, carcinogenic, etc.), too difficult to obtain or dispose or just ineffective. Suggested solvents include acetone, rubbing alcohol (any concentration), methyl ethyl ketone (MEK; 2-butanone), methylene chloride (dichloromethane), chloroform, trichloroethylene (TCE), hexane, benzene, toluene, xylene, gasoline, kerosine, diesel fuel, turpentine, paint stripper, mineral spirits (also called white spirit, mineral turpentine, turpentine substitute, petroleum spirits, Stoddard solvent, solvent naphtha), oven cleaner products or Simple Green. Oven cleaner products such as Easy-Off may contain silica as an abrasive, which is another reason to avoid their use for mineral cleaning. For additional discussion see Mortimer (2024).

3.23 Removing Oil

It is occasionally necessary to remove oil residues from specimens. Common examples include residual lubricating oil from lapidary materials, oil added to enhance luster and/or hide cracks (often with fluorite but sometimes other mineral species as well) or oily reside left by mineral tack. Oiling to enhance luster is a very casual practice with some dealers: Cooking oil is sprayed directly onto the specimens with customers nearby and the newspapers beneath these specimens are so soaked that oil drips from them! Oil may also have been applied as a barrier against losing or gaining atmospheric moisture; in these cases, the oil should not be removed unless it is an unstable oil such as cooking oil which is to be replaced with a more stable oil such as silicone oil. Many oils (especially those derived from petroleum) are fluorescent (typically a pale green under longwave ultraviolet light); these must be removed before photographing a specimen's natural fluorescence. Plant based or cooking oils will decompose over time, causing yellow staining and rancid odors. Except when used as a mineral preservative deliberate oiling is considered unethical and unscientific and steps must be taken to remove it.

In many cases specimen oiling is obvious by its oily feel and/or odor. An oily residue left on a paper towel used to blot the specimen is another easy test. When the luster looks just too good oiling must also be suspected.

Oil can often be removed by a simple wash (or better yet, sonication) in soapy water (if the specimen is water-tolerant; see Chapter 4 and www.mincleandev.com). *Use only room temperature water to avoid thermal shock, especially with fluorite (perhaps the single most frequently oiled mineral species!).* Wiping with a rag or paper towel moistened (not saturated) with a low-toxicity solvent such as rubbing alcohol (99% is best) or acetone may be effective. Goo Gone is a good alternative. The solvents discussed in Section 3.32 should also be avoided here.

Soaking in dry kitty litter (need we say unused?) is often recommended to remove oil (especially saw lubricating oil) but this technique probably fails to draw the last traces of oil out of fine cracks.

3.24 Removing Polyurethane and Lacquer Coatings

A polyurethane coating may be applied to a lapidary specimen (often a slab) to enhance luster and as a lazy way to avoid polishing. Such a coating maybe be unsightly because it is too thick, has bubbles or ripples or is uneven. Lacquer may be applied for the same reasons but is less commonly used by modern collectors.

Acetone and rubbing alcohol usually have little to no effect on polyurethane coatings whereas many paint stripper products are effective for this purpose. Klean Strip Premium Stripper was found to be particularly effective for this task. Paint stripper formulations vary widely (the product's SDS lists ten ingredients; Kleanstrip 2021). Other strippers may also be effective but have not been tested. Citrus oil-based products are safer and have less unpleasant odors compared

to products containing DMF (*N,N*-dimethyformamide) or NMP (*N*-methylpyrrolidone). Carefully review a product's ingredients listed on the SDS or label before purchasing.

Dichloromethane (methylene chloride), present in older paint stripper formulations (check the product's label or SDS) can be very effective at removing a polyurethane coating with just a wipe, but this solvent should be avoided by the amateur because it is a suspect carcinogen, requires special hazardous waste disposal and is expensive (Section 3.32). If you do have access to this chemical, *gloves are safety glasses are a must, Superior ventilation is required! Work outdoors*!

Paint stripper formulations are often flammable, toxic and irritating, so *wear safety glasses, nitrile or heavy rubber gloves and work with adequate ventilation (outdoors if possible).* Start by selecting a suitably sized *disposable* container (because the process is messy) which (if plastic) should be tested to verify it resists the stripper. A closed container is best to reduce loss by evaporation. Pour a shallow pool of the paint stripper into the container then place the slab into the stripper, coated side up (so the chemical can easily access the coating). Add stripper as needed to barely submerge the slab. Soak for 30 minutes or more then gently rinse with acetone or 99% rubbing alcohol into a separate container (to remove last traces of the stripper; wiping with a rag or paper towel is less effective). Air dry or wipe with an acetone-moistened clean rag to remove the last traces of coating and to finish drying. If the coating has not been fully removed, repeat the soak/wipe cycle as needed. Scrubbing the stripper-moistened slab with a toothbrush can also accelerate softening. Dispose of the bath container, rags, etc. in the nonrecyclable trash.

Paint stripper also removes lacquer coatings, but acetone and 99% rubbing alcohol (both less messy than paint stripper) may also work.

In one instance a slab of tourmaline encased in fine-grained lepidolite had a coating of unknown composition needing removal because it had turned brown. The coating was not altered by soaking in acetone or dichloromethane, suggesting it might be an epoxy. Soaking in drain cleaner grade concentrated H_2SO_4 for two hours followed by textile gun treatment, a soak in $NaHCO_3$ solution (to neutralize residual acid) then clean water (because the specimen is somewhat porous) was successful. This brutal chemical treatment was possible only because both minerals present have excellent chemical resistance (Chapter 4 and www.mincleandev.com).

3.25 Removing Writing and Ink

Information is sometimes written directly on a specimen, most commonly on lapidary slabs and cabochons. Before removing such writing, consider that it may record valuable information such as locality or collector and that removing the writing may cause this information to be lost.

Writing in pencil is usually easily removed by vigorous rubbing with a standard pencil eraser (one of the easiest mineral cleaning procedures there is! Figure 3-67).

Figure 3-67. Pencil marking on this rhodochrosite slab was remove by vigorous eraser rubbing.

Removing ink can be more challenging as ink may soak into a porous surface. In addition, there is a wide array of ink formulations (e.g. ball point pen ink versus Sharpie ink), each having its own properties. To remove ink, start by vigorously scrubbing the inked surface with a rag or paper towel liberally dampened with rubbing alcohol (99% is more effective than 91% or 70%) or (often better) acetone. *Always wear safety glasses and nitrile or heavy rubber gloves, and work with adequate ventilation (outdoors is best).* Although mineral incompatibility with these solvents is uncommon, check Chapter 4 and www.mincleandev.com to verify. If rubbing alcohol or acetone treatment fail soak the slab in the same solvent for 30 minutes or more (in a closed container to minimize evaporation) before rubbing again. Other solvents might also be effective but the risk/reward ratio for these is often very poor because these alternates are hazardous in some way. If the writing persists it may be necessary to resurface the specimen by air abrasion or repolishing. See Figure 3-68.

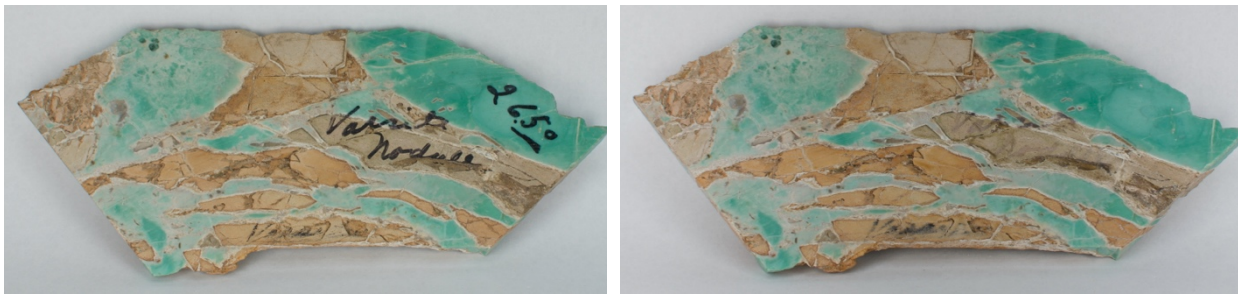


Figure 3-68. Ink on this variscite slab (left) was only partially removed by a vigorous rubbing alcohol wipe, but an acetone wipe finished the job quickly and completely (right).

3.26 Removing Adhesive Residues, Mineral Tack and Old Stands

The problems in this section are separate issues but often occur together. For example, a specimen glued to a **styrofoam block** requires one technique for dismounting the specimen without damage, and another for removing any glue residues left behind (Figure 3-69). Removing mineral tack residue necessitates a different procedure than removing glue. In some cases, the mounting may have historical or scientific value and dismounting would decrease this value in

which case the specimen should not be dismounted. Disassembling repairs and fakes are discussed in Section 5.1.

Figure 3-69. This magnesite nodule has been mounted 'old school' on an unsightly, painted styrofoam block with water-based glue. Developing this specimen to its full potential requires removing both the styrofoam and any glue residues.

Regardless of the adhesive used, when removing a specimen from a base do not just grab the specimen and base in opposite hands then twist or tug. When the bond between the adhesive and base is stronger than the physical integrity of the specimen (this is common) the specimen will be damaged as the adhesive pulls away. The trick to avoid this damage is to either destroy the base or weaken the attachment between the adhesive and base before removing any residual adhesive from the specimen itself. *The specimen is usually more precious and more fragile than the base*.

Some **styrofoam base** labels are attached by pins or glue. If the specimen has historical or scientific importance, this label should not be removed from the base. In the absence of such importance the excised label should be preserved if possible. To mitigate loss of information should the label be destroyed during removal photograph the entire specimen first and store this photo with the specimen or (better still) as part of the collection catalog. When attached by pins, just pull the pins out. When glued to the styrofoam base a paper label can be difficult to remove intact; in this case carefully cut through the styrofoam behind the label, resulting in a thin pad of styrofoam which supports the label.

To remove a specimen from a styrofoam base, weaken the base by cutting it into quarters with a sharp Xacto knife, with each cut perpendicular to the base's edge. Cut completely through the base's thickness. Then *very gently* break the base into pieces. Additional cuts along the bottom of the adhesive blob, slightly into the styrofoam block, may be necessary. Avoid the temptation to break the foam without weakening it first, as this increases the chance the specimen will break before the foam. Avoid acetone, which rapidly converts styrofoam to a sticky, stringy mess which is all but impossible to remove (wet or dry). Any glue residues are removed as described below.

Attachment between an **acrylic base** (or most other materials) and adhesive is loosened by gently poking a small, sharp Xacto knife between the base and adhesive. Slowly work around the adhesive blob and gradually probe deeper each time. Eventually the adhesive can be gently pried away from the base without damage to the specimen. It may be necessary to soften the glue first (see below). Acrylic bases are often square or round, typically a few centimeters in diameter and a few millimeters thick. Such bases are usually inexpensive and therefore not worth the effort to

salvage (remove adhesive residue, polish out scratches, etc.). Blockier acrylic bases can be expensive enough to warrant salvage and refurbishing. Numerous technique guides for polishing acrylic can be found online.

Before attempting to remove glue residue, the type of glue must be identified first. For **water-based glues** (polyvinyl acetate or PVA glue such as wood glue or Elmer's Glue-Al), start with an overnight soak in tap water then remove the softened glue (and residual styrofoam, etc.) first with tweezers then the textile gun. Repeat the soak/removal cycle as needed. Softening can be accelerated (and the residue even removed to some extent) by sonication in a warm water bath. Although hot water accelerates softening of water-based glue, use only tepid water to avoid thermal shock. (Recall that patience is your most valuable mineral cleaning tool.) Treat any glue residue immediately after removal from the water bath as the glue will set again as it dries.

Mounting specimens with **hot melt adhesive** (also called **hot glue**) has become increasing popular. When the glue glob is removed from the old base as described above the glue residue might be carefully peeled away from the specimen as a single piece. Alternately the glue can be softened by soaking in rubbing alcohol of at least 70% concentration for ten minutes. Higher concentration is better, especially for water-soluble or water-sensitive minerals; see Chapter 4 and www.mincleandev.com. Rubbing alcohol of any concentration does not attack acrylic or glass but may leach the color from wood. If the glue is sufficiently softened it can be gently peeled (finger pressure only) away from the base and/or specimen as a single piece. Avoid prying the glue blob with hard, pointy tools such as an Xacto knife if the stand is to be re-used, as acrylic is soft and scratches easily. Some collectors soften the hot glue blob by heating before attempting to dismount the specimen, but this creates a thermal shock risk. Hot glue compositions vary, so their behavior on removal may also vary. For more on applying and removing hot glue see Section 5.5C.

Silicone glue is particularly annoying to remove completely. It tears easily and thus usually cannot be peeled from the specimen as a single piece. Instead, it usually must be removed in bits. Gently and slowly work a sharp knife between the glue pad and base until the base can be removed. The glue pad can often be cautiously peeled away from the specimen; a soaking in 99% rubbing alcohol may help. A textile gun or sonication may assist removing the last bits, but complete removal is impossible in some cases, especially when the matrix is rough or porous.

Epoxies often turn brown over time. They can be softened by an overnight soak in acetone (except in the rare case where epoxy is used to mount the specimen on styrofoam) followed by very gentle tugging. The glue residue can then be removed while still wet by wiping with an acetone-soaked rag or paper towel.

Mineral tack (mineral mounting putty) is another common mounting adhesive but unlike glue does not cure (harden) over time (except for cheap or very old tack which can become brick hard in a few years). Sometimes the tack ball easily peels off as a single, cohesive blob. Residual tack can then be removed by gently dabbing or rubbing with a small ball of fresh tack, warmed by rolling between the fingers. Gently poking at or lifting any remaining tack with a toothpick followed by dabbing is also useful. Resistant tack residues may yield to the textile gun. Hardened tack can often be softened by a soak (one hour to overnight) in acetone or 99% rubbing alcohol,

followed by removal as described above. As a last resort, extended sonication - often requiring several hours - may be needed. Mineral tack may leave an oily residue (especially on porous surfaces) which can be removed as discussed in Section 3.23. Soaking in Goo Gone, Citra Solv, Weiman Wax Away or Johnson's Baby Oil have also been suggested (W. 2006) but after such treatment the product residues will still require extra work to remove the final traces (see the Goo Gone discussion in Section 3.22). Additional discussion can be found at Sutcliffe (2024) and Evanich (2024).

Residual label adhesive, often on a stand or a plastic (usually polystyrene) 'Perkie' thumbnail specimen box is easily removed by wiping with a 99% rubbing alcohol-dampened cloth. Lower strength rubbing alcohol such as 90% or 70% is much less effective. Soaking overnight may be necessary when the material is porous. *Avoid acetone on all plastics* as it readily attacks acrylic and polystyrene (Figure 3-70). Residual adhesive can be cautiously scraped off with a small, sharp Xacto knife if the material is flat and has a Mohs hardness of 6 or better (steel is typically about 5.5). Check first for scratching damage on an unimportant part of the specimen.

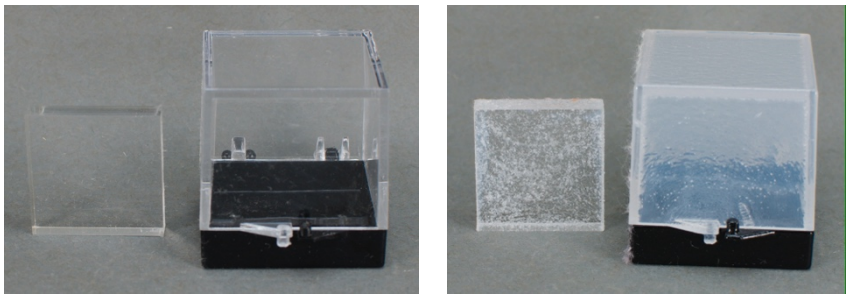


Figure 3-70. Left: An acrylic base and a polystyrene 'Perkie' box soaked in 99% rubbing alcohol for ten minutes remain unchanged. Right: Soaked in acetone instead they become cloudy and sticky in seconds.

Regardless of the adhesive type, if the specimen is to be remounted consider a balance between potential specimen damage caused by repeated glue removal cycles versus hiding the last traces of old glue when the specimen is again mounted.

3.27 Cleaning Water-sensitive and Water-soluble Minerals

Most minerals are not water sensitive, so the need to clean such minerals is uncommon. However, some minerals are either chemically altered by water (water sensitive) or to some extent dissolved in it (water soluble). Both groups are referred to as 'water sensitive' in this section. Several of the cleaning and development methods presented in this manual such as sonication or derusting with dithionite are aqueous and thus unsuitable for use with water sensitive minerals. A simple solution might be to replace water in these procedures with an organic solvent. However, the same properties which render a water-soluble mineral insoluble in such a solvent will also render the cleaning chemicals (such as dithionite) only poorly soluble or (more commonly)

completely insoluble in the same solvent. Minerals whose water sensitivity is unknown or questionable should be treated as if they are water sensitive (Guiding Principle 4).

When the mineral(s) present have been identified their water sensitivity is checked in Chapter 4 and at www.mincleandev.com. In the uncommon circumstance the mineral is not listed we can make an educated guess about the possibility of water sensitivity can be made based on the mineral's chemical formula, but this skill is often beyond the amateur mineral collector. In these cases, it is better to err on the side of caution and avoid water all together. Stoll (2002) describes a simple device based on ionic conductivity to test water solubility. However, Stoll fails to note that some rare water-soluble minerals such as acetamide which do not form ions in solution will most likely appear as water insoluble in this test. It is highly unlikely, however, that the amateur will encounter such minerals.

To consider cleaning water-sensitive minerals, we start with **dust, soil and clay** - a common problem - best handled by dry methods including gentle brushing or blowing with compressed gas. Avoid the temptation to blow dust off with your breath, which is very humid and thus can alter (produce a frosted surface, etc.) some water sensitive minerals. King (1982, 44) suggests "Short term soaking in ethyl alcohol [ethanol] followed by the use of the jet of an alcohol-filled wash bottle is often effective [for removing clay] but the alcohol on the specimen must not be allowed to evaporate to dryness until the process of clay removal has been completed." Although not specified, the alcohol should be 100% (200 proof) anhydrous ethanol, as even the small amount of water present in 95% (190 proof) ethanol may be deleterious. Rubbing alcohol of 99% concentration is likely to be an equivalent substitute. If these methods are inadequate, sonication in a nonaqueous medium such as xylene may be useful (Hardinger 2024b) but also see Section 3.32.

Some water sensitive minerals may have a **powdery white crust** which can occur when the mineral releases water into the air or absorbs water from the air (hygroscopic). A substance which absorbs enough water from the air to go into solution is termed deliquescent. These chemical changes are often accompanied by alteration of the mineral's crystal structure, resulting in anything from no visible physical changes to a decrease or loss in transparency or translucency to formation of a powdery coating (Figure 3-71). For example, a transparent crystal of borax - $Na_2(B_4O_5)(OH)_4 \cdot 8H_2O$ - rapidly loses water in dry air to form a white, powdery coating of tincalconite - $Na_2(B_4O_5)(OH)_4 \cdot 3H_2O$. Hanksite tends to decompose by absorption atmospheric moisture. In another example, torbernite - $Cu(UO_2)_2(PO_4)_2 \cdot 12H_2O$ loses four molecules of water to visually indistinguishable metatorbernite - $Cu(UO_2)_2(PO_4)_2 \cdot 8H_2O$. Gain or loss of water may occur quickly (within minutes) or more slowly (requiring years). Waller (1992) and King (1985) are good starting references for more information on water sensitivity and humidity effects. The use of oil and other coatings to preserve minerals sensitive to humidity or prone to dehydrate is discussed in Section 5.8B.

Figure 3-71. Left: This specimen began as a transparent borax crystal but rapidly lost water to gain a powdery white tincalconite coating. The coating could be removed by gentle brushing but unless properly stored and conserved it will eventually reform. Right: Despite storage in a 'sealed' glass jar for several years this hanskite specimen has absorbed atmospheric moisture forming a powdery white, friable coating. This specimen is too heavily damaged for meaningful cleaning or repair.

When stored with cotton or fiberfill for protection, some water sensitive minerals such as trona or impure halite tend to 'fuse' these fibers onto their surfaces. Remove these fibers with tweezers.

Changes caused by loss or gain of water may or may not be reversible, depending upon the mineral species involved. Cleaning or repair are usually not attempted because the change cannot be detected by the naked eye or because the damage is irreversible. These changes can only be prevented by proper storage and conservation.

3.28 Cleaning Micromounts

Cleaning micromounts generally involves the same mechanical and chemical methods as used for larger macro specimens, but extra care must be taken because micromounts are often more delicate than their larger cousins. Rare minerals for which the chemical compatibilities are less well documented (www.mincleandev.com) than for more common minerals are also more likely on micromounts than on macro specimens. Thus, when planning the cleaning of a micromount specimen, err on the side of caution and don't clean. As always, experiment on lower quality material first. In his must-read micromounting book Wight (1993, 70) provides advice specific to micromounts for removing loose debris. Kipfer (1972) and Fox (1942) provide additional perspectives. For cleaning and storing micromounts for photography see Beckham (2023).

3.29 Cleaning Radioactive Minerals

Cleaning and developing radioactive minerals can create radioactive dust and radioactive chemical waste. The hazard level of these materials will vary widely depending upon what methods are used and the intensity of the mineral's radioactivity. When selecting a cleaning or development method start with those methods least likely to create potentially hazardous products

such as dust. Great care should always be exercised when handling radioactive materials. Commonsense precautions include safety glasses, gloves and adequate ventilation (working outdoors where possible). Wash your hands after completing the work. When a sample's radioactivity is unknown test with a radiation counter or apply Guiding Principle 4: When unsure...don't. Review procedures for handling, storing and conserving radioactive minerals (Sections 5.7 and 5.8) before considering cleaning them.

Some radioactive minerals are powdery and friable. These cannot be improved by any cleaning method and therefore no cleaning should be attempted. Like more familiar mica minerals (muscovite, biotite, etc.) micaceous uranium minerals (torbernite, autunite, zeunerite, etc.) tend to flake readily and thus are easily damaged upon handling, including cleaning (Figure 3-72).

Figure 3-72. Powdery radioactive minerals such as this zippeite should be handled as little as possible, including cleaning.

3.30 Cleaning Absorbent and Porous Minerals

King (1982, 51) provides an excellent and readily accessible overview which needs no further elaboration.

3.31 Miscellaneous Problems and Methods

In this section are listed cleaning problems which do not fit well into any previous category. As such these problems are presented with little or no detail; please consult the given references.

Chamberlain (2008) describes cleaning specimens and other recovery efforts after a **barn fire**. Interesting reading even if your collection storage area never ignites.

Weathering effects such as running water or acid rain can cause changes to the surface and/or interior of a mineral sample, leaving it dull, pitted, cracked, etched and faded. Apart from surface coatings such as rust or biological residues these changes are chemical in nature and generally not reversible or repairable. Oil may be applied to restore luster but most collectors frown on this fakery.

Laser ablation has been explored for mineral cleaning, with some success (Allington-Jones 2017, 3). In this technique laser light energy is absorbed causing this material to heat, expand and flake away from the substrate or in some cases be evaporated as a plasma. Darker materials

absorb light energy most efficiently and hence are most easily removed. For example, soot and black weather crusts were removed from marble and gypsum. The technique has potential for broad application but needs further exploratory work. This could be a fruitful research area for the appropriately equipped and trained mineral collector!

3.32 Advanced Chemical Methods

This section covers methods that are likely beyond the capabilities of the typical amateur, because these methods use very hazardous chemicals, chemicals which are difficult to obtain or create wastes requiring specialized (and usually very expensive) disposal. ***An amateur who lacks adequate training and appropriate resources must not use these chemicals. If you believe your specimen would benefit from one of the methods chemicals discussed below seek out a mineral specimen preparation specialist to have the work done. No mineral specimen is worth the significant injury or death which may result from unexperienced or inappropriate use of these chemicals.*** However, persons adequately trained in handling such chemicals and who have the necessary protective equipment and training and access to proper hazardous waste disposal may find these methods useful. Duthaler and Weiß (2024) especially advocate the use of these highly dangerous procedures. Research the SDS for any reagents unfamiliar to you and avoid those having incomplete (or no) SDS information. *As always, safety is paramount.*

Sodium cyanide (NaCN) and **potassium cyanide** (KCN) are benign looking crystalline solids (Figure 3-73). They are frequently recommended reagents to clean copper (Duthaler and Weiß 2024, 104; King 1983, 63; Pearl 1982, 41 and Sinkankas 1970, 299), silver (Duthaler and Weiß 2024, 104; Gol 2004c; King 1983, 71; Pearl 1982, 44 and Sinkankas 1970, 299), copper with silver (Sinkankas 1970, 299; Duthaler and Weiß 2024, 105) and gold (Burns 1941, 158; Duthaler and Weiß 2024, 105; King 1983, 63; Pearl 1982, 23 and Sinkankas 1970, 299). Cyanide treatment is also mentioned to restore darkened proustite and pyrargyrite specimens to their original color and luster (Duthaler and Weiß 2024, 103; King 1983, 68 and Pearl 1982, 45). In a similar vein, Sinkankas (1970, 299) states that cyanide may be used to clean a wide range of silver minerals. Duthaler and Weiß (2024, 103) note that cyanide can be used to remove iridescent coatings from copper sulfides and to clean selenides. Both sodium cyanide and potassium cyanide are difficult for the amateur to obtain, exceptionally poisonous and require specialized hazardous waste disposal.

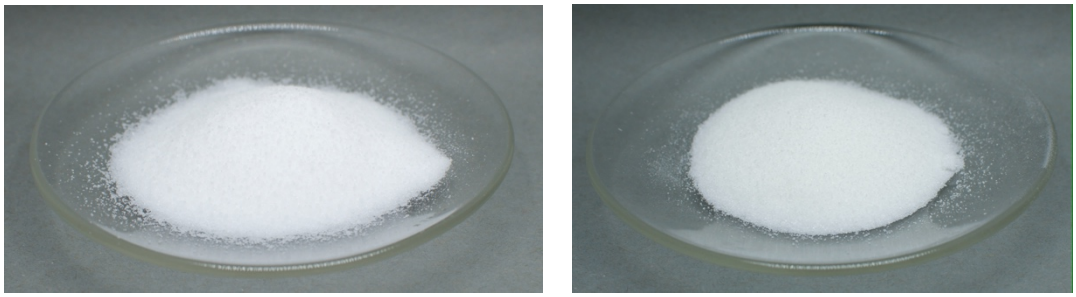


Figure 3-73. Sodium chloride (NaCl; table salt) and potassium cyanide (KCN). These white crystalline substances appear to be benign but one is a deadly poison, even in low doses.

Hydrofluoric acid (HF) is another widely recommended, but quite nasty chemical, having earned the nickname "Devil's piss." It is usually obtained as a 49% (or weaker) aqueous solution. It attacks most materials included glass, many metals and a wide range of plastics. Sinkankas (1972, 236) states: "No description of this acid could possibly overemphasize the dangers its offers to the human organism." Its most common use in mineral specimen cleaning and development is the dissolution of massive quartz enveloping gold; numerous references mention this application but without specific details. HF attacks many silicate minerals, often at different rates, so some selectivity may be achieved. For example, HF has been used to dissolve silica (usually chalcedony) and silicates from quartz (Pearl 1982, 36). Among pegmatite mineral preparators it has been used for removing "clay minerals, cookeite coatings, feldspar and other disfiguring minerals from tourmaline, spodumene, beryl, topaz crystals" (Sinkankas 1970, 296). HF can dissolve quartz while leaving underlying fluorite intact (Duthaler 2006, 118) and free hübnerite from matrix (Pearl 1982, 36). HF makes quick work of silica residues during preparation of benitoite specimens resulting in neptunites with a brilliant luster (John Veevaert, personal communication). It quickly cleans copper, gold and silver (Pearl 1982, 24 and Sinkankas 1970, 299). Burns (1941, 141) suggests HF for derusting but in this capacity there are numerous significantly safer and more selective derusting methods. Rohner (2000) and Sury (1991, 6) both mention use of "a mixture of H_2SO_4 and HF at elevated temperatures" without specifying concentration or temperature; this is *perhaps the single riskiest recommendation in all the mineral cleaning literature!*

Several commercially available cleaning products such as Whink contain dilute HF (Whink 2015) but are still quite dangerous and should be avoided by the amateur preparator. For many applications (including etching benitoite) NH_4HF_2 is a more readily available, more selective (albeit often slower) and safer replacement for HF. HF is difficult to obtain and requires a level of personal protection equipment beyond what is typical for the amateur. HF cannot be disposed down the sink; special neutralization is required.

'Accelerated NH_4HF_2' - a mixture of NH_4HF_2 with a strong mineral acid (usually HCl) produces a low concentration of HF *in situ*, which is claimed to remove quartz from fluorite (Pegler 2014). This nasty witch's brew is ***as least as dangerous as HF itself***.

Fluoroboric acid (HBF_4) has been recommended as an HF replacement, but it offers no significant advantages in cost, availability, safety, chemical selectivity or disposal (Duthaler and

Weiß 2024, 69). In many applications NH_4HF_2 is a more readily available, cheaper, more selective (albeit often slower) and safer replacement for HBF_4.

The mineral cleaning literature contains numerous recipes for cleaning copper with **chromic acid** (H_2CrO_4), generated *in situ* from sodium chromate (a bright yellow solid; $NaCrO_4$), sodium dichromate (an orange solid; $Na_2Cr_2O_7$; Figure 3-74) or the corresponding potassium salts. See for example Gol 2004c, King 1983, 63 and Sinkankas 1970, 299. Copper specimens are cleaned in seconds but develop an unnaturally bright luster which only after years reverts to a more natural patina. These solids and the waste they generate contain toxic and carcinogenic Cr^{6+} (hexavalent chromium). Nontrivial hazardous waste disposal procedures are required.

Figure 3-74. Sodium dichromate: This crystalline solid is pretty but toxic and carcinogenic!

In its dilute solutions **nitric acid** (HNO_3) is relatively innocuous. On the other hand, concentrated HNO_3 is a powerful oxidant which is difficult for the amateur to obtain and store. It is highly corrosive to many substances including metals and human flesh. Fuming HNO_3 - which emits noxious nitric oxide fumes - is especially nasty. Dilution of any strong mineral acid can be dangerous and so it is safer and cheaper to purchase a prediluted HNO_3 solution (perhaps 10% concentration) instead of the concentrated acid. Boiling in "strong HNO_3" to remove "organic incrustations" (Pearl 1982, 37) is not only dangerous but unnecessary as milder procedures are readily available. Adding HCl to HNO_3 forms **aqua regia**, an oxidizing mixture so powerful that in dissolves gold! This incredibly nasty material has been suggested (again unnecessarily so) for cleaning topaz (King 1983, 72) and a similar recipe for cleaning copper (Pearl 1982, 39).

Thiourea has been suggesting for cleaning copper and silver as well as minerals containing these metals (Pearl 1982, 42–44). This solid is a suspect carcinogen and requires specialized hazardous waste disposal so an amateur mineral preparator should first consider alternate methods for these needs.

Thioglycolates have been advocated for derusting (Duthaler and Weiß 2024, 75), particularly for treating fluorite (Duthaler 2006, 118) and for pyrite disease (Duthaler and Weiß 2024, 131). In addition, ethanolamine thioglycolate may alter color and/or luster of some minerals (King 1985, 104). Long chain **alkanethiols** have been reported (Duthaler and Weiß 2024, 133) to be useful to passivate copper, silver and gold against tarnishing. Thioglycolates and alkanethiols all possess a penetrating, persistent 'natural gas leak' stench requiring exceptional ventilation (a chemical fume hood) for proper use. The escape of even tiny quantities into the air might result in

a visit from the fire department! Accordingly, both substances require a professional laboratory setting for proper handling and specialized waste disposal. Alkanethiols are almost impossible for an amateur to obtain.

Some older references suggest the use of **chlorinated organic solvents** - methylene chloride (dichloromethane), chloroform, carbon tetrachloride and trichloroethylene - for various cleaning purposes. These solvents are difficult to obtain, difficult to dispose and are all suspect carcinogens, so procedures using them should be avoided. **Aromatic organic solvents** - most commonly benzene, toluene and xylene and mixtures containing them - gasoline, kerosine and diesel fuel - should also be avoided as these are highly flammable as well as generally neurotoxic and carcinogenic. Other less hazardous solvent choices are available such as hexane and petroleum ether, but even these have significant hazards.

Silver, dyscrasite and related minerals can be freed from enclosing elemental **arsenic** by complicated etching procedures, often cited without detail. However, such procedures produce arsenic-rich wastes requiring special hazardous waste disposal. Some recipes also run the risk of producing arsine (AsH_3), a *very toxic* gas.

Hydrogen sulfide (H_2S) has been recommended as a derusting agent (Pearl 1972, 32, Drosdoff and Truog 1935, 669 and King 1983, 58). Its use for derusting has largely been replaced by dithionite solutions. In the event dithionite fails, however, H_2S should not be used as this highly toxic gas has a very distinct and very penetrating rotten eggs odor.

CHAPTER 4: Advice for Cleaning and Developing Specific Minerals

This chapter provides advice for cleaning and developing specific mineral species likely to be encountered by the amateur such as calcite and fluorite. For a more comprehensive mineral list see www.mincleandev.com.

For general information and procedural details concerning specific mechanical or chemical methods mentioned in each entry below see the appropriate section(s) of Chapter 3, Cleaning and Development Methods. Mineral specimen preservation and conservation are covered in Chapter 5, Further Specimen and Collection Development. For examples of 'real world' applications see Chapter 6, Cleaning and Development Case Studies. As always, before starting any work with an unfamiliar mineral or unfamiliar cleaning/development method, refer to www.mincleandev.com for more information about a mineral's relevant physical properties (such as hardness, cleavage sonication or thermal shock damage risk) and chemical properties (such as tolerance to acids or dithionite). The absence of a reagent under a specific mineral's entry generally means that reagent/mineral combination has not been tested (most likely) or the reagent is ineffective for cleaning the mineral and causes no damage. Reagents which are difficult to obtain in North America (such as pure sodium dithionite) or are especially hazardous (such as cyanide or HF; Section 3.32) are also excluded. ***The absence in this chapter of information concerning the use of these dangerous chemicals should not be construed as encouragement for the amateur to work out procedures for their use by their own experiments.***

Expect results to vary somewhat between mineral associations, localities and even specimens from the same locality. Use the information below as a guideline, and (as always) apply Guiding Principle 5: Always experiment with lower quality material first before committing your best specimens to an unfamiliar procedure.

All procedures are run at room temperature unless otherwise noted. Concentrations of reagents and volumes of water are generally given under each reagent's Chapter 3 discussion. A process is generally allowed to continue until cleaning is complete or no more change appears to occur. There is no single time for every process; the appropriate exposure time varies widely with both the problem being addressed and the reagent used to address this problem.

Published recipes often lack details. For example, does "brief treatment" mean one second or one hour? Does "dilute solution" mean one gram per liter or ten? Does "warm" mean slightly above room temperature or 50ºC? Such details can be critical for successfully treating a specimen without damage. When such details are lacking, try minimal conditions first: shortest time, lowest concentration or lowest temperature.

Assume that if damage is caused by a certain procedure using a certain concentration at a certain temperature or certain time, the damage will be equal or more severe at a higher temperature, higher concentration or longer exposure. However, do not assume that damage will be less or nonexistent at a lower temperature, lower concentration or shorter exposure. Proceed with caution and when in doubt always test the procedure on lower quality material before committing your best specimens.

To reduce clutter, some sources of information which cover a broad range of minerals are not included in each individual mineral's entry. This should not be interpreted as a slight to any author or their work. Among these references - which should be in the library of every amateur who cleans and develops minerals - are: Duthaler and Weiß (2024), Gol (2004c), Howie (1992), Kandutsch (1983), King (1982, 1983 and 1986), Pearl (1982), Sinkankas (1970 and 1972) and Tschernich (1992). Additional useful information can be found in the Table of Inorganic Compounds in most any edition of the CRC Handbook of Chemistry and Physics, but this information should be used with caution as (for example) solubility may have been determined by boiling with concentrated acid for many hours (impractical conditions for mineral cleaning). Uncredited information is common knowledge (for example, nearly every collector knows that calcite is soluble in HCl, so this fact needs no literature citation), belongs to either one of these references or is an unpublished observation by this author. Information from sources containing unreproducible data have generally been omitted. Some recipes have been modified from their literature versions to improve effectiveness, clarity or safety.

Acanthite: Very soft and sectile; avoid steel tools and other harsh mechanical cleaning methods. Light-induced sooty coating removed in many cases with brief sonication. Slowly to rapidly attacked by acids, except for cold, concentrated citric acid. Treat as a Silver Mineral.

Actinolite: Easily cleaved; avoid vigorous scrubbing. Tolerates Iron OUT/EDTA. Insoluble in HCl. When iron-rich slightly attacked by warm H_2SO_4 or carbon dioxide-rich water (Weiner and Hochleitner 1998b). Minor mass loss but luster retained after seven days when treated with NH_4HF_2. Fuzzy (acicular) actinolite (byssolite) cleaned as described in Section 3.3. H_2O_2 (concentration not specified) has been used to remove rock dust from byssolite, noting "Many needles may be lost, but the specimen will be clean."

Adamite: Tolerates Iron OUT/EDTA and Jacquard Hydro but minimize exposure time as etching may occur in some cases. Turns gray in NH_4HF_2.

Adularia: Tolerates Iron OUT/EDTA as well as hot oxalic acid. Suffers some attack by hot alkali. Commonly coated with chlorite whose removal leaves a matte and pitted surface as the chlorite is partially intergrown into the adularia. See Orthoclase.

Aegirine: Often fragile; avoid vigorous mechanical cleaning. A soak in diluted water-based glue (polyvinyl acetate) followed by thorough drying before cleaning strengthens the specimen. Tolerates Iron OUT/EDTA as well as hot oxalic acid.

Agate: Agates are generally colorfast unless dyed. See Quartz.

Alabaster: Soft; easily damaged. Avoid acids, caustic alkalis, strong cleaning agents and heat. Soak in clean or water, *briefly* then rinse and dry. For obstinate stains - probably residues from handling - try acetone or alcohol (95–100% ethanol or 99% rubbing alcohol; Burns 1941, 160). See Gypsum.

Albite: Easily derusted without damage by any dithionite recipe or hot oxalic acid. Not attacked by acids. Dilute H_2SO_4 has been used to remove black organic stains. Stable to hot alkali.

Alexandrite: See Chrysoberyl.

Algodonite: Removal of tarnish is fruitless as it often quickly reappears. Usually not cleaned.

Allanite: May be radioactive. Crystals in matrix often heavily fractured; removal from matrix results in disintegration. This can, to some extent, be obviated by painting the allanite with dilute water-based glue solution (polyvinyl acetate) and allow to dry thoroughly before proceeding. Several coatings may be needed. Even if coated, removing too much matrix will cause disintegration. Stable to hot oxalic acid.

Allemontite: See Stibarsen.

Almandine-Pyrope: Adhering mica removed with steel tools or air abrasion. Air abrasion is great for removing schist matrix (Betts 2025a). Crystals embedded in graphic matrix from the Red Embers Mine prepared this way (Davis 2014). Tolerates Iron OUT/EDTA as well as hot oxalic acid. Use dilute HCl to remove enclosing calcite (Betts 2025a). In some cases, badly fractured crystals cemented together with carbonates or iron oxides, whose removal will cause the specimen to disintegrate.

Alum-(K): Soft; brittle. Water soluble. Use compressed gas to remove dust. Treat as a Water Sensitive Mineral.

Alunite: Soft, brittle. Use compressed gas to remove dust.

Alunogen: Soluble in water and acids. Clean only with compressed gas, acetone, 95–99% ethanol or 99% rubbing alcohol. Treat as a Water Sensitive Mineral.

Amazonite: Betts (2025a) reports air abrasion useful for cleaning amazonite. Derusted with any dithionite recipe or hot oxalic acid. Minor mass loss after seven days but luster retained with NH_4HF_2. See Microcline.

Amber: May become cloudy, sticky or even dissolve in organic solvents (alcohol, acetone, etc.). Use soap and warm water (Robbins and Irving 1981, 182); avoid alkalis and strong NH_3. Avoiding sonication sometimes recommended.

Amblygonite: Thermal shock sensitive; avoid warm or hot cleaning solutions.

Amethyst: Avoiding sonication sometimes recommended but nonetheless is suitable for many specimens. Sonicate at room temperature only; check for inclusions (bubbles, other minerals) or existing cracks which may make the specimen susceptible to thermal shock damage. See Quartz.

Amosite: See Grunerite.

Ampangabeite: See Samarskite.

Amphiboles: See also individual species. Stable to hot oxalic acid. Avoid NH_4HF_2. When etching from calcite or calcic marble use acetic acid at no greater than 3% (normal vinegar probably also acceptable). More vigorous effervescence produced by stronger acids and/or higher concentrations may widen existing cleavages.

Analcime: Brittle; easily dislodged from matrix. Sonicate only briefly. Avoid strong soap solutions. Tolerates Iron OUT. Potentially unstable to acetic acid and formic acid. Lustrous surfaces become dull within 24 hours with NH_4HF_2. Stable to hot alkali.

Anatase: Avoid steel tools whose careless use may result in broken terminations. Good chemical resistance. Tolerates Iron OUT/EDTA as well as hot oxalic acid. Inert to acids.

Andalusite: Adhering mica may be removed by careful use of steel tools or air abrasion. Chiastolite variety very soft and easily damaged by steel tools. Excellent overall chemical resistance.

Andersonite: Crystalline to powdery radioactive mineral. Water sensitive. Avoid cleaning, or if dusty, clean only with gentle compressed gas jet. Treat as a Carbonate and a Radioactive Mineral.

Andorite: Tolerates NH_4HF_2. Treat as a Silver Mineral and a Sulfide.

Andradite: Tolerates Iron OUT/EDTA and NH_4HF_2. Remove enclosing calcite with HCl.

Anglesite: Soft, brittle; easily scratched and cleaved. Etched by EDTA. Exposure to acids may result in dull crystal faces. Avoid NH_3. White coating formed within 24 hours with NH_4HF_2. Pale

to colorless anglesite turns yellow to red when treated with bleach; this was the source of fake red anglesites from Morocco circa 1983 (Weise 1984).

Anhydrite: Fragile; easily cleaved, thermal shock sensitive. Avoid chelators present in many detergents and soaps. When derusting avoid chelators; use Jacquard Hydro only.

Ankerite: Brittle; easily cleaved. Moderate resistance to acids (Hardinger 2024a). Can be cleaned with formic acid, acetic acid and citric acid. Acetic acid or acetic acid-based lime removers work well. Lime removers based on citric acid are milder; these dissolve carbonate deposits without attacking minerals like dolomite (no details; Rohner 2000 and Sury 1991). Tolerates acetic acid but attacked (bleached)/etched by HCl. Oiling restores lost luster. Less sensitive to acids than calcite or strontianite. Rinse thoroughly after any chemical treatment (especially acidic treatment) to avoid surface rusting. Brown surface coating removed after 24 hours with NH_4HF_2, probably by dissolution of a thin surface layer.

Annabergite: Tolerates sonication but avoid strong detergent or other chemicals.

Anorthite: For derusting tolerates brief exposure to oxalic acid but Iron OUT or other dithionite recipes a better choice.

Anthophyllite (group): Derust with Iron OUT or hot oxalic acid. Treat fibrous samples as Asbestiform Mineral.

Antigorite: Soft; prone to splintering. Avoid steel tools.

Antimony: Brittle; easily cleaved; avoid metal tools. Tolerates Iron OUT/EDTA. Etched by concentrated HCl. May be attacked by H_2O_2 or bleach.

Antlerite: Weak, soft; avoid steel tools. Tolerates brief sonication. Treat as a Copper Mineral.

Apatite: Generally stabile to detergents and soaps. Derust with Jacquard Hydro; avoid dithionite recipes with chelators (Iron OUT, Waller's solution or Bridge's solution). Soluble in mineral acids (especially carbonate-apatite) but acid susceptibility varies widely between species and specimens. Becomes dull and acquires an unattractive coating when treated with oxalic acid. Brief HCl exposure tolerated (often with some luster loss) as is a longer exposure to weak acetic acid. Limited tolerance to NH_4HF_2; best to avoid this acidic reagent. May be attacked by hot alkali. Fluorapatite or hydroxylapatite crystals in calcite or calcic marbles can be excavated with a vibratory impact tool but these crystals are often highly fractured and disintegrate when removed from matrix. Partial to complete excavation may be possible by first strengthening with multiple soak/dry cycles using a solution of cellulose acetate in acetone or dilute water-based glue (polyvinyl acetate)

followed by soaking in weak acetic acid or oxalic acid solution, then carefully remove matrix a little at a time with vibratory impact tool. Apply more coating as crystals are uncovered.

Apophyllite: Soft; easily cleaved. Avoid steel tools. Tolerates sonication. Avoid all acids; readily decomposed by 20% acetic acid. Becomes frosted and 'melted' after 24 hours with NH_4HF_2. See Zeolites.

Aquamarine: See Beryl.

Aragonite: Sefrou clusters may be held together with dried mud in which case cleaning causes disintegration. Immediately attacked with effervescence by NH_4HF_2. See Calcite and also Duthaler (2003).

Aravaipaite: Poorly soluble in water; tolerates brief water rinse followed by immediate and thorough drying. Treat as a Water Sensitive Mineral.

Arfvedsonite: Excellent chemical resistance

Argentite: Stable only above 177°C so specimens labeled as such are actually acanthite.

Arsenic: Rapidly tarnishes in air so little point in cleaning except to remove dust and related grime. Dissolved by concentrated HCl. May be attacked by H_2O_2 or bleach. For removing arsenic coatings see Section 3.32.

Arsenolite: Somewhat water soluble; avoid wet cleaning methods. Treat as a Water Sensitive Mineral.

Arsenopyrite: Water and/or atmospheric humidity may accelerate decomposition in samples where the process has already begun. If sample is partially decomposed the sonication bath may become acidic. Check bath pH and basify or replace if acid sensitive minerals (carbonates) are suspected to be present. Tolerates Iron OUT/EDTA; may be brightened. Arsenopyrite may be metastable; hence 'strong chemicals' are not recommended. When in doubt derust with Waller's solution or Bridge's solution. Gol (2004b) recommends tartaric acid for derusting. Stable to NH_4HF_2 with some samples brightened but resulting luster may become dull in hours to weeks (or longer) or may be permanent. (NH_4HF_2 probably removes a thin oxide layer which may develop again on standing.) NH_4HF_2 is acidic so associated minerals (carbonates, etc.) may be attacked. Mechanical polishing or air abrasion can restore the luster, but this treatment results in an unacceptable, unnatural appearance. Remove associated calcite with dilute HCl or cold concentrated citric acid but only treat as long as necessary then rinse thoroughly. Treat as a Sulfide.

Artinite: Acicular; fragile. Avoid water (matting); use alcohol or gentle compressed gas stream instead. Avoid acids. Treat like Okenite.

Asbestiform Minerals: Microscopic fibers toxic (asbestosis). Wear gloves, dust mask and work outside when handling; wash hands thoroughly afterwards. Minimize trimming. Avoid grinding, sawing and overall handling. Filiform; avoid water (matting); swish in alcohol or use gentle compressed gas stream instead.

Asbestos: See Asbestiform Minerals.

Atacamite: Soft, brittle. Avoid steel tools or other harsh methods. Sensitive to broad range of chemicals. Clean with chemical-free water only. Avoid detergent, soap, NH_3 and any alkaline cleaning solutions. Treat as a Copper Mineral.

Augelite: Retains luster and light green color when treated with Iron OUT/EDTA. Delustered by prolonged immersion in acids.

Augite: Derust with any dithionite recipe or oxalic acid.

Aurichalcite: Often fibrous; clean only by gentle water dip. Avoid soaps, detergents. Appears stable to Iron OUT/EDTA but use caution. Dark coatings may result from dithionite attack on other copper minerals present. Sensitive to all acids and NH_3. Treat as a Carbonate and a Copper Mineral.

Austinite: Soft, brittle; avoid steel tools and other harsh mechanical cleaning methods, also soaps and detergents. Attacked by acids. Barthite (copper bearing austinite) tolerates sonication.

Autunite: Radioactive; soft, micaceous, friable. Avoid cleaning except for simple removal of dust with gentle compressed gas jet. Avoid water as dehydrated samples (meta-autunite) may disintegrate on rehydration. Specimens from Hunan Provence, China have been stabilized with 5% Butvar B-76 or two treatments with 10% Paraloid B-72. Treat as a Micaceous Mineral and a Radioactive Mineral.

Axinite: Easily chipped with metal tools. Attached chlorite best left in place; see Adularia for further discussion. Resists acids and NH_4HF_2. Use HCl to remove enclosing calcite.

Axinite-(Fe): See Axinite.

Axinite-(Mn): See Axinite.

Azurite: Brittle; avoid steel tools; use bamboo sliver or toothpick to dislodge mud. Avoid scrubbing with toothpaste (some toothpaste formulations include an abrasive) or a paste made from $NaHCO_3$. Quickly attacked by hot water. Tolerates sonication but avoid adding soap or detergent. There is no derusting method known that does not cause some damage to azurite, including all dithionite recipes. Metallic copper (easily removed) is deposited within minutes when treated with Iron OUT or pure sodium dithionite. Quickly attacked to some extent by most acids including acetic acid, formic acid and HCl (Hardinger 2024a). Bruises may sometimes be 'healed' by localized application of a few drops of dilute HCl followed by immediate and thorough rinse. Avoid NH_3 and any alkaline cleaning solutions. Quickly attacked by NH_4HF_2. Treat as a Carbonate and a Copper Mineral.

Babingtonite: Tolerates sonication. Some samples are actually babingtonite over a heavily altered, rusty core; any cleaning attempts cause disintegration.

Barthite: See Austinite.

Baryte: Soft, brittle, easily cleaved; avoid steel tools especially to dislodge particles between blades. Susceptible to thermal shock damage. Stability to sonication varies between specimens, so when in doubt avoid sonication. Tolerates Iron OUT/EDTA, but some luster loss may be noted on high luster specimens due to barium chelation by EDTA. (Luster loss not noticeable when baryte is already dull; luster survives when EDTA omitted. Luster retained at pH 5.4 but some loss at pH 10.7). Tolerates Jacquard Hydro, hot oxalic acid or overnight immersion in 10% H_3PO_4. No luster change when treated with citric acid or citrate at any pH. Remove clay with HCl. NH_4HF_2 causes some loss of luster but no measurable loss in mass. Black stains were removed in 30 minutes from Hale Creek, California baryte with inesite using a 1:1 mixture of 12% H_2O_2 and 5% HCl. Baryte from Carterville, Georgia required overnight immersion in the same mixture for complete cleaning. Baryte having poor luster survives a 1:1 mixture of 12% H_2O_2 and 30% acetic acid without further luster loss. For removing bitumen from baryte see Section 3.22. Removing a baryte crust is only possible with mechanical methods (air abrasion); no chemical methods are known to selectively achieve this removal.

Barytocalcite: Brittle; easily cleaved. Avoid metal tools. Otherwise treat as Calcite.

Bastnäsite: May be attacked by dithionite formulations containing EDTA or citrate (chelators). Tolerates Jacquard Hydro. Less sensitive to acids than calcite or strontianite. Treat as a Carbonate.

Bavenite: Fragile; easily damaged by any tools, even brushes. Clean by brief, gentle dip in water. May disintegrate on sonication.

Bayldonite: Attacked by dithionite. Treat as a Copper Mineral.

Benitoite: With the closure of the California State Gem Mine and unprepared benitoite specimens already scare on the mineral market, it is unlikely that most collectors will have the pleasure of etching their own specimens. However, it is because of this paucity of unprepared material that existing specimens be correctly prepared. Thus, this section contains more detail than most other sections in this chapter. Every experienced benitoite preparator has their own technique, developed by trial-and-error and with much practice.

As always, practice on lower quality material to develop your technique. If you are in doubt about your ability to prepare a specimen, ask someone more experienced in this fine art to prepare the specimen for you. The richest, best prepared benitoite specimens can be worth tens of thousands of dollars and perhaps even more as the supply of unetched material continues to dwindle.

Benitoite is usually enclosed in a matrix of massive, white natrolite which is usually removed via an acid etch. Preparing specimens by etching in HCl or HNO_3 is nearly as old as the mine itself (Hawkins 1917). Production of an aesthetic specimen, however, requires more than just "throw it in a bucket of acid for awhile."

The minerals mentioned below have excellent resistance to the chemicals used, except for natrolite and copper sulfides, both of which are attacked by and/or dissolved in HCl.

The specimen is first examined for any visible crystals. Benitoite fluoresces brightly under shortwave ultraviolet light, aiding in its location. Etching is planned to reveal the benitoite and other minerals, but where possible, not all the natrolite should be removed, as a blanket of white natrolite provides a superb contrast to the blue benitoite and (especially) the lustrous black neptunite. Tiny brown joaquinite crystals and dark metallic copper sulfides often (but not always) lie close to the crossite matrix surface. Broken crystals might be sacrificed; being more common than benitoite, incomplete neptunite crystals are often lost at the expense of benitoite crystals, even if the latter are damaged. Thick natrolite veins lacking matrix may yield neptunite, joaquinite and (perhaps) copper sulfides but are usually barren of benitoite. John Veevaert (personal communication) recommended sawing through the middle of a thick vein to better expose any benitoite there and reduce etching time, but also laments the damage to benitoite crystals there.

Initial etching is done for a few hours to overnight in a bath of a 3:1 solution of concentrated HCl and water. (No other acid is as effective or as inexpensive for this purpose.) A sealed, plastic container is best. Acidic vapors will still leak out and can cause havoc with metal items nearby so perform the etching outdoors. It is critical to evaluate etching at least daily (if not more often) to assess progress. Remove the specimen from the acid bath (gloves!) and rinse thoroughly. A thick silica gel precipitate may be present at this point which is conveniently removed with a textile gun. Gel formation is acceptable at this point of more aggressive etching but if it continues to appear after a few more etching cycles the acid bath is too concentrated or the bath contains too much dissolved silica and should be replaced.

Allow the specimen to dry thoroughly (often overnight), cautiously treating again with the textile gun to remove any dried silica or fibrous crossite. This cleaning step is critical to making a meaningful evaluation before proceeding. Yellow stains (if any) can be ignored at this point.

Examine the specimen for the presence of benitoite and other minerals. If nothing is seen, return the specimen to the bath for another round of etching. If crystals are seen, one must decide if further etching should be selective (i.e. some of the natrolite should be preserved) or not. Natrolite to be preserved is 'painted' with hot paraffin wax. (Other coating materials are less useful for this purpose.) For this step, melt some clean paraffin wax in a heat-resistant metal or glass container on an electric hot plate. Do not use an open flame as paraffin wax liquid and vapors are flammable (candles are often made of paraffin wax). Once melted, apply the wax to the specimen with a small paint brush while thinking ahead as to how the specimen will look. (Purchase high quality brushes as the hot wax may quickly destroy cheaper ones.) Applying wax requires patience, practice and a bit of an artistic touch. Large areas can be protected by dipping.

Care should be taken to avoid if possible, heating any djurleite present as this species is unstable above 90ºC (Cook 1972). Paraffin wax's melting point is typically between 49–66ºC but once molten it can easily reach temperatures of 200ºC or more before igniting. In practice, however, this somewhat impractical precaution is usually ignored.

Return the waxed specimen to the acid bath. Additional etching must be slower for better control, so the acid bath should now be no more than 9:1 water to acid and the specimen is evaluated more frequently (perhaps every few hours). Remember that etching is irreversible, so patience is critical to producing an artistic specimen. The acid bath/rinse/dry/evaluate/wax cycle is repeated as needed until the etching is judged to be complete. This often takes a month or more of daily attention, but the result can be satisfying and quite valuable!

It is often necessary to remove the wax (as described below) for best evaluation before deciding if more etching is necessary.

It is important to note that the wax does not prevent etching of whatever it covers but instead only slows down the etching, especially along the edges of the wax which can be undermined by etching.

When evaluating for further etching avoid the temptation to etch too far as crystals may become dislodged from the matrix. If you are unsure as to whether continue etching at a certain spot, apply Guiding Principle 4: "When unsure...don't."

To remove the wax the specimen is covered with room temperature water in a crock pot. To avoid thermal shock damage do not place a room temperature specimen into hot water. Add a squirt of dishwashing soap to neutralize acid residues and to act as a surfactant to assist lifting wax from the specimen. A few grams of NaOH or KOH per liter are also effective for this purpose. The same crock pot used for hot oxalic acid treatment works well for this. The pot is slowly heated until the molten wax rises to the water's surface. Avoid boiling if copper sulfides are present (see cautionary statement above). When all the wax is judged to have been lifted allow the water and specimen to cool together to avoid thermal shock. Once at room temperature, rinse well (sonication is even better) and allow to dry thoroughly before evaluating. Examine the specimen under magnification for any residual wax blobs; these are removed by picking with a toothpick or bamboo sliver or repeating the hot water dewaxing procedure.

When etching is complete, and the wax removed a few additional steps are necessary to produce the best possible specimen. Rust which may occasionally be present is conveniently removed by treatment with Iron OUT/EDTA or other dithionite recipes. Benitoite crystals and (especially) neptunite crystals may appear dull at this point, due to a thin layer of residual silica. This is best removed by treating for three hours with a bath containing 2.5 g of NH_4HF_2 per liter of tap water (John Veevaert, personal communication). Magnetic stirring is useful but not necessary. This fluoride treatment will impart a stunning luster to most neptunite crystals. Follow fluoride treatment with sonication and thorough drying to complete the specimen preparation procedure.

Some benitoite crystal faces are naturally bright while others are naturally etched and frosted. This is not a result of acid or fluoride treatment to remove natrolite. No treatment yet discovered (except perhaps polishing by selective air abrasion) can restore this luster.

Any copper sulfide minerals present must be protected against attack by prolonged exposure to the acid bath. If a green rim appears (usually on drying) the crystal has suffered some attack. Soak the specimen overnight in a dilute $NaHCO_3$ solution to neutralize residual acid, dry thoroughly then entomb the sulfide crystal and some surrounding matrix in wax. As is common with other sulfide minerals discussed in this chapter terminal NH_4HF_2 treatment may brighten these copper sulfide minerals a bit.

Between treatment cycles pay careful attention for white blades or sprays of the rare (but quite valuable) mineral jonesite (useful photos at www.mindat.org). One experienced benitoite preparator reports having found just one such jonesite spray, only a few mm in size, in perhaps one hundred kilograms of untreated benitoite specimens.

Air abrasion has been used experimentally to prepare benitoite specimens (Rick Kennedy, personal communication). "Glass beads are great for shaping the matrix and removing gunk from previously etched matrix. The fronts of specimens are [trickier]. Bicarbonate should be used instead of glass and if the benitoite or neptunite crystals have fractures they will open up in a bad way." Compared to acid etching air abrasion can be controlled more precisely and the results seen more quickly. Air abrasion produces a smoother, less rippled surface than acid treatment. No waxing is required but the technique requires time to master and equipment which may be beyond the typical amateur. This promising technique merits further exploration. Vibratory impact tools also show some promise but require more experimentation before precious specimens are prepared this way.

Veevaert (2015; has excellent photos of the process) and Kennedy (2010) are excellent references which need no further elaboration. These should be studied by anyone planning to prepare their own benitoite specimens.

Beryl: All varieties susceptible to thermal shock damage. Macleod (1970) suggests avoiding sonication whereas other preparators use this tool frequently to clean beryls. (The true issue may be thermal shock resulting from immersing a room temperature beryl in a hot sonication bath.) Avoid sonication with oiled specimens and faceted emeralds as sonication may remove this oil.

Superior chemical resistance. Tolerates Iron OUT/EDTA and hot alkali. Generally stable to NH_4HF_2 but damage reported in some cases; appears to vary between pegmatites and preparators. Behling (2011) describes the preparation of emerald crystals in a massive quartz matrix; these were exposed, trimmed and otherwise developed by a diamond saw, vibratory impact and air abrasion tools. Chemical treatment was avoided due to concerns of insufficient selectivity in dissolving quartz versus emerald. An unspecified 'stabilizer' (resin?) was used to stabilize emeralds within the matrix during processing.

The pink of some morganites is due to red clay in deep recesses. Removing this clay decreases the specimen's color intensity and so the clay is normally left intact. However, with aquamarines this clay-induced color is a distraction and thus the clay should be removed.

Beryllonite: Attacked slightly by NH_4HF_2.

Berzelianite: Removing tarnish is pointless because it usually reappears upon exposure to air. Treat as a Copper Mineral.

Betafite group: A broad groups of minerals. Often radioactive and metamict, sometimes intergrown with other species (apatite) so physical and chemical behavior varies widely and can be unpredictable. If specimen must be cleaned, use only the briefest exposure to the mildest of methods. Attacked quickly by NH_4HF_2. Treat as a Radioactive Mineral.

Biotite: Easily cleaved. Dissolves slowly in concentrated HCl. Treat as a Micaceous Mineral.

Bismuth: Brittle; easily cleaved. Etched by concentrated HCl. May be attacked by H_2O_2 or bleach. Iridescent tarnish on a lab-grown crystal is immediately replaced with a bright luster by dipping in a solution of one part concentrated HCl and six parts water or by one hour in 30% acetic acid.

Blödite: Water and acid soluble. Clean only with gentle compressed gas jet or gentle organic solvent stream (acetone, 95% ethanol or 99% rubbing alcohol) from wash bottle along with gentle brushing to remove loose debris. Treat as a Water Sensitive Mineral.

Boleite: Often on or in a soft, crumbly matrix (clay and/or gypsum) from which it is easily dislodged. Specimens frequently repaired (or constructed) by gluing crystals back on matrix. Crumbly matrix often needs stabilization. Darkens on exposure to dithionite. Treat as a Copper Mineral.

Boracite: Very slightly soluble in water so quick water cleaning with immediate drying acceptable. Treat as a Water Sensitive Mineral.

Borax: Rinse only with the liquor in which the specimen was initially formed (King 1982, 46). May alter somewhat on contact with solutions of wrong mineral content. Brine (saturated aqueous NaCl), ethanol (95–100%) or rubbing alcohol (99%) less satisfactory. Unless coated against water loss dehydration to tincalconite with loss of luster and transparency is inevitable. Treat as a Water Sensitive Mineral.

Bornite: Behavior similar to Chalcopyrite. Sonication of decomposed samples may cause the bath to become acidic; check pH and make alkaline with a little $NaHCO_3$, NaOH or KOH (or replace the bath water) if acid sensitive minerals (carbonates) are suspected to be present. Humidity or immersion in water may accelerate decomposition in samples where the process has already begun. Some samples brightened by NH_4HF_2; resulting luster may become dull in hours (or longer) or may be permanent. Derust with any dithionite recipe. A 25% solution of oxalic acid can also be used (no more than eight hours) but samples cleaned this way are prone to rapidly tarnish again. Avoid removing associated azurite and malachite; these common oxidation products are often part of the normal mineral paragenesis. Treat as a Copper Mineral and a Sulfide.

Botallackite: Quickly attacked by dithionite. Treat as a Copper Mineral.

Boulangerite: Frequently found in filiform habit. Avoid cleaning if possible. If cleaning is necessary, rinse in ethanol or 99% rubbing alcohol. Avoid water; can become matted (King 1982, 44). Avoiding sonication sometimes recommended. Treat as a Sulfide.

Bournonite: Brittle; easily damaged by metal tools. Tolerates Iron OUT/EDTA. Treat as a Sulfide.

Braunite: Tolerates water but avoid acids.

Brazilianite: Brittle, easily cleaved; avoid metal tools. Tolerates Iron OUT/EDTA. Stable to NH_4HF_2.

Breithauptite: Associated calcite can be removed by dilute HCl or organic acids; attacked by other acids.

Brochantite: Frequently quite delicate. Poor tolerance for sonication. Acid sensitive; use distilled water only without any additives. Treat as a Copper Mineral.

Bromargyrite: Attacked by sodium thiosulfate byproduct of dithionite decomposition; avoid all dithionite derusting recipes. See Silver Minerals.

Brookite: Thin crystals very fragile. Not attacked by acids. Tolerates Iron OUT/EDTA and hot oxalic acid. Stable to NH_4HF_2.

Brucite: Soft; easily damaged by wooden tools. Tolerates sonication. Avoid chemical exposure.

Bustamite: When removing calcite luster is best preserved by using mechanical means (vibratory impact tool) instead of chemical means. If calcite must be removed chemically sample may be delustered by HCl; use organic acids instead. Acid treated crystals tend to turn dark in sunlight more rapidly than untreated crystals.

Byssolite: See Actinolite.

Cacoxinite: Tufts very delicate; avoid any cleaning if possible. Dust and other loose debris best removed by gentle swish in alcohol. Avoid HCl.

Calcite: This section is about cleaning calcite. For removing crusts and coatings of calcite and other carbonates see Section 3.18. Soft; easily scratched and cleaved. Thermal shock damage possible. Damage most notable on transparent and/or lustrous specimens. Use care with forceful water jet tools especially the textile gun. Avoid vigorous brushing. Avoid metal brushes; use only soft (nylon) brushes. Many samples can be cleaned by sonication but check for pre-existing cracks. In the sonication bath avoid detergents and soaps containing chelators (EDTA, citrates, etc.) as these may dissolve Ca^{2+} and cause etching (Duthaler 2003, 104).

Water solubility (about 15–20 mg per liter) is low but enough that lustrous crystal faces will be frosted on long (overnight) exposure due to dissolved CO_2, even in a freshly opened bottle of distilled water. (Recall the carbonate-bicarbonate-carbonic acid equilibrium which dissolves limestone and deposits stalactites and stalagmites.) Although many literature sources recommend (unnecessarily) using distilled water for cleaning minerals calcite is best cleaned in hard water because this water has a high dissolved calcium content which slows etching. Etching by dissolved CO_2 is also prevented when the solution is strongly alkaline (pH 12).

May be etched/delustered by dithionite derusting agents due to dissolved CO_2 and/or Ca^{2+} chelators. Iron OUT delusters calcite due to EDTA. Buffered derusting recipes (Waller's or Bridge's solutions) etch due to citrate. Use only Jacquard Hydro to derust calcite and remove the specimen as soon as rust has disappeared (often an hour or less). Some calcites may have a pale yellow or pale brown color due to a thin rust coating; remove this with Jacquard Hydro.

Attacked by all acids to some extent (Hardinger 2024a). Minor surface nicks and scratches can be smoothed (but not hidden or repaired) by a brief dip in dilute HCl followed by immediate and thorough rinsing in water or (better) a dilute $NaHCO_3$ solution. Avoid this treatment with lustrous or high-quality specimens as a dull patch will result. Overdoing this will result in unnaturally rounded edges and a frosted, delustered surface. To apply acid to a localized area, use a small paint brush or eyedropper. This 'repair' method works to some extent on other carbonates as well. Immediately and vigorously attacked by NH_4HF_2. Etched by $HONH_2$ (hydrochloride or sulfate) but not when alkaline (pH 13). Gol (2004c) and King (1983, 62) note (but without details) that bleach causes "slight discoloration."

Some authors suggest calcite can be cleaned with formic acid, acetic acid or citric acid. Acetic acid or acetic acid-based lime removers work well for this purpose. Lime removers based on citric acid are milder; these dissolve carbonate deposits without attacking minerals like dolomite (no details; Rohner 2000 and Sury 1991). CLR is commonly recommended to either derust or dissolve calcite, but which of the numerous CLR branded products should be used is not specified.

Some massive calcite and marble specimens can benefit from brief acid etching to remove tenacious surface dirt. Check first that other minerals present will tolerate this treatment.

Caledonite: Delicate; avoid tools. Tolerates sonication but use distilled water only, avoiding soaps and detergents. Treat as a Copper Mineral and a Carbonate.

Carbonates: For relative sensitivity to acids see Hardinger (2024a). Some susceptible to etch at acidic pH due to dissolved CO_2, even in distilled water from a freshly opened bottle. When in doubt treat as acid sensitive. Refer to individual mineral listings. More reactive carbonates quickly attacked by NH_4HF_2 (weakly acidic); less reactive carbonates may tolerate a short exposure. Minor nicks and scratches may be 'repaired' with acid; see Calcite.

Carnallite: Brittle and soft; avoid metal tools. Water soluble; clean with acetone or alcohol. Treat as a Water Sensitive Mineral.

Carnotite: Powdery; avoid cleaning. If cleaning is necessary, remove dust or loose dirt with gentle compressed gas stream or (if this is inadequate) a quick dip in acetone or alcohol. Treat as a Radioactive Mineral and a Water Sensitive Mineral.

Carrollite: Often partially to fully encased in a calcite/dolomite matrix in which the crystals are often cracked; removing too much matrix can cause the specimen to disintegrate. Remove matrix with vibratory impact tool or soaking overnight in a 1:1 solution of HCl and water. Derust with tartaric acid (Gol 2004b). Stable to NH_4HF_2 (but carbonate matrix is attacked). Some specimens tarnish after cleaning. Treat as a Copper Mineral and a Sulfide.

Cassiterite: Scum on some samples removable with razor blade. Excellent chemical resistance. Stable to hot alkali and NH_4HF_2.

Cavansite: Pentagonite (elongated crystals) more fragile than cavansite.

Celadonite: Tolerates Iron OUT.

Celestine (Celestite): Brittle; cleavable; soft. Easily breaks from matrix. Use wooden toothpick or bamboo sliver to carefully clean between crystals. Sonicate with care. Stable to oxalic acid but watch for commonly associated minerals (calcite, gypsum) which may be attacked.

Cerargyrite: See Chlorargyrite.

Cerussite: Soft, brittle. Easily cleaved; avoid force. Easily susceptible to thermal shock damage. Remove loose dirt, dust with gentle stream of alcohol or acetone from wash bottle. Avoid strong detergents. Attacked by most acids (Hardinger 2024a) but in some cases (30% acetic acid) luster may be retained. Suffers some degree of etching with both Iron OUT and Jacquard Hydro, also with citrate alone (a chelator in Iron OUT) or EDTA alone. Attacked by NH_4HF_2. Black stains - often attributed to Mn hydroxides/oxides - may in fact be Pb minerals and therefore not removed by H_2O_2 or $HONH_2$ methods. May become colored when treated with bleach. Treat as a Carbonate.

Chabazite: Brittle; fractured crystals tend to disintegrate on sonication. May be stable to heating with mildly alkaline laboratory cleaner or household dish soap, but generally avoid strong detergents, soap and NH_3. Acids should be avoided but can be withstood for a short time if needed. Becomes snow white and matte when treated with oxalic acid. Attacked by 20% formic acid and hot alkali. See Zeolites.

Chalcanthite: Fragile, brittle and very soft. Avoid heating; dehydrates at 63ºC. Easily water soluble. Best cleaned with dry methods; remove dust or other loose debris with gas stream. Avoid wet methods if possible but, if necessary, use gentle stream of ethanol (95%), rubbing alcohol (99%) or (less satisfactory) brine (saturated NaCl solution) from wash bottle. Treat as a Copper Mineral and a Water Sensitive Mineral.

Chalcedony: Some samples sensitive to thermal shock damage. Broad tolerance to sonication. Sonicate oiled samples in warm to hot, soapy water. Derust with any dithionite recipe or with hot oxalic acid. Tolerates hot alkali/TKPP. Attacked by NH_4HF_2 faster than opal-AN or quartz. Encrustations on pink chalcedony from New Mexico removed by air abrasion (Betts 2025a). Chalcedony limb casts cleaned by the sequence textile gun, hot oxalic acid, textile gun, NH_4HF_2, textile gun, hot alkali (if needed) then finally textile gun. Black coatings removed by bleach, oxalic acid or Mn coating procedures. Calcite or gypsum coatings removed with dilute HCl.

Chalcocite: Some samples stable to dithionite whereas others rapidly turn metallic red (Cu^0?). Derust with tartaric acid (Gol 2004b). Ubiquitous sooty coating can be partly to completely removed with soapy water and brushing or sonication but tends regain the sooty appearance after cleaning, so cleaning is best avoided (Homenuke 2018). Treat as a Copper Mineral and a Sulfide.

Chalcophyllite: Fragile; can be damaged by prolonged soak in cleaning baths. Avoid brushes and tools. Treat as a Copper Mineral.

Chalcopyrite: Behavior similar to Bornite. Fragile, brittle and soft; avoid metal tools. If decomposed, sonication may cause acidic bath; check pH and basify or replace if acid sensitive

minerals (carbonates) are suspected to be present. Water or humidity may accelerate decomposition in samples where the process has already begun. Even slightly decomposed samples may have rough crystal faces whose luster can only be restored to an unnatural state by mechanical polishing or air abrasion. Attacked by most acids but can be etched from enclosing calcite with vibratory impact tools, dilute HCl or cold saturated citric acid. Minimize acid exposure; remove from acid bath as soon as etching is complete (prolonged exposure to even dilute HCl can leave green copper mineral stains and/or iridescent coating). Follow acid bath with soak in one part NH_3 in twenty parts water then fresh water, drying between water washes. If the NH_3 odor persists, soak in clean water bath. Calcite-encased crystals may be fractured and will thus disintegrate if too much matrix is removed. Acid treatment has been used to deliberately impart iridescent coating to some specimens. Tolerates Iron OUT/EDTA, which frequently increases luster temporarily to permanently. Can also be derusted with tartaric acid (Gol 2004b). Films of black oxidation products removed with 6% oxalic acid (approximately 8 hours). Some samples brightened by NH_4HF_2; resulting luster may become dull in hours (or longer) or may be permanent. Even slightly decomposed samples may have rough crystal faces whose luster only be restored to an unnatural state by mechanical polishing or air abrasion. Treat as a Copper Mineral and a Sulfide.

Chalcotrichite: Fragile; avoid gas or water jet tools. Contact with water can cause matting. Better to swish in alcohol or acetone and air dry. See Cuprite.

Chiastolite: See Andalusite.

Childrenite: See Childrenite-Eosphorite.

Childrenite-Eosphorite: Cannot distinguish visually between the two end members and may often be intergrown. Brittle and soft; avoid metal tools. Fractured crystals likely to disintegrate on sonication. Stable to NH_4HF_2.

Chiolite: Soft, micaceous; avoid tools. Likely has enough water solubility to be problematic. Clean only with compressed gas, alcohol or acetone. Treat as a Micaceous Mineral.

Chlorargyrite: Soft; easily scratched even wooden tools. Attacked by thiosulfate produced during decomposition of aqueous dithionite; avoid dithionite derusting recipes. See Silver Minerals.

Chlorite group: May be intergrown with matrix mineral (often quartz or adularia); removal leaves a rough surface. Generally removed by careful work with steel tool. Interesting to polish one or more but not crystal all faces, as this retains some of the natural paragenesis but allows one to see what is inside the crystal. Some samples may tolerate oxalic acid at room temperature for a few days, but many examples are attacked by hot oxalic acid solutions. In some samples the green color (due to Fe^{2+}) is lost, and the sample disintegrates because the Fe^{2+} is essential to keeping the

mineral's layers together. Oiling may restore the original color. Acids may bleach this mineral. Dissolves slowly in concentrated HCl. Stable to hot alkali.

Chondrodite: Matrix crystals usually heavily pitted and fractured; liable to disintegrate if too much matrix is removed. Associated asbestiform/filiform minerals removed carefully with steel tools and stiff brush.

Chromian Clinochlore: Treat as Chlorite.

Chrysoberyl: Adhering biotite can be removed by careful work with steel tools but air abrasion likely a better choice. Avoid sonication (Macleod 1970).

Chrysocolla: Often friable and earthy. Sometimes porous so any wet treatment should be followed by a prolonged soak(s) in clean water. Chemical composition not fixed; varies between localities and even within the same locality so samples may respond somewhat differently to cleaning methods. Avoid detergents, soaps and NH_3. Usually attacked by dithionite. Treat as a Copper Mineral.

Chrysoprase: Treat as Chalcedony.

Chrysotile: When fibrous treat as Asbestiform Mineral.

Cinnabar: Soft, brittle; avoid metal tools. Broad tolerance to sonication. Stable to Iron OUT with or without EDTA. Avoid strong acid treatment as this may destroy rare associated species. Crystals in calcite/dolomite matrix may be fractured; avoid removing too much matrix as crystals likely to disintegrate. Use only cold, concentrated citric acid (and much patience) if enclosing calcite/dolomite matrix is to be etched. Dark surface coatings may on occasion be partially removed by gentle work with a cotton swab. Fake samples, often having numerous 'drill bit' twinned crystals glued to an appropriate matrix were once abundant; look for fluorescing glue under ultraviolet light or loosening of crystals/whitening of glue during a soak in water or acetone.

Clay Minerals: Avoid water; causes many clay or clay-like minerals to disintegrate. Methods for removing clay are given in Section 3.20.

Cleavelandite: Individual crystals fragile; avoid temptation to poke into crevices between crystal plates. Use care with water get tools. Tolerates Iron OUT/EDTA. Stable to NH_4HF_2. See Albite.

Clinochlore: Behaves same as Chlorite. Micaceous; prone to swelling and exfoliation with prolonged water contact. Dissolves slowly in concentrated HCl at room temperature but quickly when heated. Treat as a Micaceous Mineral.

Clinoclase: Some samples survive dithionite without loss of color or luster, but some crystals may be lost due to clay matrix disintegration; other samples dulled. Soluble in acids and NH_3 (Weiner and Hochleitner 1998c). Treat as a Copper Mineral.

Clinozoisite: Crystals commonly fractured and cleaved; removing too much matrix or sonication may cause disintegration. Stable to hot oxalic acid.

Clintonite: Etch from enclosing calcite with dilute HCl. See Micaceous Minerals.

Cobaltite: Avoid acids as these may destroy associated species (erythrite, etc.). If etching is desired remove enclosing calcite with vibratory impact tools or (less preferable) HCl. Stabilization by soaking/drying several times in dilute water-based glue (polyvinyl acetate) may stabilize prior to mechanical matrix removal. Matrix crystals often fractured; removing too much matrix may cause disintegration. Treat as a Sulfide.

Cobaltoan Calcite: Treat as Calcite.

Colemanite: Brittle; avoid steel tools. Bladed, spearpoint crystals very fragile; use only wooden toothpick or bamboo sliver and gentle touch to remove clay. Small but sufficient water solubility so that prolonged soak may dull crystal faces. Avoids soaps and detergents. Some associated species (tincalconite, kernite etc.) may absorb or lose water causing specimen to disintegrate over time; if present these species are perhaps best removed by water soak to enhance specimen's storage lifetime. Rapidly becomes hazy with NH_4HF_2.

Columbite: See Columbite-Tantalite.

Columbite-Tantalite: Crystals in matrix commonly fractured; use care when removing supporting matrix, especially crystals which are thin or metamict (look for radiation halo). Highly lustrous or freestanding cavity crystals more likely to be free of cracks. Tolerates Iron OUT/EDTA. Stable to most acids.

Conichalcite: Delicate and brittle. Tolerates sonication but avoid soap and detergent. Damaged by most cleaning chemicals. Treat as a Copper Mineral.

Cookeite: Usually found coating pegmatite gem crystals and therefore rarely preserved. Remove with steel tools or NH_4HF_2/hot alkali/textile gun cycle as many pegmatite gem minerals are highly tolerant of this protocol. Like chlorite, however, underlying crystal faces may be dull and pitted. Tolerates Iron OUT/EDTA and hot oxalic acid.

Copper: Treat copper-silver intergrowths as both copper and silver (see also Silver-Copper Intergrowths below). Flexible but tends to break easily where connection points are small. Remove dust and other loose debris with sonication. There are more chemical methods for cleaning copper than any other mineral species; both the most effective and most amusing are summarized here. No single procedure is best for all specimens.

- The Al/$NaHCO_3$/NaCl procedure for cleaning silver also works on copper. The result is an improvement but not obnoxiously bright.

- Soak the specimen in a solution of 93 g EDTA (assumed to be the disodium dihydrate) in one liter water until clean. Warm if needed. In the Byron Method ("arguably one of the best methods") the sample is immersed in a solution containing approximately 90 g EDTA (probably the tetraacid) dissolved in 250 mL water. Some samples brightened by Iron OUT/EDTA; this effect may be due to Cu^{2+} chelation by EDTA (the solution turns blue) and not by any cleaning effect by dithionite.

- Several sources (Sinkankas 1970, 299; King 1983, 63; Burns 1941, 159; Robbins and Irving 1981, 183; Lieber 1978; Pearl 1972, 39–40; Duthaler 2003 and Gol 2004c) recommend removing green patina and/or black oxides by treating with a solution made from 15 parts by weight Rochelle salt and 5 parts NaOH in 100 mL tap or distilled water. Exposure time recommendations vary from 'dipping' to several hours. Agitation (magnetic stirring), thorough brushing and sonication may assist this cleaning. This recipe is said to be selective for coating, leaving the copper unharmed. The solution turns blue as copper impurities dissolve. When cleaning is satisfactory rinse thoroughly and dry. An alternate recipe: In 500 mL distilled water dissolve 25 g KOH then add 75 g tartaric acid. (This does not immediately form a homogeneous solution.) Immerse specimen overnight. Solutions turns blue. Little to no change to copper may be evident at this point, but sonication now results in a cleaner but not unnaturally bright specimen (based on Sinkankas 1972).

- Hot oxalic acid removes oxides, carbonates, etc. and produces an unnaturally bright luster which fades a bit in subsequent days. Derusts matrix. No loss in copper mass.

- "The classical method involves treating the specimen with a strong acid, whose action is neutralized using $NaHCO_3$. Other bases should be avoided, especially NH_3, even in dilute solution. HCl or H_2SO_4 can be used successfully. However, HNO_3 alone is not recommended due to its excessively aggressive nature." No further details given other than these methods tend to slightly attack native copper (Gol 2004c). More detailed recipe: To four parts water add two-thirds part H_3PO_4, one part H_2SO_4 and one part HNO_3 (or use more H_3PO_4 and less water; Pearl 1972, 41). Soak specimen in either solution until clean. The highly acidic nature of this solution is incompatible with many other minerals.

Alternate recipe: Soak specimen in solution made by adding four parts H_2SO_4, two parts HNO_3 and one part HCl (probably concentrated acids in each case) to four parts water. A brighter effect is achieved by increasing the amount of HCl and decreasing the amount of H_2SO_4 a little bit (Pearl 1972, 39).

- Green patina removed by immersing in solution composed of one part glacial acetic acid in ten parts water. (Alternates: Dilute 20% acetic acid with equal volume water, or one volume 30% acetic acid with two volumes water.) Rinse thoroughly while brushing away any adhering particles. Sonication may also be used instead of brushing (Burns 1941, 159 and Robbins and Irving 1981, 183). Pearl (1972, 39) gives a similar procedure.

- Remove green coating and restore original color by brief immersion in dilute citric acid or very dilute HCl; attacks coating but not the copper underneath (Lieber 1978).

- When the surface is marred by natural etching, start with mechanical cleaning. Use a detergent (such as Neodisher LM3) and soft brush or sonication. If this is insufficient, try a commercial copper cleaner or any of these water solutions: 10% acetic acid, 5–10% citric acid or Rochelle salt.

- Copper specimens may be improved somewhat without becoming unnaturally bright by overnight treatment in a solution containing about 1 g ammonium acetate per 100 mL of water, followed by brief sonication.

- NH_4HF_2 cleans native copper in 30 minutes resulting in an unnaturally bright patina and no mass loss but also making crystalline pattern more obvious (based on Sinkankas 1970, 299). Overnight exposure gives the same result but with minor mass loss.

- Sheet copper from Michigan is immersed in Heinz ketchup (!) for 10–30 minutes. Most specimens are brightened to some extent, some becoming unnaturally bright (based on Kim 2021). Unlike a water solution usually used for mineral cleaning, ketchup's viscosity prevents it from flowing freely around the specimen, resulting in uneven cleaning. For complete cleaning deposit a layer of ketchup into the bottom of the cleaning vessel before adding the specimen and covering with more ketchup. White vinegar also works on some specimens. A little added NaCl helps in obstinate cases. Many associated minerals will be unharmed, except carbonates such as calcite, azurite or malachite.

- Gol (2004c) describes some questionable treatments, presented without details: whey (liquid phase of coagulated milk), olive oil or $FeCl_3$ (used in etching of copper printing circuit boards).

- Numerous commercially available copper and silver cleaner products have been recommended, but most of these contain thiourea - a suspect carcinogen (Section 3.32; check the product's SDS) and therefore should be avoided. Wright's Copper Cream lacks thiourea but contains quartz as an abrasive and thus should also be avoided. Coca-Cola (or probably any soft drink containing H_3PO_4) is also frequently recommended as safe and effective (Eastman 2006).

Numerous collectors state that it is acceptable to remove dirt and dust but not the patina. Dark/black tarnish is tenorite or melaconite; reddish is cuprite; greenish is a mixture brochantite, malachite, atacamite or other copper carbonates/hydroxides. These coatings are mineralogically important and should not be disturbed. Removal tends to produce unnaturally bright specimens and therefore should be done sparingly if at all. Some procedures using strong acids which will also etch the underlying copper. Copper cleaned by these methods tends to tarnish quickly. Avoid cleaning native copper to the point where the natural patina is lost. Common advice is "never clean native copper." Trilon-B attacks copper salts including cuprite but not native copper.

In one case a native copper specimen was immersed in HCl (no details given; some specimens may be etched by concentrated HCl) leaving a "penny-bright" specimen; immersion in 12% H_2O_2 for an hour resulted in a "pleasant patina" (based on Luppescu 2013). Scott (1926, 64–68) gives a recipe for repatination which may be acceptable for some museum objects but generally not for mineral specimens.

For removing calcite from copper, a solution consisting of one volume concentrated H_2SO_4 in four volumes water is used. This removes calcite without seriously damaging the copper. Sulfamic acid can also be used and is preferred to other acids for this purpose; it is assumed to be less likely to damage copper than HCl and faster than acetic acid (Rosemeyer 2023).

Additional reading: Whiteman (1983).

Copper Minerals: Often darkened and/or reduced with dithionite forming a red to black coating or precipitate. If individual crystals are sufficiently sturdy, air abrasion with a soft medium may be the only effective derusting method (but this does not appear to have been explored yet). Avoid detergents containing succinic acid or succinate (Rastsvetaeva *et al.* 1996). Avoid NH_3 and acetic acid.

Copper-Silver Intergrowths: Treat as both Copper and Silver.

Cordierite: Only very slightly attacked by concentrated acids; for cleaning ordinary acids safe to use. Weathered, pseudomorphed or otherwise altered samples with unknown composition should not be treated with chemicals.

Cornetite: Sonication may remove cornetite from matrix. Treat as a Copper Mineral.

Corundum: Very hard; tough. Develop with steel tools, vibratory impact tools or air abrasion. Crystals in matrix may be cracked and therefore liable to come apart if too much supporting matrix is removed. Resistant to most mineral cleaning chemicals. Tolerates Iron OUT/EDTA, hot oxalic acid, hot alkali and NH_4HF_2.

Covellite: Easily cleaved even by rough brushing. Tolerates sonication with added detergent. Sonication of decomposed sample may cause acidic bath; check pH and basify or replace if acid sensitive minerals (carbonates) are suspected to be present. Brightened by Iron OUT/EDTA; still bright after ten days. Gol (2004b) suggests derusting with tartaric acid. Treat as a Copper Mineral and a Sulfide.

Crandallite: Avoid oxalic acid.

Creedite: Brittle; easily cleaved; avoid steel tools. Mexican material commonly polluted with dried mud, which is removed by soaking in water to soften then gentle work with a wooden toothpick or bamboo sliver. Avoid strong detergents.

Cristobalite: Tolerates sonication.

Crocidolite: See Riebeckite.

Crocoite: Brittle; weak. Avoid cleaning specimens having mostly fine needles on a friable matrix as these often disintegrate upon chemical treatment (may need stabilization with polyvinyl acetate glue, Paraloid B-72 or Duco cement; Section 5.8E). Easily damaged by stiff brushes. Tolerates sonication. Avoid water jet tools and air abrasion. Stable to dithionite and bleach. Black Mn-rich coatings removed in a few hours with $Na_2S_2O_5$ or a 1:1 mixture of 12% H_2O_2 and 30% acetic acid. Coating turns gray then can be removed by mechanical means. Repeat bath as needed. White/whitish material is gibbsite; to remove soak one day to weeks in concentrated H_3PO_4. This dissolves the gibbsite, but gibbsite could be holding the specimen together so use judgement as to how long for treatment. When satisfied soak in clean water a day or two to remove residual H_3PO_4. To test for residual acid, add a little $NaHCO_3$ to bath. Effervescence indicates that acid remains and a soak in fresh water is needed. (Altering the sequence of these steps may result in formation of white crusts, which are removed by soaking in concentrated H_3PO_4.) Rare mineral associations - yellow ('chromian') cerussite, dundasite - may be destroyed by even weak acids such as acetic acid. Avoid chemical treatment (if possible) when these minerals are present. "I must admit that I have never actually tried to clean any dundasite or cerussite specimens from the Adelaide Mine with any acid as generally they do not need it. If these two minerals are present, then they are normally the last thing to have happened and as a result are uncoated/unscathed otherwise they tend to disappear. I do not think they would be destroyed completely by acetic acid nor most other acids but would definitely not recommend doing so especially not for any length of time" (Adam

Wright, personal communication). Light-induced surface darkening and overall opacity is irreversible and cannot be removed by chemical treatment. Gol (2004c) states that H_3PO_4 can 'rejuvenate' crocoites that have darkened, but it may also weaken the crystals (probably by dissolving gibbsite matrix). No details given.

Cryolite: Only very slightly soluble in water, so quick sonication tolerated. Avoid wet cleaning, if possible, otherwise minimize water exposure time. Treat as a Water Sensitive Mineral.

Cubanite: Treat like Chalcopyrite.

Cumengeite: Avoid acids, NH_3 and strong detergents. Clean with water only or use dry methods. Treat as a Copper Mineral.

Cuprite: Tolerates sonication. Acicular to fibrous chalcotrichite variety may become matted in water and can be so brittle than any cleaning should be avoided. Avoid NH_3 and strong detergents. Brief exposure to dithionite tolerated by some samples but not all; test first on low quality sample from the same locality (and same pocket if possible). May turn dark (tennorite?) or be reduced to metallic copper. Dark coatings may result from attack on other copper minerals present. Soluble in acids. May be improved somewhat without becoming unnaturally bright by overnight treatment in a solution containing about 1 g ammonium acetate per 100 mL of water followed by brief sonication. Nunes (2015) reports without details that ammonium acetate and tetrasodium EDTA (Trilon B) can be used to clean cuprite. In one case, however, the cuprite became more translucent while the surface remained dark and became slightly frosted. The ammonium acetate/EDTA recipe also attacks other copper minerals (malachite, chrysocolla). Treat as a Copper Mineral.

Cuprosklodowskite: Treat as Sklodowskite and a Copper Mineral.

Cyanotrichite: Filiform; fragile. Best to avoid any chemical or other wet treatment but some specimens tolerate water and sonication. Dust and loose debris can be removed by swishing upside down in alcohol or acetone then allowing to air dry. Probably intolerant to dithionite. Avoid acids, detergent, soap, NH_3 and any alkaline cleaning solutions. Treat as a Copper Mineral.

Cylindrite: Stable to NH_4HF_2 in which some samples are brightened.

Cyrtolite: See Zircon.

Danburite: Tolerates sonication, Iron OUT/EDTA and NH_4HF_2. Very slightly attacked by HCl but can be used to remove enclosing calcite. Try milder acids first. Crystal may be naturally fractured and cemented together by calcite; removal can cause specimen disintegration. Coatings other than calcite (quartz, chalcedony, apophyllite) common; their removal requires other

chemicals or mechanical methods (vibratory impact tools or air abrasion). Chalcopyrite may also be associated which further limits possible chemical treatments.

Datolite: Fragile and brittle. Attacked slowly by concentrated HCl but this acid still acceptable for calcite removal with brief exposure. Soluble in hot concentrated citric acid.

Davidite: Good chemical stability, but earthy coatings general not removable. May be radioactive; treat as a Radioactive Mineral.

Demantoid: Enclosing asbestiform minerals removed with steel tools. See also Andradite and Garnet.

Descloizite: Tolerates sonication. Avoid metal tools and all acids. Sparkly black descloizite was unchanged when treated with dithionite overnight. Tan coating quickly forms with NH_4HF_2.

Diaboleite: Brittle; can be damaged by brushing. Poor chemical resistance. Avoid acids, alkalis, NH_3, soap and detergents. Clean using water only. Treat as Boleite and a Copper Mineral.

Diamond: Very hard but can be cleaved. Sensitive to thermal shock damage. Avoid sonication when included (Macleod 1970). Exceptional chemical resistance.

Diaspore: Bladed crystals brittle; avoid steel tools and poking into spaces between crystals. May crumble during sonication. Stable to hot alkali.

Diopside: Coatings removed with steel tools or air abrasion. Soaking in oxalic acid weakens clays for easier removal. Stable to NH_4HF_2. Excellent acid resistance. Remove enclosing calcite with HCl.

Dioptase: Soft, brittle, easily cleaved; avoid metal tools. Generally stable to sonication but some sources indicate fogging may occur. Stubborn clay and mud may be removed by cautious use of a textile gun. Generally stable to Iron OUT/EDTA (no loss of color or luster) but iron hydroxide/oxide coatings commonly too thick for removal with this chemical so use caution when derusting with dithionite and minimize contact time. Attacked by NH_4HF_2, all acids except acetic acid and only slowly by 10% HNO_3. Mineral acids attack quickly whereas organic acids are slower. Dilute acetic acid "gives a good luster to dioptase" (Pearl 1972, 26) and "boosts" luster (Gol 2004c). Sinkankas (1970, 295) recommends 30% acetic acid to remove calcite from dioptase although Wilson and Currier (2001) report this acid delusters the dioptase. Dilute HNO_3 (10% or less) is also useful; purchase a diluted solution to avoid the dangers of having to store and dilute this aggressive acid yourself. HNO_3 is an oxidizer which poses a greater threat to other minerals present compared to acetic acid (Heitner 2016). Duthaler and Weiß (2024, 96) report that HCl

attacks dioptase and instead recommend using a somewhat elaborate (although very mild) procedure for calcite removal involving ion exchange resin. A much simpler version of this procedure, in which the resin is in direct contact with the specimen (Section 3.18B) is also useful but rather slow. When preparing to remove calcite from dioptase make sure the calcite is not underneath the dioptase as calcite removal in this case will cause anywhere from loss of a few crystals to complete specimen disintegration. Treat as a Copper Mineral.

Djurleite: When waxing and dewaxing (see Benitoite) avoid excess or prolonged heating; djurleite unstable above 90°C (Cook 1972) but this is rarely considered in benitoite preparation cases. Treat as a Copper Mineral and a Sulfide.

Dolomite: Etched by EDTA, citrate (in Iron OUT, Waller's solution or Bridge's solution) and other chelators. Derust with pure sodium dithionite or Jacquard Hydro. Derust by brief immersion in dilute HCl (but some etching is expected) if dithionite methods not feasible. Good but imperfect resistance to acids (Hardinger 2024a). Tolerates acetic acid but attacked (bleached) by HCl. Can be cleaned with formic acid, acetic acid or citric acid. Acetic acid or acetic acid-based lime removers work well. Remove calcite with acetic acid, formic acid (Gol 2004b) or cold concentrated citric acid. Lime removers based on citric acid are milder; these dissolve carbonate deposits without attacking minerals like dolomite (Rohner 2000 and Sury 1991; no details given). A quick dilute acid dip may improve surface (chips, scratches, etc.). Oiling can restore luster lost by acid attack but is not recommended. Treat as a Carbonate.

Domeykite: Quickly alters in air to form dull coating thus no point in cleaning unless sample is to be immediately coated.

Dravite: Remove mica encrustation with steel tools and calcite with HCl. Stable to Iron OUT/EDTA and hot oxalic acid. See Tourmaline.

Duftite: Green duftite turned to gray green when treated with dithionite overnight. Treat as a Copper Mineral.

Dumortierite: Excellent chemical resistance. Derust with any dithionite recipe or hot oxalic acid.

Elbaite: See Tourmaline.

Elpasolite: Soft and brittle. Clean with water.

Embolite: Avoid dithionite as this mineral is attacked by thiosulfate produced during aqueous decomposition of this agent. Treat as Silver Mineral.

Emerald: Mica encrustations and matrix can be removed with steel tools, vibratory impact tools or air abrasion; fractured crystals may disintegrate if too much supporting matrix is removed. Chivor specimens in limestone matrix should be derusted with dithionite as oxalic acid will attack the limestone matrix. See Beryl.

Enargite: Some crystals have an unremovable dull coating. Treat as a Copper Mineral and a Sulfide.

Enhydro Quartz: Growth features and fluid inclusions cause susceptibility to damage by thermal shock or sonication. See Quartz.

Eosphorite: See Childrenite-Eosphorite.

Epidote: Tolerates Iron OUT/EDTA (and by extension other dithionite recipes as well). Stable to acids. No luster lost when derusted with hot oxalic acid. Stable to NH_4HF_2. Skarn minerals such as epidote often exposed from enclosing calcite by acid treatment, but prolonged exposure may deluster. Crystals in skarn matrix may be cemented together by calcite so acid treatment causes specimen to fall apart (Sinkankas 1970, 294–295).

Epistilbite: Potentially unstable to acetic acid and formic acid. Attacked by hot alkali. See Zeolites.

Epsomite: Water soluble. Clean with alcohol or acetone. Treat as Water Sensitive Mineral.

Erionite: See Zeolites. When fibrous treat as Asbestiform Mineral.

Erythrite: Crystals easily bent; brush only with soft camelhair brush. Inconsistent tolerance to sonication. Delustered rapidly even in weak acids. Avoid strong detergents, soaps and NH_3.

Ettringite: Slightly attacked by water. Inconsistent tolerance to sonication. Treat as a Water Sensitive Mineral.

Euchroite: Readily soluble in HCl and HNO_3. Unstable in alkalis; avoid soap, detergent and NH_3 (Weiner and Hochleitner 1998d). Treat as a Copper Mineral.

Euclase: Cleaves easily. Avoid sonication when cleavage is imminent. Excellent chemical resistance.

Eudialyte: Crystals commonly cracked; take care when removing enclosing (supporting) matrix.

Euxenite: Excellent chemical resistance. Typical brown coatings not removable. May be radioactive; treat as a Radioactive Mineral.

Fayalite: Derust with any dithionite recipe or oxalic acid.

Feldspars: Good chemical resistance. Tolerates any dithionite recipe or hot oxalic acid but steps must be taken to avoid yellow stains on drying especially when porous. Tolerates alkali (with or without TKPP) at room temperature but may be attacked above 85°C or on prolonged exposure.

Fenster Quartz: Growth features cause some susceptibility damage by thermal shock or sonication. See Quartz.

Ferberite-Hübnerite: Fragile; use only a wooden toothpick, a bamboo sliver or sonication to remove adhering clay, etc. Tolerates Iron OUT/EDTA without luster loss. Lightly corroded by hot alkali/TKPP.

Fergusonite: Crystals in matrix commonly fractured internally. Use care when removing supporting matrix. Brown earthy coatings generally cannot be removed. Sonication of fractured crystals contraindicated.

Ferrocolumbite: See Columbite-Tantalite.

Ferrotantalite: See Columbite-Tantalite.

Fiedlerite: Poorly soluble in water; tolerates brief water rinse followed by immediate and thorough drying. Treat as a Water Sensitive Mineral.

Fluor-buergerite: See Tourmaline.

Fluorapatite: Tolerates Iron OUT/EDTA. See Apatite.

Fluorite: Soft, easily cleaved. All mechanical and chemical methods must be applied with caution. There are numerous contradictions in the mineral cleaning literature on this topic; the suggestions presented here are generally agreed upon and/or tested by the author. Avoid metal tools. Use care with forceful water jet tools especially the textile gun. Susceptible to damage by thermal shock. Macleod (1970) recommends avoiding sonication, but this technique has been successfully applied to numerous samples without incident. For air abrasion use only plastic beads (Duthaler 2006, 117). Stable to CO_2-rich water at room temperature but etched by hot distilled water (which precludes the use of hot alkali).

Avoid detergents with chelating agents as these may dissolve calcium and result in dull, etched surface (Duthaler 2006, 117). Response to chelators (EDTA, citrate) varies between samples; some retain bright luster whereas others become frosted. Best therefore to avoid derusting agents containing chelators including Iron OUT, Waller's solution and Bridge's solution. Iron OUT has been recommended for derusting fluorite (Danilo 2005) but use Jacquard Hydro or pure dithionite only. Derusting recipes which include chelators may be acceptable for fluorites already having a dull luster or etched faces, but further delustering may result even in these cases.

Literature reports as to acid tolerance are inconsistent. Some samples may tolerate limited exposure while others are rapidly etched (see for example Mork 2009). Avoid oxalic acid for derusting as this acid causes frosting even at room temperature. Fluorite is (in general) unaltered by immersion in dilute (10%) or concentrated (85%) H_3PO_4 overnight so this acid may have some value for derusting. Commercial derusting products containing H_3PO_4 are frequently recommended but should be used only with caution or avoided altogether as other ingredients present may be harmful. Fluorite is stable to glacial acetic acid, 90% formic acid, tartaric acid and citric acid although Gol (2004b) recommends avoiding tartaric and citric acids. Fluorite is attacked (etched to some extent) by concentrated H_2SO_4 (although some sources say attack is only very slow or not at all; these may refer to dilute acid), concentrated HCl (although 10% HCl may be tolerated), sulfamic acid or concentrated HNO_3. Treatment of fluorite already having a dull luster with any of these acids may be tolerable.

Kandutsch (1983) states "[Alpine cleft] fluorite(s) are almost completely resistant to acids in their unweathered state. Therefore, one can safely etch away sinter coatings with HCl. More caution is required with weathered fluorites." Concerning cleaning Knappenloch fluorites (Bacher 2023 and personal communication) notes "Yes, most fluorites had a light coating of clay or sinter. The fluorites were first carefully cleaned with a high-pressure cleaner and any remaining impurities were removed with diluted hydrochloric acid. (Ratio 1 liter of [concentrated] HCl to 2 liters of water.) So it's a pretty crude approach. If you are interested, you can also read the report on my homepage [Bacher 2024]. You will also find a few interesting videos there."

Vinegar is slow but effective to remove calcite and some other carbonates from fluorite (see Hardinger 2024a). Dilute (10%) HNO_3 is much faster and poses no risk to luster. Calcite can also be removed by the ion exchange procedure (Section 3.18B); fluorite is not etched when in direct contact with the resin.

For removing quartz treatment with NH_4HF_2 (to which fluorite is usually inert) is often recommended to weaken or remove thin layers but details are sparse. After treatment the quartz layer may be sufficiently weakened to allow removal with the textile gun or by air abrasion (Jesse Fischer, personal communication). However, the underlying fluorite faces may be frosted and pitted due either to deposition of the quartz or by etching due to prolonged (two weeks) exposure to NH_4HF_2 so quartz removal may result in an unattractive specimen. Rogerley Mine fluorites may have hydrocerussite associated with galena; the former is removed first with sulfamic acid otherwise derusting with H_3PO_4 can result in pyromorphite deposition on the galena (Jesse Fischer, personal communication).

Removing bitumen is discussed in Section 3.22. Fluorite tolerates the base bath soak procedure. For more on cleaning fluorite see Duthaler (2006) and Danilo (2005).

Forsterite: Sinkankas (1970, 288) notes that tumbling may be applied to remove clay and better reveal a specimen's inner beauty. However, this technique is frowned upon by many 'serious' collectors, especially if precious crystal faces or the natural mineral paragenesis are destroyed. Derust with dithionite. Can be derusted with cold dilute oxalic acid but best to avoid acids altogether.

Franklinite: Crystals often highly fractured, so use care when removing supporting matrix. Sharper, more lustrous crystals are generally less likely to have internal fractures. Tolerates dithionite for derusting (has also been recommended for calcite removal but this would be slow and expensive). Remove black coatings with H_2O_2/vinegar, H_2NOH or $NaHSO_3$. Use HCl to remove enclosing calcite (Betts 2025a) but stability towards HCl varies somewhat between samples so better to use an organic acid (cold saturated citric acid).

Gadolinite: Typical brown coatings generally cannot be removed without destroying the specimen. May be radioactive; treat as a Radioactive Mineral.

Gahnite: Tolerates Iron OUT/EDTA.

Galena: Soft; easily chipped and cleaved. Avoid steel tools. Exercise care with the textile gun. Sensitive to thermal shock damage. Although numerous recipes are given in the mineral cleaning literature, a grey dull luster often cannot be improved. Removing a surface coating often reveals a dull face beneath (even in samples where no decomposition is evident) which is no more attractive than before cleaning. Polishing or air abrasion are also sometimes recommended but this leaves an unnaturally bright surface and examination under magnification usually reveals obvious signs of this treatment (parallel or concentric scratches). For derusting tolerates any dithionite recipe; some samples brightened. When minerals sensitive to dithionite are present derust with tartaric acid (Gol 2004b). Sensitive to mineral acids but much less so to organic acids. Calcite encrustations often removed with vinegar but check effect on exposed crystal faces before proceeding. Stable to bleach. Tolerates hot alkali/TKPP without change to existing luster. Tolerates NH_4HF_2 without luster decrease but some matrix may be removed and some samples brightened. Treatment with ammonium acetate solution is frequently recommended for brightening (no details are given) but this method is rarely to never effective. Sometimes coated with a thin crust (cerussite and/or hydrocerussite and/or anglesite) which may make the specimen dull. This crust may sometimes be removed with dilute acids, but the galena may be attacked as well. EDTA (10 grams in one liter tap water overnight) effective against this crust without damaging the underlying galena, but a dull surface is likely to remain as crust formation etched the existing crystal face. Acids may also leave unacceptable unnaturally etched surface. Galena from the Rogerley Mine may be coated with

hydrocerussite which is first removed with sulfamic acid otherwise derusting with H_3PO_4 can deposit pyromorphite on galena (Jesse Fisher, personal communication). Galena subject to oxidative decomposition ('pyrite rot'); see Section 5.8D for treatment and conservation. Treat as a Sulfide.

Garnet: Excellent chemical resistance. As a group mostly resistant to attack by mineral acids (except grossular). Generally stable to hot oxalic acid. Internally fractured crystals may be cemented together with calcite or iron hydroxides/oxides; exercise care when removing these and avoid temptation to treat to excess. Garnets from the Red Embers Mine (Franklin County, Massachusetts) are revealed by air abrasion of the surrounding graphite schist matrix (Greene 2016). Also see individual species entries.

Geodes: Pearl (1972, 24) recommends cleaning quartz geodes with warm solution of NH_3 and distilled water, which "restores the brilliance of the quartz and leaves it free of spots." Remove rust stains with oxalic acid unless calcite or gypsum are present (dithionite methods are usually more suitable). Avoid HCl for derusting as it may leave yellow stains. HNO_3 can also be used if followed by a thorough rinse. Iridescence inside a calcite geode is due to a thin layer of stilpnosiderite, which should be left intact. Before cutting, clean the outside of the geode to reduce debris accumulation inside during the cut. Open with hammer and chisel instead of a saw, as cutting oil residues will ruin some minerals and washing can flush out tiny or loosely held crystals from the interior (which may also be dislodged by hammer and chisel blows).

Gersdorffite: Decomposition may be initiated by moisture so keep dry and use only dry mechanical cleaning methods or anhydrous organic solvents (acetone, ethanol or rubbing alcohol of the highest available concentration). Treat as a Sulfide.

Glauberite: Rinse only with the mother liquor in which the mineral was initially formed as mineral may be altered by other dissolved minerals (King 1982, 46). Wear gloves and safety glasses as this strongly alkaline liquor is corrosive to skin. Treat as Water Sensitive Mineral.

Goethite: Samples often attacked by dithionite; varies widely between localities. Replacements after pyrite (for example from Pelican Point) often stable to Iron OUT/EDTA. Pseudomorphs should be derusted with caution; best to use the alkaline dithionite procedure for calcite. Behavior towards oxalic acids varies. Some samples (bright or very compact) show excellent resistance and can be derusted by this reagent, while other spongy or more limonitic samples are slowly to rapidly attacked. Hematite and goethite can be cleaned with HCl (dilute at room temperature is better than warm and/or concentrated HCl) but not for too long, as it may be delustered. Hematite can sometimes be removed from goethite by warm, concentrated HCl. Some examples become somewhat rusty with NH_4HF_2 even 'highly stable' goethite replacing pyrite from Pelican Point.

Gold: Soft and easily scratched; avoid metal tools and brushing or scraping, especially of thin sheets or wires. Highly malleable. Flexible but can break easily especially where crystals meet. Pure gold does not tarnish but impure samples and alloys (electrum) may. Unlike copper and silver a bright luster is acceptable (and even ideal). Color and luster may be 'off' due to natural alloys. Cleaning with compressed gas, sonication (soapy water) or a textile gun is often all that is needed.

Excellent chemical resistance but take care to avoid incompatibilities with associated mineral species. Dilute HCl is commonly recommended (Burns 1941, 157; Robbins and Irving 1981, 183; Pearl 1972, 23 and Gol 2004c) but details such as concentration or contact time are omitted (and probably unimportant for this mineral). Dilute HNO_3 is also commonly recommended to clean gold (Pearl 1972, 23; Gol 2004c and Wilson 2024) but no details are given. Sinkankas (1970, 299) mentions HCl, HNO_3 and NH_4HF_2 to clean gold but no details are given. Burns (1941, 157), Robbins and Irving (1981, 183) and Gol (2004c) suggest using a 10% NH_3 solution.

For removing calcite encrustation any acid is suitable, but vinegar (and patience) is recommended, as vigorous effervescence caused by more concentrated acetic acid solutions or stronger acids may dislodge weakly bound gold particles. Enclosing quartz can be removed with NH_4HF_2 (and much patience), but the process is quite slow (months). Avoid temptation to use more aggressive methods (Section 3.32) as safety is more important than time.

Gonnardite: Sensitive to acids but cleaning with water harmless. See also Zeolites.

Goshenite: See Beryl.

Goslarite: Readily soluble cold water. Rinse with acetone, ethanol or rubbing alcohol (highest concentration possible) from wash bottle. Treat as a Water Sensitive Mineral.

Graftonite: Avoid detergents, soaps, NH_3 and other alkaline solutions.

Grandreefite: Poorly soluble in water; tolerates brief water rinse followed by immediate and thorough drying. Treat as a Water Sensitive Mineral.

Graphite: Soft; easily scratched and cleaved (foliated) even by the softest of tools. High chemical resistance including to acids. Derust with any dithionite recipe (but take care if associated calcite is lustrous). Etch from calcite or marble with dilute HCl.

Grossular: Tolerates Iron OUT/EDTA. Stable to hot oxalic acid at 6 g per liter but may be attacked at higher concentrations. Stable to NH_4HF_2 (which attacks associated calcite; see below). Skarn minerals often exposed from enclosing calcite by HCl, but prolonged exposure may deluster some minerals. Crystals of skarn specimens may be cemented together by calcite so acid treatment can cause specimen to disintegrate; especially problematic with grossular due to grossular/calcite

intergrown zones (Sinkankas 1970, 294). Better to remove calcite by mechanical methods - steel tools, vibratory impact tools or air abrasion. See also Garnet.

Grunerite: Treat the fibrous form (amosite; brown asbestos) as an Asbestiform Mineral.

Gummite: A mixture of uranium mineral alteration products, so chemical composition (and therefore response to chemical treatments) variable. Soft, powdery. Treat as a Radioactive Mineral.

Gypsum: This section is about cleaning gypsum. For removing gypsum coatings and crusts see Section 3.19.

It is widely believed that gypsum cannot be cleaned because of its softness, its water solubility and its propensity to cleave and bend. These issues do not prevent its cleaning, but it must be treated with care. Minor damage and frosting are especially apparent on the water-clear selenite variety. Minor scratches and rubs can often be reduced or eliminated by polishing with a dry (or moistened) cloth or finger. When this fails, the specimen can be 'polished' by placing in the toilet tank for an hour to overnight or longer, checking progress frequently. A bucket of warm (40–50^{o}C) tap water is also suitable. Excessive exposure will result in an unnaturally rounded specimen to complete dissolution. Some sources recommend using flowing water from a hose or faucet, but this is an unconscionable waste of water. When removing clay avoid metal tools (gypsum is easily scratched by a fingernail); some clay can be removed by gentle work with a wooden toothpick, bamboo sliver or very careful application of a water jet tool. Avoid vigorous brushing even with soft brushes.

Other than the methods mentioned above, wet cleaning methods should be avoided because other water-sensitive species are frequently present. Treat as a Water Sensitive Mineral. Cleaning solutions tend to infiltrate cleavage planes via capillary action leaving films which are especially visible in the selenite variety and encourage cleavage (King 1982, 52). Soaps are particularly problematic as they may react with the gypsum to deposit opalescent films of poorly soluble calcium salts. Soaps and detergents should also be avoided because many contain chelating additives which dissolve enough gypsum to cause discernable frosting. Numerous sources recommend using rinse solutions saturated with various salts (NaCl, $NaHCO_3$, NH_4Cl, gypsum, etc.) suggesting no damage will result due to gypsum dissolution (Sinkankas 1970, 299). This is simply untrue as dissolution is an equilibrium phenomenon in which dissolving gypsum can displace salts already dissolved. Brief (ten seconds) sonication can be tolerated; longer exposure often causes frosting. Avoid acids, as gypsum is more soluble in acids than in plain water. When derusting is needed avoid dithionite recipes containing chelating agents (Iron OUT, Waller's solution or Bridge's solution); try a limited exposure to Jacquard Hydro (or if available pure sodium dithionite) first.

Gyrolite: See Zeolites.

Halite: Soft; easily cleaved; sensitive to thermal shock. Fiber fuzz is a common issue; remove by gentle 'polishing' with dry toothbrush. Avoid polishing with a moist cloth as this leaves a frosted surface (which might be clarified by abrasion with very soft abrasive or a dry cloth). Rinse only with the mother liquor in which the mineral was initially formed (King 1982, 46) as halite may exchange with other dissolved ions resulting in frosting. In such cases wear gloves and safety glasses as the halite mother liquor is corrosive to skin. Rinsing with brine (water saturated with NaCl), acetone or 95–100% alcohol (ethanol or rubbing alcohol) is less satisfactory. Treat as a Water Sensitive Mineral.

Hambergite: Derust with dithionite or oxalic acid. Slightly attacked by NH_4HF_2; use with caution and limit exposure.

Hanksite: Rinse only with the mother liquor in which the mineral was initially formed as mineral may be altered by other dissolved minerals (King 1982, 46). Wear gloves and safety glasses as this strongly alkaline liquor is corrosive to skin. Conserve by adding a surface coating such as oil and store in a humidity-controlled environment. Treat as a Water Sensitive Mineral.

Hannebachite: Poorly soluble in water; tolerates brief water rinse followed by immediate and thorough drying. Treat as a Water Sensitive Mineral.

Hausmannite: Luster susceptible to even cold, dilute acids. Remove calcite only by mechanical means such as steel tools, vibratory impact tools or air abrasion.

Hedenbergite: A sample from China with light brown crust was treated with concentrated HCl for two days, resulting in a pleasing green color but much silica was dissolved; sample was most likely ilvaite replacing hedenbergite (ilvaite is attacked by HCl; Nicastro 2022). White coating forms over 24 hours with NH_4HF_2. Mostly stable to hot alkali but some luster lost.

Heliodor: See Beryl.

Helvine: Luster and color improved when treated with Iron OUT/EDTA.

Hematite: Sensitive to thermal shock. May be intergrown with decomposing pyrite, causing the sample to disintegrate under numerous treatments. Generally stable to dithionite but some samples may be attacked. Large, lustrous crystals generally have good acid resistance. Hematite may be treated with a solution of one part concentrated HCl in twenty parts water at room temperature but not for too long, as it may be delustered. Stable to concentrated HCl for a few hours but etched and dissolved on prolonged contact. Hematite was partially to fully freed from its enveloping hydrotalcite/lizardite matrix by treating first with hot alkali/TKPP then the textile gun, without damage to the hematite. With the same material partial matrix removal was achieved in undiluted

Dawn Ultra dish soap at 60–80ºC for eight hours followed by textile gun treatment. Stable to a solution of 6 g oxalic acid per liter of water at room temperature for two weeks; higher concentrations or heating may be problematic. Stable to NH_4HF_2.

Hemimorphite: Fragile; avoid steel tools; use only wooden toothpick or bamboo sliver. Use only water for cleaning. Tolerates sonication which is especially useful to remove powdery limonite. Tolerates Iron OUT/EDTA but some samples may be slightly dulled; Iron OUT (without EDTA) or Jacquard Hydro should be viable alternatives. Readily attacked by all acids. Slightly attacked by alkalis.

Herderite: Most samples are hydroxylherderite. Tolerates dilute oxalic acid, acetic acid or citric acid. Derust with any dithionite recipe.

Herkimer Diamond: Broad tolerance to sonication except when already cracked (Betts 2025a). See Quartz.

Heterosite: Dark alteration coatings removed carefully with dilute HCl, but mineral will eventually be etched or even dissolved. See Purpurite.

Heulandite: Brittle, easily cleaved and dislodged from matrix. Avoid strong detergents, soap and NH_3. Said to be sensitive to prolonged immersion in water (other than distilled). Acids (types not specified) should be avoided but can be tolerated for a short (unspecified) time if needed. Becomes snow white and matte when treated with oxalic acid. Attacked by hot alkali. See Zeolites.

Hörnesite: Avoid oxalic acid.

Howlite: Adhering clay removed by water wash and mild scrubbing. Avoid detergents and soaps.

Hübnerite: See Ferberite-Hübnerite.

Hurlbutite: Avoid strong detergents and soaps.

Hyalite: Most samples tolerate sonication without damage. Stable to acids; attacked by hot alkalis. Small mass loss when treated with hot alkali/TKPP but remains water clear and glassy. See Opal.

Hyalophane: See Feldspars.

Hydrocerussite: Removed from galena with sulfamic acid, otherwise derusting with H_3PO_4 can deposit pyromorphite on galena (Jesse Fisher, personal communication). Treat as a Carbonate.

Hydroxylapatite: See Apatite.

Hydroxylherderite: See Herderite.

Hydrozincite: Use water only in cleaning. May be attacked by detergents and soaps. Treat as a Carbonate.

Iceland Spar: See Calcite.

Idocrase: See Vesuvianite.

Ilmenite: Stable to hot oxalic acid. Calcite removed with dilute HCl at room temperature. Attacked only slowly by hot concentrated HCl. Consider mechanical removal first.

Ilvaite: Brittle; matrix crystals frequently fractured; use care when removing supporting matrix. Derust with any dithionite recipe. Rapidly attacked by most acids including oxalic acid and other organic acids. Rapidly attacked by NH_4HF_2 forming a white film.

Imperial Topaz: See Topaz.

Inderite: Somewhat water sensitive but can be cleaned with quick exposure to cold water. Treat as a Water Sensitive Mineral.

Inesite: Rapidly attacked by acids (except for dilute HNO_3) causing the mineral to turn white (Currier 2010b). Black Mn stains were removed from Hale Creek inesite in 30 minutes using a 1:1 mixture of 12% H_2O_2 with 5% HCl. Minimize exposure due to acid sensitivity. Rapidly attacked by NH_4HF_2 resulting in a white coating after 24 hours. When removing calcite from inesite use dilute HNO_3 (up to 20%) as even weak HCl ruins the mineral (Wilson and Currier 2001, 338).

Iolite: See Cordierite.

Iron: Recipes for cleaning museum objects of iron may be applicable to native iron specimens (Scott 1926, 25). In general use only dry mechanical methods for cleaning. Slowly to rapidly attacked by acids, even vinegar. Concentrated H_2SO_4 sometimes mentioned for cleaning but "is quite unthinkable." Pearl (1972, 26) reports a personal communication from William D. Panczner who gives a recipe for "a bright dip for iron minerals": two ounces oxalic acid, 100 mL 30% H_2O_2, 875 mL room temperature water and 25 mL [concentrated?] H_2SO_4 (but see Section 3.32 regarding 30% H_2O_2; 12 % concentration probably equally effective). Another recipe from Pearl (1972, 29) is "Iron of archaeologic value can be cleaned of rust by contact with granulated Zn in the presence of NaOH," but no concentrations are given. Burns (1941, 156) gives the following methods for

cleaning archaeological iron which may also be applicable to native iron mineral specimens: "Iron artifacts may be cleaned chemically by several methods. The objects should first be freed of dirt and loose rust [with] brushes and steel wool. For small objects, or a small quantity, rust may be removed [with] a solution of two parts $SnCl_2$ to eight parts of water." Scott (1926, 64–68) gives a repatination recipe but unnatural restoration of patina is not recommended. Conserve by storing in a dry atmosphere (well-sealed container with desiccant).

Jamesonite: Frequently found in filiform habit. Often so delicate that cleaning should be completely avoided. If cleaning is warranted, however, avoid water; can become matted (King 1982, 44). Rinse in alcohol (95–99% ethanol or rubbing alcohol). Treat as a Sulfide.

Jarosite: Generally tolerant of sonication.

Jasper: Treat as Quartz but may be decolored by hot oxalic acid.

Jeffersonite: Excellent chemical resistance. HCl can be used to remove enclosing calcite but matrix crystals often internally fractured so take care when removing supporting matrix. Mechanical methods sometimes used for calcite removal as well.

Jet: Brittle; chips easily; avoid metal tools. Clean with soap and water. Attacked by organic solvents.

Joaquinite: Stable to any HCl concentration on even prolonged exposure. Stable to NH_4HF_2 for at least three hours. To etch from encasing natrolite, see Benitoite.

Kalinite: See Alum.

Kämmererite: See Chromian Clinochlore.

Kaolinite: Often softens and disintegrates in water. Treat as a Water Sensitive Mineral.

Kermesite: Fragile; cleaves and splinters easily. Avoid detergents and soaps. Whitish grey to yellowish coatings (stibiconite and related hydroxides/oxides?) may be removed with 5–10% NaOH however if replacement is sufficiently advanced specimen may disintegrate. Treat as a Sulfide.

Kernite: White powdery coatings (usually tincalconite) are best removed by gentle blowing from a compressed gas source followed by gentle brushing with a cotton swab. Clusters of kernite often intergrown with borax/tincalconite and thus are fragile and tend to disintegrate when cleaned or handled. Avoid water; treat as a Water Sensitive Mineral.

Kidwellite: Avoid oxalic acid.

Köttigite - Parasymplesite: Chemical tolerance varies unpredictably with composition. One sample turned darker with Jacquard Hydro, but color was restored upon thorough drying. Remove enclosing gypsum with the toilet tank or ion exchange procedures.

Kunzite: see Spodumene.

Kurnakovite: Clean in water (in which it is insoluble); avoid chemicals. Treat as a Water Sensitive Mineral.

Kutnohorite: Stable to 12% H_2O_2.

Kyanite: Cleaves easily; avoid metal tools. Commonly encased in massive, fractured quartz which is tempting to remove but rarely with success. Broad chemical resistance. Tolerates Iron OUT and oxalic acid but when blades are embedded in fractured, massive quartz care must be taken to avoid yellow stains on drying. Attacked slowly by NH_4HF_2; use caution and limit exposure.

Labradorite: Tolerates Iron OUT/EDTA. High chemical resistance except to NH_4HF_2 but iridescence may be reduced if immersed in acid too long. See Feldspars and Anorthite.

Lapis Lazuli: A mixture of minerals some of which are readily attacked by acids. Use mechanical methods only to remove enclosing calcite. See also Lazulite (a major component of this material).

Laumontite: Tends to dehydrate rapidly and disintegrate in air. Avoiding sonication recommended. Best cleaned in soapy water (Weiner and Hochleitner 1998a). Attacked by 20% formic acid, oxalic acid and hot alkali. Often dehydrates and become very fragile. Protect against dehydration by immersion in water (He 2019 and Weiner and Hochleitner 1998a). See Zeolites.

Laurionite: Slightly soluble in water; clean only by brief exposure to water (no detergent or soap) followed by immediate and thorough drying. Treat as a Water Sensitive Mineral.

Lawsonite: Adhering micaceous material removed by steel tools or air abrasion but with care, as crystals frequently have internal cracks. Stabilize with diluted water-based glue (polyvinyl acetate) solution before beginning work. Excellent chemical resistance.

Lazulite: Remove matrix by mechanical means: steel tools, vibratory impact tool or air abrasion when possible. Attacked by acids except for HCl which is used to etch enclosing marbles. Do not confuse with Lazurite.

Lazurite: Crystals often quite fragile; use care when removing supporting matrix; strengthen by coating with diluted water-based glue (polyvinyl acetate) solution before beginning work. Samples from Afghanistan are often etched from an acid-sensitive matrix, probably marble. Attacked and decolorized by 20% acetic acid. Attacked by hot alkali. Slightly attacked by NH_4HF_2. See also Lapis Lazuli. Do not confuse with Lazulite.

Lead: Very soft and malleable; readily gouged by wood, bamboo and plastic tools. Avoid abrasives. Handle with care; in some cases, native lead is easily peeled away from matrix. Avoid cleaning to produce unnaturally bright luster. Recipes (without details) for cleaning museum objects may be applicable to native lead specimens (Scott 1926, 32). Gray coatings often readily removed by sonication. Remove carbonate crusts by soaking in 10% acetic acid then 1% NaOH. The EDTA procedure for cleaning galena may also apply. Wash thoroughly in distilled water, preferably boiled immediately before use as dissolved CO_2 may cause carbonates to form again (Burns 1941, 158). Tarnishes easily especially in moist air. Natural lead samples usually tarnished; removing tarnish can result in an unnaturally bright luster which is inevitably lost when tarnish forms again. Conserve by storing in sealed container with desiccant.

Leadhillite: Soft; easily damaged. Avoid any mechanical cleaning methods as well as detergent and soap. Exfoliates in hot water. Treat as a Water Sensitive Mineral.

Legrandite: Treat as Adamite.

Lepidolite: When micaceous said to exfoliate and flake apart in water (due to intercalation of water between sheets) but this is a false generalization; many samples are stable even after prolonged treatment with water, especially if the 'book' is tight. Not an issue with fine-grained, lapidary-quality lepidolite. Stable to Iron OUT/EDTA, hot alkali and NH_4HF_2.

Leucite: Crystals brittle and often internally fractured. Use care when removing supporting matrix.

Libethenite: Fragile; avoid steel tools. Avoids acids, NH_3 (in which it is readily soluble), detergents and soap. Treat as a Copper Mineral.

Liebigite: Fragile; often powdery. Avoid cleaning if possible. Treat as a Carbonate and a Radioactive Mineral.

Limonite: This is not a well-defined mineral species but instead a broad term for various earthy and loose to solid, well-aggregated mixtures of iron hydroxides/oxides. Thus, no overarching advice can be given. Some samples disintegrate easily and can be removed mechanically or by sonication while in other cases more vigorous mechanical methods (vibratory impact tools or air abrasion) are needed. Always experiment first on a disposable test sample or when this is not

possible on an unimportant area of the specimen. See also Goethite, with which limonite is often confused.

Linarite: Fragile, brittle; avoid metal tools. Clean with water but avoid detergent and soap or prolonged water contact. Avoid NH_3 and HCl. Attacked by most acids. Turns black in a few hours with bleach. Treat as a Copper Mineral.

Lindgrenite: Avoid NH_3, soap and detergent; rinse in pure water only. Treat as a Copper Mineral.

Liroconite: Avoid NH_3, detergent and soap. Treat as a Copper Mineral.

Lithiophilite: Avoid detergents and soaps.

Löllingite: Attacked by HNO_3 and cold saturated citric acid solutions, but not by HCl; use the latter to remove calcite. Dull gray coating is due to surface features and cannot be removed.

Londonite: Treat as Rhodizite.

Ludlamite: Fragile, brittle, easily cleaved; avoid hard tools. Tolerates brief sonication; use only mild detergent in bath. Tolerates Jacquard Hydro.

Luzonite: Treat as Enargite.

Maghemite: Treat as Magnetite.

Magnesioriebeckite: See Riebeckite.

Magnesite: Massive material porous; prolonged soaks in fresh water necessary after chemical treatment. Good but imperfect resistance to acids at room temperature (Hardinger 2024a). Readily soluble in warm acids. Less sensitive to acids than calcite or strontianite. Treat as a Carbonate.

Magnetite: Matrix-enclosed crystals likely to be internally fractured (take care removing supporting matrix) whereas freestanding (cavity) crystals tend to be cohesive and tough. Generally stable to dithionite but some samples are attacked. Good acid resistance except for HCl. Tolerates oxalic acid (6 g per liter) at room temperature for two weeks, but higher concentrations or heating may be problematic. Becomes pitted and matte after 24 hours with NH_4HF_2. Some specimens partly to completely altered to hematite which must be considered when planning treatment.

Malachite: Avoid scrubbing with toothpaste (some toothpaste formulations include an abrasive) or a paste made from sodium bicarbonate. Avoid detergent, soap, NH_3 and any alkaline cleaning

solutions. Avoid all dithionite derusting recipes; forms a metallic Cu precipitate within minutes with Iron OUT. Attacked to some extent by hot water. Moderate resistance to acids (Hardinger 2024a); bruises may sometimes be 'healed' by localized application via dropper of dilute HCl followed by immediate and thorough rinse. Avoid acetic acid. Treat as a Carbonate and a Copper Mineral.

Manganite: Thin, sooty coatings may succumb to sonication. Avoid HCl; generates toxic chlorine gas.

Manganoan Calcite: See Calcite.

Manganocolumbite: See Columbite-Tantalite.

Manganotantalite: See Columbite-Tantalite.

Marble: Generally, has same chemical resistance as calcite but tends to react more slowly. When specimen is delicate treat first with solution of one part sodium dihydrogen citrate to six parts water then flush with solution of $NaHSO_4$ (concentration unspecified); etching will occur. Treat as Alabaster. See also Calcite and Dolomite.

Marcasite: Has a reputation for instability but many samples are quite stable. Samples having a metallic or sulfurous odor should be conserved as pyrite or just discarded. Atmospheric humidity and water can initiate or accelerate decomposition of marcasite, pyrrhotite and some pyrites ('pyrite rot') so a dry-cleaning method is needed. Pearl (1982, 51–53) recommends dry brushing. If decomposed, sonication bath may become acidic; check pH and basify or replace if acid sensitive minerals (such as carbonates) are suspected to be present. Tolerates Iron OUT/EDTA; Gol (2004b) recommends derusting with tartaric acid (while other sources recommend avoiding all acids). Some collectors recommend removing tarnish with 25% HCl or vinegar (Wingard 2003). Stable to NH_4HF_2 in which some samples brightened but resulting luster may become dull in hours to weeks (or longer) or may be permanent. (NH_4HF_2 probably removes a thin oxide layer which may reform on standing.) NH_4HF_2 is acidic so associated minerals (carbonates, etc.) may be attacked. Remove calcite with cold concentrated citric acid. For conservation see Section 5.8D. For cleaning marcasite samples found in black shale (including pyrite 'suns') see Delano (2015 and 2017) as well as Pyrite (below). 'Pyrite suns' are either marcasite, pyrite or a mixture of the two. Treat as a Sulfide.

Matlockite: Attacked by acids; clean with pure water only.

Mercury: Easily dislodges from matrix. Remove dust and other loose debris with very gentle gas puffs; otherwise avoid cleaning.

Mesolite: Needles very fragile. Remove dust and other loose debris with very gentle gas puffs or swishing in water, alcohol or acetone; otherwise avoid cleaning. See Zeolites.

Meta-autunite: Treat as Autunite.

Metatorbernite: Treat as Torbernite.

Metavauxite: Treat as Paravauxite.

Metazeunerite: Treat as Zeunerite.

Meyerhofferite: Soft and fragile. Slowly soluble in water. Avoid cleaning or clean only in distilled cold water or alcohol. Treat as a Water Sensitive Mineral.

Miargyrite: See Silver Minerals.

Micaceous Minerals: Often easily cleaved; use care with forceful water jet tools. Said to exfoliate and flake apart in water (due to intercalation of water between sheets) especially on prolonged immersion but this is a false generalization as many samples remain unchanged even after overnight soaking. 'Tight' books less prone to defoliation. As a precaution avoid prolonged exposure to water and blot dry immediately after removal from any chemical bath. Many (but not all!) species have good acid resistance. See also individual species.

Microcline: Avoid thermal shock, especially when other minerals (quartz, goethite etc.) are attached. Colorado amazonite has been cleaned with air abrasion (Betts 2025a). Excellent chemical resistance. Tolerates all dithionite recipes as well as hot oxalic acid. Take precautions against yellow stains (mostly with oxalic acid) on drying with porous crystals (especially bonespar variety). Well-formed crystals resist NH_4HF_2 but bonespar variety may be quickly attacked leaving a white powdery crust. See also Feldspars and Amazonite.

Microlite (group): Crystals in matrix often internally fractured; use care when removing supporting matrix. May be stabilized with dilute water-based glue (polyvinyl acetate) prior to matrix reduction. Brown/black halos surrounding crystals may be due to radiation; these halos are not removable, and these crystals may have light to heavy internal radiation-induced damaged (metamict) causing them to be weak and crumbly.

Micromounts: See Section 3.28.

Milky Quartz: See Quartz.

Millerite: Fragile. Attachment to matrix often weak. Overgrowth and oxidation products generally part of normal paragenesis and should be retained. Subject to 'pyrite rot'; see Pyrite and Marcasite. Avoiding sonication recommended. Filiform crystals very fragile; remove loose debris by gentle swishing in alcohol or acetone or better yet avoid cleaning altogether. Gol (2004b) recommends derusting with tartaric acid, but this water-based treatment should probably be avoided. Treat as a Sulfide.

Mimetite: Brittle. Generally tolerant of sonication. Avoid detergents, soaps, NH_3 and other alkaline solutions. Stable to all dithionite recipes. Attacked by HCl; avoiding all acids sometimes recommended. Removing associated calcite with any acid (including organic acids) often results in dulled crystal faces.

Mohawkite: Treat like Domeykite.

Moldavite: Surprisingly resistant to thermal shock but take care. Tolerates sonication. Stable to all common cleaning chemicals except (probably) NH_4HF_2. Much material sold as moldavite is fake (etched glass); this material should be discarded instead of cleaned.

Molybdenite: Fragile; easily scratched and defoliated. Tolerates Iron OUT/EDTA or hot oxalic acid unless the matrix is calcite or marble, which is etched by oxalic acid. Treat as a Sulfide.

Monazite: Crystals in matrix commonly have internal fractures; use care when removing supporting matrix. Stabilize first by painting with dilute solution of water-based glue (polyvinyl acetate). Monazite-(Ce) tolerates Iron OUT/EDTA but in some cases removing rust stains leaves a dull, pitted surface. Stable to hot oxalic acid or 15% HCl at room temperature but very slightly attacked by warm concentrated HCl. Remove enclosing calcite with dilute HCl or organic acids but minimize exposure. May be radioactive; treat as a Radioactive Mineral.

Montebrasite: Treat as Amblygonite.

Montmorillonite: Soft, friable, easily broken. Pink color may fade with acidified H_2O_2.

Mordenite: See Zeolites.

Morganite: See Beryl.

Morion: See Quartz.

Mottramite: Tolerates all dithionite recipes but use caution as associated copper minerals may darken. Attacked by most acids. Treat as a Copper Mineral.

Mountain Leather: Regardless of the mineral species present (palygorskite, actinolite, etc.) easily damaged. Clean only with gentle gas stream or tweezers, or not at all. Treat as Asbestiform Mineral.

Mullite: Avoiding sonication sometimes recommended.

Muscovite: Micaceous minerals are said to exfoliate and flake apart in water (due to intercalation of water between sheets), but this is a false generalization; many samples remain stable (especially when the 'book' is tight) even after an overnight soak. Easily cleaved; use care with forceful water jet tools. Tolerates Iron OUT/EDTA and Jacquard Hydro. Stable to hot alkali/TKPP. Stable to NH_4HF_2 but may defoliate. See Micaceous Minerals.

Natrolite: Often delicate; avoid forceful mechanical methods. Use only gentle faucet stream or the mildest of water jet tools. Delicate sprays tolerate sonication well (Betts 2025a) and can also be cleaned by holding the specimen upside in water and gently swishing. Readily attacked by HCl (see Benitoite) or 20% formic acid. Stable to hot alkali. See Zeolites.

Nepheline: Readily attacked by mineral acids. Associated calcite removed with organic acids.

Nephrite: Tolerates sonication; include detergent, soap or NH_3 in bath to remove "handling crud." Excellent chemical resistance.

Neptunite: Stable to HCl (any concentration) which is used to etch enclosing natrolite although may be slowly dulled on exposure for excessive time (see Benitoite). When removing enclosing natrolite watch for fractured crystals held together by natrolite in crevices. After natrolite removal use a dilute solution of NH_4HF_2 for three hours to dissolve dried silica gel residue causing lustrous neptunites to 'pop.' Naturally dull crystals not significantly improved by this treatment. Avoid metal tools for silica gel removal.

Niccolite: Use dilute HCl to remove calcite.

Nobleite: Sensitive to water, acids, alkalis and alcohol. Clean by mechanical means only. Treat as a Water Sensitive Mineral.

Norbergite: Treat as Chondrodite.

Obsidian: Excellent chemical resistance. Sensitive to thermal shock damage. Derust with any dithionite recipe or hot oxalic acid.

Offretite: See Zeolites.

Okenite: Needles very delicate; avoid brushing. Difficult and tedious to clean; dust and fuzz are the only common issues. Becomes matted in water; remove loose debris by swishing in alcohol or acetone. Avoid force (air or water jets). Best cleaned by tedious work with needle point tweezers. See Zeolites.

Oligoclase: Tolerates Iron OUT/EDTA. See Albite and Feldspar.

Olivenite: Sonication with detergent or soap in bath tolerated. Darkens and yields a fine copper metal precipitate with dithionite. Avoid acids and NH_3. Treat as a Copper Mineral.

Olivine: Thermal shock sensitivity. Attacked by oxalic acid.

Onyx: Test with a drop of concentrated HCl. If effervescence is observed, treat as Calcite. If not treat as Chalcedony. Some samples are a mixture of these two minerals and so should be treated as the more delicate species (Calcite).

Opal: Opal which has crazed or cracked due to dehydration is unrepairable. Avoid sonication (Cook, Gaber and Clifford 2007, 49; Macleod 1970 and Pearl 1972, 27). Common opal and opal-AN tolerate any dithionite recipe. Survives hot oxalic acid without luster loss but often heat sensitive. Attacked by NH_4HF_2; sustains mass loss (overnight) but remains gemmy, glassy and lustrous even after two weeks. Etched slower than chalcedony but faster than quartz. Uranium content of fluorescent varieties is insufficient to require treatment as a radioactive mineral. Typically stored in a sealed plastic bag containing a damp paper towel or under glycerine in a closed container, but Cook, Gaber and Clifford (2007, 49) recommend avoiding storage in water for long periods or in glycerin or oil for any length of time. Sury (1991) recommends opals should be periodically given a brief water immersion to prevent dehydration damage. Avoid extreme temperatures. Clean with a soft cloth using mild soap and warm (not hot) water. See also Hyalite.

Orpiment: Soft; brittle; easily cleaved. Avoid stiff brushes and hard tools. Slowly attacked by hot water. Tolerates Iron OUT/EDTA. Enclosing calcite customarily removed with dilute HCl (watch for fractured crystals), but acetic acid is a milder choice. Treat as a Sulfide and a Water Sensitive Mineral.

Orthoclase: High chemical resistance. Derust with any dithionite recipe or with hot oxalic acid but pay attention to associated species. Slightly attacked by hot alkali. May be attacked by NH_4HF_2 (most samples have good stability), but feldspar can be coated against attack if this reagent is used to clean/remove other species present. Use caution and limit exposure. See Feldspars.

Ottrelite: Treat as Chlorite.

Paigeite: See Vonsenite.

Palygorskite: Fragile, especially mountain leather variety. Clean only with gentle gas stream or tweezers or not at all. Treat as Asbestiform Mineral.

Paragonite: Derust with any dithionite recipe or with oxalic acid.

Parasymplesite: See Köttigite-Parasymplesite.

Paratacamite: Use only distilled water to clean. Treat as a Copper Mineral.

Paravauxite: Fragile; brittle.

Pargasite: Excellent chemical resistance.

Parisite: Derust with any dithionite recipe. Remove calcite with cold, dilute acids but watch out for associated minerals. Some samples are parisite replacements by limonite or other minerals; because of mixed or unknown composition these specimens should not be cleaned chemically.

Peacock Ore: Formed by oxidation of bornite or chalcopyrite or a mixture of these minerals. Chemical treatment may remove the peacock iridescence; best to avoid any chemical treatment. Treat as a Copper Mineral and a Sulfide.

Pearceite: See Silver Minerals.

Pectolite: Crystals delicate; avoid tools. Wears gloves while handling as crystals can be needle sharp. Terminated crystals tolerate sonication well (Betts 2025a). Broad intolerance to acids.

Pegmatite Minerals: To remove kaolin crust soak in Coca-Cola 24 hours then flake off and brush (Anonymous, 1970). Other sodas containing H_3PO_4 are probably equally effective. May include minerals having excellent chemical resistance (quartz, tourmaline, beryl, etc.) to those having poor chemical tolerance (strengite, calcite, etc.). See individual mineral species.

Penfieldite: Poorly soluble in water; tolerates brief water rinse followed by immediate and thorough drying. Decomposed by prolonged water immersion. Treat as a Water Sensitive Mineral.

Pentagonite: See Cavansite.

Periclase: Slightly soluble in water; clean with alcohol or acetone only.

Pericline: Treat as Albite.

Peridot: Treat as Forsterite.

Peridotite: Green color may be bleached (due to Fe^{2+} loss) by oxalic acid.

Peristerite: Treat as Albite.

Perlite: Some samples sufficiently porous so care must be taken to rinse thoroughly after chemical treatment. Treat as Obsidian.

Petrified Wood: Excellent chemical resistance. Most frequently colorfast. Sinkankas (1970, 299) indicates black petrified wood can be bleached in laundry bleach or oxalic acid. Treat as Quartz.

Pharmacolite: Broad chemical sensitivity; clean only in pure water.

Pharmacosiderite: Avoid detergents, soaps, NH_3 and other alkaline solutions. In one case a color change was noted which was reversed upon brief exposure to 5% HCl.

Phenakite: Broad chemical resistance. Derust with oxalic acid (watch for thermal shock) or (better) any dithionite recipe.

Phillipsite: Avoiding sonication or HCl sometimes recommended. Potentially unstable to acetic acid and formic acid. Attacked by hot alkali. See Zeolites.

Phlogopite: See Micaceous Minerals.

Phoenicochroite: Fragile; use care when cleaning.

Phosgenite: Soft; brittle; easily scratched. Avoid steel tools. Sensitive to thermal shock. Quickly attacked by acids resulting in dull crystal faces. Quickly turns brown upon exposure to bleach. Treat as a Carbonate.

Phosphophyllite: Soft; easily cleaved; brittle. Thermal shock sensitive.

Pitchblende: Avoid cleaning if possible. Treat as a Radioactive Mineral.

Plagioclase: Treat like Albite.

Planerite: Tolerates Iron OUT/EDTA.

Platinum: Highly resistant to chemical attack. Derust with any dithionite recipe or with hot oxalic acid. Does not tarnish.

Plumbogummite: Stable to dithionite and bleach.

Plumosite: Treat as Boulangerite.

Polianite: Treat as Pyrolusite.

Polybasite: Soft; easily scratched and chipped. Sooty coating removed by sonication. Treat as Silver Mineral.

Polycrase: See Euxenite.

Powellite: Soluble in HCl and HNO_3 (Weiner and Hochleitner 1998e).

Prehnite: Tolerates Iron OUT/EDTA. Rust sometimes penetrates deeply between fibrous crystals and is impossible to remove. Sources disagree on tolerance to oxalic acid; avoid this for derusting. Alternately, remove rust via air abrasion with limestone sand; quartz sand is too harsh (Pearl 1972, 34). Slowly attacked by HCl which produces white coatings but quick immersion in diluted HCl (perhaps to remove calcite) acceptable in some cases. Calcite coatings effectively removed with 30% acetic acid but thin plates may disintegrate if intergrown with calcite. Stable to hot alkali. May be stable to heating with mildly alkaline laboratory cleaner or household dish soap. Black coating seen on some samples is todorokite and thus should not be removed (Wilson and Currier 2001).

Probertite: Best exposed from its ubiquitous green-gray clay matrix by brief (30 seconds) sonication followed by immediately patting dry. Any residual clay tends to be very friable after drying and thus easier to remove. Treat as a Water Sensitive Mineral.

Prochlorite: Treat as Clinochlore.

Proustite: Very soft and easily chipped. Sensitive to thermal shock damage. Avoiding sonication sometimes recommended. Tolerates Iron OUT but Gol (2004b) recommends derusting with tartaric acid. Avoid oxalic acid as silver oxalate salts which may form can be explosive when heated (Gol 2004b). See Silver Minerals.

Pseudomalachite: Fragile. Treat as a Carbonate and a Copper Mineral.

Psilomelane: A generic term for unidentified manganese hydroxides/oxides. Composition not fixed so response to cleaning chemicals can be variable. Releases toxic chlorine gas on exposure to HCl. Large or thick masses can be removed with oxalic acid if tolerated by associated minerals.

Purpurite: Remove dark alteration coatings with dilute HCl. Specimens labeled as purpurite are commonly heterosite instead. See also Heterosite.

Pyrargyrite: Avoiding sonication sometimes recommended. Derust with tartaric acid and avoid oxalic acid as silver oxalate salts which may form can be explosive (Gol 2004b). Treat like Proustite. See also Silver Minerals.

Pyrite: This section is about cleaning pyrite. For halting oxidative decay ('pyrite disease') and pyrite conservation measures see Section 5.8D.

A widespread mineral whose exact composition and stability may vary somewhat between localities and even samples from the same locality so best to test any chemical cleaning method which lower quality material from the same locality (and even same pocket if possible) before committing superior quality material. Notes here cover general properties more than the exceptions. Often associated with marcasite; any cleaning plan must therefore tolerate both species.

Water may initiate and promote decomposition of some pyrites ('pyrite rot') so dry cleaning methods are generally preferred (Pearl 1972, 51–53). Specimens with a metallic or sulfurous odor are decomposing. Additional symptoms include cracks, crumbly and/or grey crystals/matrix and/or efflorescence. While this decomposition can be treated and the specimens conserved in most cases it is better for the rest of the collection to discard the problematic specimen. Even slightly decomposed samples may have rough crystal faces whose luster cannot only be restored to an unnatural state by mechanical polishing or air abrasion, but abrasion with a soft medium has been recommended (DeLano 2015). When handling even slightly decomposed pyrite wear gloves as the odor will persist on the skin even after thorough washing with soap and water.

A dull or brown tarnish on pyrite is self-passivating and should not be removed by chemical means (Allington-Jones 2017, 2). Pearl (1972, 51) recommends dry brushing to clean marcasite; the same method should be considered for pyrite. Tolerates sonication unless decomposition is advanced. Sonication of even slightly decomposed samples may cause the bath to become acidic; check pH and make alkaline with NaOH, KOH or $NaHCO_3$ or replace bath if acid sensitive minerals (carbonates) are suspected to be present. Change bath water immediately after sonicating decomposed sulfides even if still alkaline. Soft marl matrix of Ampliación a Victoria Mine samples rapidly disintegrates (seconds) when sonicated.

Tolerates any dithionite recipe. May be brightened by Iron OUT/EDTA; in some cases, this effect is brief (few hours) while in other cases it may be permanent. For derusting King (1983, 68) recommends Waller's solution while Gol (2004b) suggests tartaric acid. King (1983, 68) further recommends that to avoid decomposition derusted specimens should be kept cool (no more

than 22°C) and dry (relative humidity 55% or less). Avoid concentrated mineral acids; pyrite is slowly etched by concentrated HCl but is stable to half this concentration. To preserve the typical, thin oxidation layer treat only briefly with oxalic acid. Said to be brightened with Lime-A-Way (the brightening agent in this product is probably H_3PO_4) if not "weathered too much" (Currier 2010a). Some samples brightened by NH_4HF_2 but resulting luster may become dull in hours to weeks (or longer) or may be permanent (NH_4HF_2 probably removes a thin oxide layer which may develop again on standing). NH_4HF_2 is acidic so associated minerals (carbonates, etc.) may be attacked. Faller (2023) reports that a pyrite specimen soaked it in a strong Alconox [Powdered Precision Cleaner] solution for about eight hours made the specimen "blindingly brilliant."

Pyrite 'suns' are pyrite or marcasite or a mixture thereof. Often brittle and with cracks which may not be visible. Water causes decomposition to begin in some cases (if decomposed treat as above; see also Section 5.8D). Suns are sometimes bleached to initiate or enhance iridescence, but this treatment also initiates or accelerates decomposition unless sun is immediately coated with polyurethane or lacquer (but coating is unnatural and undesirable, and its protective value has been questioned; Section 5.8D). Bleached, uncoated suns typically decompose in months, but unusual cases can be stable for decades. Allow untreated suns to sit for a few weeks to few months before beginning cleaning so that any suns which have already begun irreversible rot will have obvious symptoms of rot. Removing the black coating (shale) is the major cleaning task. Start with brass brush then textile gun followed by sonication. (Shale removal by air abrasion - avoiding all water - may reduce loss to decay.) For a brighter sun (and to assist removal of the most tenacious shale residues) soak in a 1:5 concentrated HCl to water solution for a few minutes prior to sonication. Natural attachment to shale matrix is tenuous and so suns on matrix often glued (based on DeLano 2015 and Delano 2017).

Pyrite nodules from Pakistan encased in a tough, unidentified black matrix were partially excavated by alternating treatment with a textile gun and with a vibratory impact tool. Air abrasion is likely a viable alternate in this case but was not explored due to the poor ratio of sample value versus preparation time for this procedure.

Calcite enclosing pyrite can be removed with dilute HCl but contact time should be minimized. Nodules in shale matrix may be freed by soaking in soapy water for a few days followed by textile gun or sonication to complete the process (DeLano 2015).

Treat as a Sulfide.

Pyrolusite: Avoid oxalic acid. Inert to HNO_3 but soluble in hot HCl with evolution of toxic chlorine gas (King 1983, 69). Dissolves in 12% H_2O_2 with vigorous evolution of oxygen gas in 1–2 hours (many Mn minerals are attacked by this reagent). This effervescence can be utilized to remove soil and other loose debris by immersing in 12% H_2O_2 for one minute (significant effervescence and some heating) followed by brief sonication. See also Psilomelane.

Pyromorphite: Fragile; soft; avoid hard tools. Some samples suffer some luster loss when treated with Iron OUT/EDTA. Jacquard Hydro may be a viable alternative. Avoid detergents, soaps, NH_3

and other alkaline solutions. Attacked by acids and alkalis (King 1983, 69) so calcite removal impractical. Brown coloration often due to rust inclusions and are thus not removable.

Pyrope: See Almandine-Pyrope and Garnet.

Pyrophyllite: Partially to fully derusted by hot oxalic acid.

Pyroxene group: Easily cleaved; prone to effervescence-induced splintering during carbonate dissolution by acid. Use only vinegar for extraction from carbonates as this acid causes less vigorous effervescence than HCl (King 1983, 69). Attacked by NH_4HF_2.

Pyrrhotite: This section is about cleaning pyrrhotite. For repair of oxidative decomposition ('pyrite disease') and conservation see Section 5.8D.

Prone to decomposition. Decomposing specimens (crumbly, white crusts or metallic/sulfurous odor) best discarded. Tabular crystals more prone to decomposition than prismatic crystals. Water and humidity may accelerate decomposition in samples where the process has already begun so cleaning and developing by dry methods is preferred. Pearl (1982 51–53) recommends dry brushing. Even slightly decomposed samples may have rough crystal faces whose luster can only be restored to an unnatural state by mechanical polishing or air abrasion. If decomposed, sonication may cause bath to become acidic; check pH and basify or replace if acid sensitive minerals (carbonates) are suspected to be present. Replace bath (regardless of pH) immediately after sonicating.

Thin crevices between stacked tabular crystals may harbor cleaning chemical residues so thorough pure water soaking and rinsing mandatory (with sonication beneficial) after any chemical treatment. Tolerates any dithionite recipe; some samples may be brightened. Gol (2004b) recommends derusting with tartaric acid. Stable to NH_4HF_2. Some samples brightened but resulting luster may become dull in hours to weeks (or longer) or may be permanent. (NH_4HF_2 probably removes a thin oxide layer which may develop again on standing). NH_4HF_2 is acidic so associated minerals (carbonates, etc.) may be attacked. Calcite is removed with HCl without serious damage to luster. Attached siderite more difficult to remove as chemicals which attack siderite are likely to also attack pyrrhotite.

For many other cleaning issues can be treated as Pyrite. Treat as a Sulfide.

Quartz: Quartz has superb chemical resistance suggesting it should be among the easiest of minerals to clean. However, 'just cook it in acid' is a recipe for disaster. Numerous issues must be considered when planning the cleaning of a quartz specimen. The comprehensive article by Currier (2014) is a good place to start.

Thermal shock damage potential is high, especially when cracks, inclusions (rutile, tourmaline, etc.), fluid bubbles (liquid, gas or biphasic) or any other stress-inducing factors are present. Twinned samples also prone to break along the twinning plane when thermally shocked.

Some sources recommend avoiding sonication when any of these factors are present while other workers use sonication frequently. Scepter quartz is sometimes intolerant to sonication whereas (unstressed) Herkimer diamond quartz is stable (Betts 2025a). Allington-Jones (2017, 3) recommends a latex-free cosmetic sponge to clean amethyst. Amethyst geodes must be treated with care because calcite and other minerals inside can be quite fragile. Use compressed gas or (only if necessary) gentle application of a textile gun.

Exceptional chemical resistance. Many recommendations to avoid certain chemicals are due to intolerance of associated minerals and not the quartz itself. Stable to any dithionite recipe but rust and clay deep in cracks almost impossible to remove. All forms of quartz tolerate all dithionite recipes. Famously stable to hot oxalic acid but care must be taken to avoid thermal shock damage. Kandutsch (1983) states "Clean with oxalic acid and avoid HCl if possible" but the latter precaution is nonsense unless the issue is to avoid yellow stains when dry. King (1983, 58) recommends derusting with tartaric acid. Tolerates 10% H_3PO_4. Stable to hot alkali (with or without TKPP) but may be attacked on prolonged exposure. Many sources state NH_4HF_2 etches quartz but the effect is generally slow (unobservable after 24–48 hours but notable mass loss without frosting after 9 days was seen). Longer exposure (weeks to months) is said to slowly cause frosting. Brief exposure can often be tolerated but check on lower quality material first. Better quality crystals such as Arkansas rock crystal are more resistant. NH_4HF_2 etches crystalline quartz more slowly than chalcedony or opal-AN.

Much 'red quartz' is merely hematite- or rust-stained, colorless to pale quartz. When the color is truly due to hematite inclusions and not just a surface stain it persists after treatment with hot oxalic acid solution. Surface hematite can be removed with concentrated HCl but the surface beneath is often rough.

A thin white surface crust maybe a carbonate (test with HCl) or a silica/quartz layer. If nothing besides quartz and calcite are present the calcite is easily removed by treating as described in Section 3.18. Lieber (1978) describes a procedure for selective calcite removal in which portions of the specimen to be protected against acid are wrapped in plasticine or coated in liquid beeswax. After treating with a solution made by adding concentrated HCl to an equal volume of water the beeswax is removed with acetone. (Benzene is also suggested but must be avoided as it is a highly flammable and a known human carcinogen.) The beeswax coating must be thick to be effective. It is easily prone to damage, requiring very careful handling and frequently reapplication. The effectiveness of beeswax to prevent acid attack is limited because acid can seep underneath the edges of the coating. The beeswax must then be removed before final rinse/soak steps (such as $NaHCO_3$) to remove last traces of acid. If acid fails to remove the coating it may yield instead to the methods for removing silica sinter (Section 3.17) or air abrasion. In other cases, the coating is ingrown into the crystal face or may be natural etching and cannot be removed by any method short of unacceptable grinding and polishing. Removal of any quartz coating by chemical methods may leave a dull (frosted), pitted surface. Whink Rust Stain Remover (liquid) has been recommended to clean quartz due to its HF content (Danilo 2005), but this product has been

recently reformulated to exclude this exceptionally dangerous chemical (Section 3.32). The new formula does not include any ingredients which will etch quartz.

For removing chlorite and similar micaceous coatings see Chlorite.

Several Pala Mining District (California) quartz crystals were cleaned of their enclosing pink montmorillonite clay without luster loss by treating with undiluted Dawn Ultra dish soap at 60–80ºC for eight hours followed by textile gun treatment.

Radioactive Minerals: Minimize handling such as cleaning and sonication. If cleaning is necessary, work outdoors and wear good quality disposable gloves which are discarded after use. See also Section 3.29.

Rammelsbergite: Green coatings are annabergite which might possibly be removed (if not natural) by careful acid treatment.

Realgar: Soft, brittle; thermal shock sensitive. Light sensitive. Alters to orange pararealgar and not orpiment as is widely thought (Douglass, Shing and Wang 1992). Avoiding sonication sometimes recommended. Gol (2004b) recommends derusting with tartaric acid. Readily attacked by concentrated acids (King 1983, 69) and alkalis. Enclosing calcite removed with dilute HCl but minimize exposure time. Treat as a Sulfide.

Reinite: Treat as Ferberite.

Rhodizite: Crystals often badly fractured and likely to disintegrate. Use care when removing supporting matrix.

Rhodochrosite: For derusting avoid recipes having chelators as these may dissolve Mn^{2+}. Tolerates Jacquard Hydro. Brown coatings resistant to mechanical cleaning methods may be ferroan rhodochrosite which cannot be removed without damage. Good but imperfect resistance to acids at room temperature (Hardinger 2024a) but readily soluble in dilute warm mineral acids (King 1983, 69). Other sources indicate rhodochrosite is attacked to some extent by all acids and note that Argentinian material is attacked unevenly across its surface. One unpublished report recommends avoiding oxalic acid whereas Pearl (1972, 31) states "becomes strikingly attractive" when cleaned with oxalic acid. A quick dip in dilute HCl may mask minor chips and scratches. Stable to 12% H_2O_2. Miller (1971) gives this recipe for removing black Mn coatings: "May be removed without damage to the specimen by immersing it in water, adding a few drops of HCl (concentration not mentioned but assumed to be muriatic acid) and a few milliliters of 3% H_2O_2. Specimen will effervesce as the coating dissolves. Of course, an excess of acid must be avoided to prevent damage to the rhodochrosite." Weathering may cause a dark Mn-rich surface coating to develop which is removeable but leaving a dull, pitted surface. Gypsum is removed from Mexican rhodochrosite via an ion exchange procedure (Section 3.19). Treat as a Carbonate.

Rhodonite: Brittle; easily cleaved. Take care when exposing crystals from supporting matrix. Coat crystals with several layers of diluted water-based glue (polyvinyl acetate) to stabilize before reducing matrix. Some specimens slowly attacked by HCl resulting in dull crystal faces. HCl treatment can also deposit black Mn-containing material (MnO_2?) which might be removed by the procedures given in Section 3.16. Highly sensitive to other acids even citric acid.

Richterite: Treat fibrous material as Asbestiform Mineral.

Riebeckite: Treat fibrous material as Asbestiform Mineral.

Rock Crystal: See Quartz.

Rosasite: Delicate; easily bruised. Clean only by gentle rinse in distilled water or by gentle gas puffs. Attacked by Iron OUT/EDTA. Treat as a Carbonate and a Copper Mineral.

Rose Quartz: See Quartz.

Rubellan: Treat as Biotite.

Ruby: Treat as Corundum.

Rutherfordine: Treat as a Radioactive Mineral.

Rutilated Quartz: Inclusions cause susceptibility to damage by thermal shock or sonication. See Quartz.

Rutile: Broad tolerance to sonication (especially large, well-formed crystals) unless cracked. Crystals in matrix may be fragmented; use care when removing supporting matrix. Pyrophyllite matrix easily excavated with vibratory impact tools. Pure TiO_2 is white (a common paint pigment), but natural rutile specimens are almost always a red to brown color due to Fe and cannot be made white by any procedure short of destroying the specimen. Excellent chemical resistance. Tolerates all dithionite recipes. Not attacked by acids (King 1983, 69). Stable to hot oxalic acid which may be used to derust (even when in pyrophyllite matrix) without luster loss. May be partially to fully etched from a limonite matrix with hot oxalic acid solution. Stable to hot alkali/TKPP. Good resistance to NH_4HF_2.

Saleeite: Treat as a Radioactive Mineral.

Samarskite: Brittle. Frequently heavily fractured; matrix removal often results in disintegration. May be altered internally to a brown, powdery mass so avoid removing surface coatings. Earthy surface coatings generally not removable. May be radioactive; treat as Radioactive Mineral.

Sanidine: Treat as Albite.

Sapphire: Treat as Corundum.

Satin Spar: Treat as Gypsum.

Scapolite: Some samples have crumbly outer surface layers which are easily damaged by hard tools. Stable to all acids but see below. Tolerates any dithionite recipe as well as hot oxalic acid. Extract from carbonate matrix using vinegar. Acetic acid of higher concentration or any mineral acids likely to result in effervescence-induced splintering (King 1983, 69). Remove calcite with dilute HCl but minimize exposure because this acid slowly attacks scapolite. Opal coatings generally not selectively removable by any chemical or mechanical method and therefore best left alone.

Scheelite: Brittle; may chip or crack with rough treatment. Matrix crystals may be fractured; use care when removing supporting matrix. Tolerates any dithionite derusting recipe. Chemically pure scheelite is colorless; natural samples tend to be orange to black due to Fe which cannot be made colorless without destroying the specimen. Sinkankas (1972) indicates excellent acid resistance whereas Kandutsch (1983) states "soluble in acids" [a falsely broad statement] but "can be placed in HCl without hesitation to remove any [carbonate] sinter." However dilute HCl causes frosting and some luster loss after 24 hours.

Schorl: Treat as Tourmaline.

Schröckingerite: Treat as a Radioactive Mineral.

Schulenbergite: Avoid detergent, soap, NH_3 and any alkaline cleaning solutions. Treat as a Copper Mineral.

Scolecite: Attacked by 20% formic acid. Stable to hot alkali. See Zeolites.

Scorodite: Fragile; cleavable; easily damaged. Avoid detergents, soaps and NH_3. Clean by sonication in distilled water.

Scorzalite: Treat as Lazulite.

Selenite: Treat as Gypsum.

Sericite: Usually removed with steel tools sometimes assisted with alternating baths in oxalic acid. Treat as Muscovite.

Serpentine: Tolerates Iron OUT/EDTA.

Serpierite: Avoid detergent, soap, NH_3 and any alkaline cleaning solutions. Treat as a Copper Mineral.

Siderite: Tolerates any dithionite derusting recipe. Good but imperfect resistance to acids (Hardinger 2024a). Tolerates acetic acid but attacked (bleached) by HCl especially when hot. Oiling suggested to restore luster but not recommended. Slowly soluble in cold HCl but very rapidly in warm HCl with obvious CO_2 evolution (Weiner and Hochleitner 1998f). Attacked by NH_4HF_2 which is weakly acidic. Avoid hydrogen peroxide. Treat as a Carbonate.

Silicate Minerals: Wide range of properties and chemical resistance. See individual listings.

Sillimanite: Fibrous habit may trap residual chemicals; rinse thoroughly after chemical treatment (King 1983, 70). Stable to all mineral acids.

Silver: Handle with care. Flexible but tends to break easily where connection points are small (herringbone crystals or thin sheets). Sheets often easily peeled away from matrix. Avoid brushing as brushes stiff enough to remove coatings and embedded particles will likely scratch the silver; can also leave rounded edges with unnatural appearance. In general, avoid mechanical cleaning of finely crystallized silvers. Acceptable to remove dirt and dust but not patina. Sonication often recommended whereas chemical treatment is disdained. In one case, a large, crystalline Michigan native silver specimen was significantly improved by sonication for two hours; some grey to black coating was removing revealing bright silver beneath but the silver did not become unnaturally bright. Tolerates Iron OUT/EDTA usually with increase in luster but without becoming unnaturally bright. Brief (one minute) sonication after dithionite treatment resulted in further improvement but again without becoming unnaturally bright.

King (1983, 70) recommends starting with just soap and water. If cleaning is insufficient either accept the specimen's current state or try other methods. King and Sinkankas (1970, 299) also gives this procedure: In glass container cover specimen with solution of 30 g $NaHCO_3$ and 30 g NaCl in 2 liters of distilled water. Use purest quality water possible; analytical grade preferred. Add strip of Al foil (in contact or not in contact with specimen is not specified). Al pan can be used but it corrodes over time. Heat but do not boil (time not specified). Rinse and dry thoroughly. Method said to be particularly effective for silver-copper intergrowths. The Burns method (1941, 157) is similar except that the silver being cleaned must be in contact with the aluminum (or zinc)

vessel. The cleaning solution is composed of 28 g each $NaHCO_3$ and NaCl in two quarts water and is boiled. Robbins and Irving (1981, 185) give this procedure to clean badly tarnished silver: In a glass, porcelain or plastic vessel (never metal) soak in a solution of equal volumes NH_3 and water then 10% formic acid for at least two minutes. When only lightly tarnished soak in 5% formic acid for two minutes. Remove tarnish with cotton swab dipped in the same solution. The aluminum pan method used to clean native copper may be used for silver and accelerated and/or the need for heat obviated by adding Na_2CO_3 or Na_3PO_4 to the solution (Pearl 1972, 45). Another recipe (after Robbins) is given by Gol (2004c): Immerse specimen in 50% NH_3 solution. Rinse. Immerse specimen in 10% formic acid solution for a few minutes (5% is adequate if tarnish is only slight). An interesting recipe but lacking in detail (and perhaps in chemical logic) involves soaking in Worcestershire sauce and $NaHCO_3$, rinsing then washing in $NaHCO_3$ solution.

Various household silver cleaners have been recommended with no product being favored despite a wide range of formulations (Lieber 1978). However, silvers cleaned this way are easily tarnished. A 'dip' product is better than a 'wipe' (polish) product as the latter usually contains an abrasive. In addition, many silver cleaners contain thiourea - a suspect human carcinogen - and thus should be avoided (check the product's SDS; see also Section 3.32).

NH_4HF_2, HCl and HNO_3 are said by Sinkankas (1970, 299) to clean native metals but no details are given. Silver is quickly tarnished by powerful oxidants such as H_2O_2 and bleach. In some samples silver may be oxidized to silver chloride; Scott (1926, 22) gives methods (but without details) for reduction back to silver.

Humic soil is removed from crystalline Michigan silver using a dilute sulfamic acid solution (concentration not specified) leaving a good but not unnaturally bright luster (Rosemeyer 2025).

Tarnish is common and natural; bright silver is unnatural. Resistance to tarnish varies widely between specimens and their storage environments. Avoid storing near sulfides, sulfosalts and native sulfur. Crystals of acanthite (Ag_2S) have been reported to form on silver specimens in a sulfur-rich environment (Heyman 2025). Some cleaning methods may result in unnaturally bright luster and completely lacking in dark patina; experiment on lower quality material from the same find first (natural impurities in silver may influence outcome of cleaning method so success with silver from one find does not guarantee success with silver from a different find). Bright silver generally reacquires a tarnish after chemical or mechanical cleaning. Many silver cleaning products will remove tarnish but unless the specimen is coated tarnish inevitably reappears. Store in a well-sealed container when possible. Numerous anti-tarnish products such as Silver Saver or a block of camphor (caution: strong odor) are worth exploring.

See also Silver-Copper Intergrowths.

Silver Minerals: There is an abundance of household silver cleaning products on the market but for cleaning silver-containing minerals these have received mixed reviews. Some collectors claim excellent results with some products while other collectors report the products to be anywhere from ineffective to damaging. This entire category of products should most likely be avoided

unless you have good experience with a specific product applied to specific mineral(s) from a specific locality (see also Section 3.32). Clean with soapy water and brushing (Homenuke 2018). Sodium thiosulfate produced during aqueous decomposition of dithionite attacks silver halides (chlorargyrite, bromargyrite, embolite) so avoid all dithionite recipes. Avoid oxalic acid; silver oxalate salts which may be formed can be explosive when heated (Gol 2004b). Black and white photographic film developers (hydroquinone and metol) have been suggested to clean silver minerals (Gol 2004c) but should most likely be avoided as these developers work by reducing Ag^+ to metallic Ag.

Silver-Copper Intergrowths: These can be cleaned by any of the methods given for copper or silver, but care must be taken to select a method compatible with both species. Iron OUT/EDTA followed by sonication gives mixed results. In one case the copper was brighter after one hour, but the silver was little improved. Extending treatment to overnight provided satisfactory cleaning of the silver as well. In another case treatment for one hour with Iron OUT/EDTA resulted in a grayish precipitate. After sonication for one minute the copper and silver had both brightened but not unnaturally so. Continued overnight treatment and sonication did not change the copper but improved the silver somewhat. The aluminum pan method used to clean silver generally does not improve the copper portion of the specimen.

Sklodowskite: Very fragile; clean only with very gentle gas puff but best to avoid cleaning altogether. Treat as a Radioactive Mineral.

Skutterudite: Tolerates Iron OUT. Tolerates NH_4HF_2; some samples may be brightened but may become dull again in hours (or longer) or be permanent. Use HCl or citric acid to remove associated calcite.

Smaltite: Treat as Skutterudite.

Smithsonite: Derust with any dithionite recipe followed by soak in NH_3. In one case derusting with Jacquard Hydro caused a black coating with distinct rotten eggs odor (H_2S) to develop (without loss of luster); the coating was unaffected by the textile gun but faded after sonication and thorough air drying. Easily attacked by most acids even those as weak as citric acid (Voelter 2010, 94 but see Hardinger 2024a). Upon acid treatment fibrous forms often become glossy whereas coarser forms tend to become rough and cavernous. Samples sometimes oiled which may be removed by soak in acetone or 99% rubbing alcohol but then watch for repairs which are likely to come apart. Use $NaHCO_3$ if cleaning by air abrasion as harder media cause damage. Treat as a Carbonate.

Smoky Quartz: Treat as Quartz.

Soapstone: See Talc.

Soddyite: Treat as a Radioactive Mineral.

Spangolite: Attacked by acids; clean only with pure water. Treat as a Copper Mineral.

Spessartine: Derust with any dithionite recipe. Slow mass loss when treated with NH_4HF_2 but luster and sharp crystal edges retained. See also Garnet.

Sphalerite: Brittle and easily cleaved; avoid metal tools. The pure mineral is colorless and light yellow to black with increasing iron content; cannot be rendered colorless by any treatment which preserves the specimen. Tolerates any dithionite recipe; treatment may brighten the sample temporarily to permanently. Luster and mass preserved when treated with EDTA (used to clean galena). Can be derusted with 3% oxalic acid (King 1983, 71). Readily attacked by acids. Even when attack is minimal rotten eggs smell (H_2S) noticeable. Bright crystal faces rapidly dulled by HCl; use acetic acid or citric acid to remove calcite. Stable to NH_4HF_2; some samples brightened. Treat as a Sulfide.

Sphene: See Titanite.

Spinel: Crystals may be fractured so use care when removing supporting matrix. Broad chemical resistance. Tolerates Iron OUT/EDTA. Use HCl to remove enclosing calcite (Betts 2025a).

Spodumene: Sensitive to thermal shock; easily cleaved along c-axis. Macleod (1970) recommends avoiding sonication, but many samples successfully cleaned by this method. Broad chemical resistance (King 1983, 71). Tolerates Iron OUT/EDTA. Gemmy samples (kunzite, triphane) stable to NH_4HF_2. Crystals on crumbly montmorillonite matrix often need stabilization especially when internally fractured.

Staurolite: Some samples partly to fully replaced by other minerals so use care in cleaning these specimens. Tolerates Iron OUT/EDTA. May become pitted with NH_4HF_2. Crystals frequently exposed from matrix by air abrasion (Lauf and Clifford 2018 and Betts 2025a).

Steatite: See Talc.

Stellerite: See Zeolites.

Stephanite: Sooty film often removable by sonication. See Silver Minerals.

Stibarsen: Soft; brittle. Fragile and easily cleaved. Prone to irreversible bending especially at terminations. Clean only to remove dust and other loose debris. When removed tarnish rapidly returns.

Stibiconite: Often soft and flaky; easily damaged. Dark stains may be unreplaced stibnite or other minerals. Tolerates sonication. Overall chemical composition not fixed or homogeneous so avoid chemical cleaning methods.

Stibnite: Soft; cleavable. Readily chipped and scratched. Easily bent especially at terminations. Avoid aggressive physical methods and metal tools. Gentle brushing or gentle water jet tool (wash bottle) maybe best but overly aggressive brushing and rubbing destroys surface luster. Impacted clay and other dirt may be gently scraped away with wooden toothpick or bamboo sliver (King 1983, 71). Forms a self-protective tarnish coating which should not be chemically removed (Allington-Jones 2017, 2). Whitish, yellow or grey coatings are often oxidation products (stibiconite, valentinite, etc.) and/or pseudomorphous which may be removed with 5–10% NaOH however if replacement is sufficiently advanced specimen may disintegrate. Removal of replacement minerals should be carefully considered as these are part of the natural paragenesis. Tolerates Iron OUT/EDTA but occasionally leaves surface dull or iridescent. Gol (2004b) recommends derusting with tartaric acid. Attacked by and completely soluble in weak acids. Alkalis destroy surface luster; avoid detergents, soaps and NH_3.

Stilbite: Easily cleaved; use care with forceful water jet tools. Remove crevasse dirt and dust by gentle water jet treatment or sonication without detergents, soap or NH_3. Overly vigorously cleaning may dislodge from matrix especially when matrix is soft and crumbly. Derust with any dithionite recipe. Tolerates EDTA. Avoid all acids. Soluble in HCl; bruises sometimes 'healed' by treating rough spots with a drop of concentrated HCl followed by immediate and thorough rinsing. Attacked by hot alkali. Frosty after 24 hours in NH_4HF_2. See Zeolites.

Strontianite: Soft; easily scratched. Fragile. Poor resistance to acids (Hardinger 2024a). Treat as a Carbonate.

Sturmanite: Turns gray but retains luster when treated with Jacquard Hydro overnight but the color was restored after ten minutes in 12% H_2O_2.

Sulfides: Water or humidity may accelerate decomposition in samples where the process has already begun. Sonication of decomposing samples may cause the bath to become acidic; check pH and basify or replace if acid sensitive minerals (carbonates) are suspected to be present and replace bath immediately after sonication. Some sulfides (chalcopyrite, galena, pyrite, pyrrhotite, sphalerite and others) may be brightened by Iron OUT/EDTA but this improved luster may fade in hours (or longer) or be permanent. However, chalcocite rapidly forms a coating of metallic

copper. Gol (2004b) recommends derusting with tartaric acid. Soaking in dilute oxalic acid may restore luster of tarnished specimens but care must be taken to avoid unnecessarily long exposure. Avoid concentrated acids for this purpose (King 1985, 104). Many sulfides are attacked by HCl but a quick dip in this acid (concentration unspecified) may clean tarnish from sulfide minerals; thorough rinsing is needed to remove last traces of acid (Sinkankas 1970, 299). Some samples of some sulfides including arsenopyrite, bornite, chalcopyrite, marcasite, pyrite, pyrrhotite and others may be brightened with NH_4HF_2. This improved luster may fade in hours (or longer) or be permanent. If fine gray precipitate is formed or H_2S (rotten eggs smell) is evolved the sample is likely somewhat decomposed. In this case remove from the solution immediately, sonicate and dry thoroughly. Disintegration is likely in such cases. Dilute acetic acid (vinegar) is slow but effective to remove calcite and some other carbonates (see Hardinger 2024a) from sulfides which may be harmed by more concentrated acetic acid or by other acids. Avoid H_2O_2. See also individual mineral species.

Sulfosalts: Avoid H_2O_2.

Sulfur: Soft; brittle; easily cleaved. Exceptionally sensitive to thermal shock. Hand warmth can cause damage ('crackling noise'). Specimens and cleaning solutions should both be equilibrated at room temperature for at least a few hours before work to avoid cracking and fragmentation. Consider twice before starting any cleaning attempts. Insoluble in water and scarcely attacked by strong acids. Tolerates 12% H_2O_2 and 30% acetic acid. Avoid organic solvents (in which sulfur may be poorly to readily soluble) unless otherwise specified (King 1983, 71). For bitumen removal see Section 3.22.

Sulphohalite: Rinse only with the mother liquor in which the mineral was initially formed (King 1982, 46) because other solutions including brine (water saturated with NaCl) may alter the specimen. Wear gloves as this liquor is usually strongly alkaline and corrosive to the skin. Treat as a Water Sensitive Mineral.

Sylvite: Soft; brittle; easily cleaved. Water soluble; clean only with alcohol or acetone. Treat as a Water Sensitive Mineral.

Synadelphite: Surface rapidly alters when exposed to air, so cleaning is fruitless.

Synchisite: Less sensitive to acids than calcite or strontianite. Treat as a Carbonate.

Taeniolite: Treat as Micaceous Mineral.

Talc: Among the softest of minerals. Quite easily foliated, scratched, dented or otherwise damaged even by soft tools. Tolerates Iron OUT/EDTA. Stable to NH_4HF_2 but some discoloration may occur. May be contaminated with asbestiform minerals; treat accordingly.

Tantalite: See Columbite-Tantalite.

Tanzanite: See Zoisite.

Tarnowitzite: Treat as Aragonite.

Tennantite-Tetrahedrite: May be brightened somewhat by NH_4HF_2. Treat as a Sulfide and a Sulfosalt.

Thénardite: Rinse only with the mother liquor in which the mineral was initially formed (King 1982, 46) because other solutions including brine (water saturated with NaCl) may alter the specimen. Wear gloves as this mother liquor is usually strongly alkaline and corrosive to the skin. Crusts may sometimes be removed by gentle brushing with a toothbrush. Treat as a Water Sensitive Mineral.

Thomsonite: See Zeolites.

Thorianite: Insoluble in HCl; may be used to remove calcite. Treat as a Radioactive Mineral.

Thorite: Treat as a Radioactive Mineral.

Tiger's Eye: May be bleached by oxalic acid or laundry bleach.

Tincalconite: Soft and powdery; easily damaged. Treat as Borax and a Water Sensitive Mineral.

Titanite: Macleod (1970) recommends avoiding sonication whereas many other workers indicate sonication is well tolerated. For derusting tolerates all dithionite recipes as well as hot oxalic acid. Not attacked by HCl, oxalic acid or acetic acid. Use dilute HCl to remove calcite. Stable to hot alkali. Attached chlorite often intergrown into adjacent titanite face; removal leaves rough and pitted surface so therefore best to leave chlorite in place.

Todorokite: Removed from prehnite with acidified H_2O_2 but no details given (Wilson and Currier 2001).

Topaz: Easily developed basal cleavage; take care to avoid cleaving from matrix. Sensitive to thermal shock damage. Fairly hard; some coatings readily removed with steel tools. Deep red

brown color of Mexican topaz due to microscopic rutile inclusions which cannot be removed. Macleod (1970) recommends avoiding sonication which is an appropriate warning for cracked crystals, otherwise this species is generally tolerant of this treatment. Derust with any dithionite recipe. Use hot oxalic acid only when dithionite fails (take care to heat slowly due to thermal shock risk). Broad acid resistance. Coatings can be removed "quite effectively" by strong acids including aqua regia (King 1983, 72; but aqua regia should be avoided - see Section 3.32). Stable to NH_4HF_2; sandy rhyolite partially removed by this reagent followed by textile gun, but the rhyolite is usually also included within crystal and therefore cannot be completely removed.

Torbernite: Micaceous and brittle; flakes easily. Treat as a Micaceous Mineral and a Radioactive Mineral.

Tourmalinated Quartz: Inclusions cause susceptibility to damage by thermal shock or sonication. See Quartz and Tourmaline.

Tourmaline: This is a group consisting of about 50 distinct mineral species whose compatibilities with mechanical and chemical cleaning methods are all essentially identical for the most common members. Fairly hard. Coatings are commonly removed by scraping with steel tools or by air abrasion but residues in confined spaces usually need chemical treatment or air abrasion. Tourmaline clusters may be held together by clay or other minerals; take care when removing these accessory minerals. Crystals in matrix may be fractured (especially when 'frozen') so use care when removing supporting matrix. A vibratory impact tool and air abrasion are useful for this purpose (Sinkankas 1970, 287). San Diego County pink tourmaline is frequently exposed from enclosing lepidolite with air abrasion (Betts 2025a).

Broad chemical resistance. Derust with any dithionite recipe. Excellent resistance to all mineral acids and organic acids including hot oxalic acid which may be necessary for derusting if dithionite fails (King 1983, 72). Stable to hot alkali (with or without TKPP; including Neodisher LM3) and NH_4HF_2 but many other associated species (cookeite, phosphates, etc.) are attacked. Alternating NH_4HF_2 with hot alkali treatment often more successful than either reagent alone for removing coatings.

Travertine: Porous; take care to rinse thoroughly after any chemical treatment. Otherwise treat as Calcite (but travertine is tougher).

Tremolite: Stable to all acids. Fibrous or asbestiform habit can retain chemical traces so rinse thoroughly after any chemical treatment (King 1983, 72). Use HCl to remove calcite; crystals may be fibrous or fractured so use care when removing supporting matrix. When fibrous treat as Asbestiform Mineral.

Tridymite: Tolerates sonication.

Triphane: See Spodumene.

Troilite: Treat as Pyrrhotite.

Trona: Rinse only with the mother liquor in which the mineral was initially formed as mineral may be altered by other dissolved minerals (King 1982, 46). Wear gloves and safety glasses as this strongly alkaline liquor is corrosive to skin. Treat as a Water Sensitive Mineral.

Tsavorite: See Grossular.

Tunellite: Soft, cleavable; remove clays with bamboo sliver or wooden toothpick. Tolerates brief wash in pure water but otherwise treat as a Water Sensitive Mineral.

Turgite: Iridescence destroyed by Iron OUT/EDTA. See Goethite and Hematite.

Turquoise: Clean only with distilled water; avoid detergents, soaps and NH_3. Oils and greases from handing may soak in; remove by prolonged soak in alcohol or acetone, changing the bath several times and allow to dry between treatments to evaluate cleaning progress. Sinkankas (1970, 288) notes that tumbling may be applied to remove clay and better reveal a specimen's inner beauty. However, this technique is frowned upon by many serious collectors especially when precious crystal faces or natural mineral paragenesis are destroyed. "Never use NH_3, soap or detergent on genuine turquoise. NH_3 will turn it white. A drop on the back of specimen is used to test genuineness" (Anonymous 1970). Avoid HCl. Likely unstable to any dithionite recipe. Destroyed by oxalic acid. Treat as a Copper Mineral.

To stabilize turquoise, add some unmixed, two-part epoxy to a pint of acetone in a closeable container. Avoid an epoxy which expands as it cures. Stir until homogeneous. Soak the turquoise a few days to a week (close the lid) then remove and allow to drip dry for several days. If the solution begins to look cloudy the epoxy is beginning to polymerize, and the turquoise should be removed at once. More advanced techniques involve infusion of the stabilizer under vacuum.

Tyuyamunite: Often soft and powdery; avoid cleaning. Treat as a Radioactive Mineral.

Ulexite: Slowly attacked by water, turning cloudy due to atmospheric moisture. Clean fibrous variety by swishing in alcohol or acetone. Compact masses with parallel fibrous crystals ('TV stone') soft and easily split parallel to fibers. Careful work with steel tools or air abrasion useful to excavate ulexite and reveal enclosed calcite. Treat as a Water Sensitive Mineral.

Uraninite: Treat as a Radioactive Mineral.

Uranocircite: Micaceous; easily defoliated. Treat as Micaceous Mineral and a Radioactive Mineral.

Uranophane: Fibrous material should be gently rinsed in distilled water, alcohol or acetone only. Treat as a Radioactive Mineral.

Uranospinite: Fragile; micaceous. Treat as a Micaceous Mineral and a Radioactive Mineral.

Uranothallite: See Liebigite.

Uvarovite: May be fractured; use care when removing supporting matrix. Tolerates Iron OUT/EDTA. See Garnet.

Uvite: See Tourmaline.

Vanadinite: Brittle; fragile. Easily chipped; avoid firm tools. Red to brown color due to Fe in crystal structure and cannot be lightened or rendered colorless. Tolerates sonication but a few crystals very loosely bound to matrix may be lost. Tolerates derusting with any dithionite recipe without luster loss. Slowly attacked by acids; mineral acids more aggressive than organic acids. Stable to bleach. Quickly discolored by NH_4HF_2. Black coating (Mn minerals; common on Moroccan specimens) removed with mixture of equal volumes 12% H_2O_2 and 30% acetic acid without loss of color or luster. Remove calcite with acetic or formic acid (Gol 2004b).

Vandenbrandite: Treat as a Radioactive Mineral.

Vanuralite: Treat as a Radioactive Mineral.

Variscite: Sinkankas (1970, 288) notes that tumbling may be applied to remove clay and better reveal a specimen's inner beauty. However, this technique is frowned upon by many serious collectors especially when precious crystal faces or the natural mineral paragenesis are destroyed. Porous; easily absorbs water; soak in pure water (several times) after any chemical treatment and allow to dry thoroughly. Use distilled water only; avoid detergents and soaps. Avoid NH_3 and HCl.

Vauxite: Treat as Paravauxite.

Verdelite: See Tourmaline.

Vermiculite: May be contaminated with other asbestiform minerals; treat as such.

Vesuvianite: Crystals may be fractured; use care when removing supporting matrix. Some crystals have a dull, loosely attacked outer layer whose removal reveals a bright underlying surface. Stable to hot oxalic acid at 6 grams per liter but may be attacked at higher concentration. Slowly attacked by dilute HCl but use of this acid to remove enclosing calcite usually does little harm (Betts 2025a). Minimize acid bath immersion time; prolonged exposure may deluster some skarn minerals (grossular, epidote, etc.). Crystals may be intergrown with calcite so acid treatment causes specimen to fall apart. Consider using mechanical methods instead (steel tools, vibratory impact tools or air abrasion). Stubborn 'calcite' which does not effervesce with HCl is likely wollastonite, requiring mechanical removal (Sinkankas 1970, 294).

Violarite: Tarnishes easily; removing tarnish is therefore pointless.

Vivianite: Fragile and soft. Readily cleaved; easily peels and splits with rough handling. Use only wooden toothpick or bamboo sliver. Said to rapidly darken in water (and thus wet cleaning should be avoided) but darkening not observed by numerous other workers. Avoid detergents, soaps, NH_3 and other alkaline solutions. Green vivianite from Bolivia retained its color and luster after 24 hours in Iron OUT/EDTA. Readily attacked by all acids except acetic acid. Black vivianite a result of air oxidation which is irreversible. Associated pyrite may also be unstable and disintegrate; hence store in sealed, air-tight container, preferably in an inert atmosphere (nitrogen, argon) if available. Avoid wet cleaning of vivianite specimens having associated pyrite (King 1983, 72). Keep away from evil (Petrov 2023).

Vonsenite: Acicular varieties fragile; clean only with gentle gas puff or swishing in water, alcohol or acetone.

Wad: Treat as Psilomelane.

Water Sensitive Minerals: Minerals damaged or dissolved by water are common enough that these properties must be considered when cleaning them. Although damage and solubility might be low it is best to err on the side of caution and avoid water and humid environments altogether. Remove loose debris by gentle puffs of canned gas. Do not blow on the specimen as breath contains enough moisture to fog some water sensitive minerals. Remove loose debris 'fused' to the specimen surface use needle tweezers or very light work with a soft brush. Rinse only in organic solvents having minimal to no water content (99% rubbing alcohol or ethanol) then immediately blot dry. Avoid acetone as its rapid evaporation absorbs enough heat from the specimen to cause atmospheric water vapor to condense. If debriding with canned gas or an organic solvent is unsatisfactory rinse only with the mother liquor in which the mineral was initially formed as mineral may be altered by other dissolved minerals (King 1982, 46). Wear gloves and safety glasses as this strongly alkaline liquor is corrosive to skin. Water sensitive minerals are often oiled

to protect against atmospheric moisture; this oil should be left alone, but if it must be removed see Section 3.23.

Wavellite: Sonicate to remove clays and other debris, but avoid detergents, soaps and NH_3. All acids damage luster.

Wernerite: Treat as Scapolite.

Willemite: When enclosed in calcite avoid acids as these attack willemite. Excavate with vibratory impact tool instead (Betts 2025a) or air abrasion but use care while removing supporting matrix as crystals may be fractured. Stabilize with polyvinyl acetate glue solution before removing matrix.

Winchite: When fibrous treat as Asbestiform Mineral.

Window Quartz: See Fenster Quartz.

Witherite: Clean only with pure water; avoid detergent or soap. Poor resistance to acids (Hardinger 2024a). Brushes and scratches may be 'healed' by applying a drop of concentrated HCl followed by immediate and thorough rinsing. Treat as a Carbonate.

Wolframite: An intermediate member in the ferberite-hübnerite solution series. Variable composition so response to cleaning chemicals also variable. Some specimens sensitive to thermal shock or sonication damage. See Ferberite-Hübnerite.

Wulfenite: Brittle. Easily cleaved, especially tabular crystals. Thin crystals extremely delicate; blockier crystals more robust. Rinse only in slow stream of tepid water or acetone; avoid force, especially with more aggressive water jet tools (King 1983, 72). Sonication tolerance depends on thickness. Thick, tabular crystals tolerate sonication better than thin crystals. Associated mineral species may have poor sonication tolerance. Stable to any dithionite recipe. Readily decomposed by acids with slight to severe damage to luster (King 1983, 72). Attacked by NH_4HF_2; luster reduced. Develops a yellow to deep brown coating in hours with bleach.

Wurtzite: Often associated with metastable minerals (marcasite, schalenblende, etc.). Due to water-sensitive sulfide associations best to use dry cleaning and development methods only. Readily soluble mineral acids especially HCl.

Xanthoconite: See Silver Minerals.

Xanthophyllite: See Clintonite.

Xenotime: Stable to hot oxalic acid and 15% HCl. Some samples radioactive; treat as Radioactive Mineral.

Xonotlite: Filiform; clean by rinsing with dry alcohol (95% ethanol or 99% rubbing alcohol) then allow for thorough drying in air. To derust avoid Iron OUT, Waller's solution or Bridge's solution (chelators may attack due to Ca in formula); use Jacquard Hydro (Hochleitner and Weiß 2018). Attacked by HCl and oxalic acid.

Yugawaralite: Brittle and fragile. Wash with soapy water only followed by gentle rinse or sonication. Stable to acids; remove calcite with HCl. Attacked by KOH (Weiner and Hochleitner 1998g).

Zeolites: Any collector needing to clean zeolite specimens should read *Zeolites of the World* (Tschernich 1992). Recommended methods to clean zeolites (in order of increasing possible damage): mechanical (mildest), pressurized gas, running water, pressurized water, Biz Bleach or soap, bleach, ascorbic acid, oxalic acid, acetic acid and HCl (most aggressive). Delicate or fibrous crystal clusters (okenite) can be cleaned by holding the specimen upside in water, acetone or alcohol and gently swishing. Sonication is also useful especially for delicate natrolite sprays and terminated pectolite (Betts 2025a). Some workers add Biz Bleach added to the bath. Acids can be used for example to remove calcite (Tschernich 1992 gives specific acid recommendations for specific zeolites) but use the mildest acid which is effective and keep the exposure time as short as possible. Hardinger (2024a) categorizes common mineral cleaning acids by their aggressiveness. Zeolites with high silicon content are stable in some acids. Tschernich presents a nice table organizing zeolites by silicon content and corresponding acid resistance. Many zeolites are attacked by oxalic acid, acetic acid and dilute HCl (see Benitoite). When in doubt avoid all acids.

Acicular forms often easily damaged; use only gentle gas puffs or swishing in water, alcohol or acetone for cleaning. Mineralogically pure zeolites should be colorless or white, but these minerals often trap various metal cations as well as dirt particles and other debris during growth resulting in unremovable coloration. Kandutsch (1983) states "Zeolites have large 'holes' [channels] in their lattice structure, which [allows them to] readily absorb acids. [When] they release the water, ions from the acid remain in the lattice, resulting in unnatural colors (e.g., brown for stilbite)." To derust use only Jacquard Hydro as dithionite recipes with chelators (Iron OUT, Waller's solution or Bridge's solution) may absorb metal cations and dull the specimen luster.

Due to their general acid sensitivity assume enclosing calcite cannot be removed by acid treatment. Zeolites covering other minerals tend to be intergrown into the surface of the mineral underneath. Removal of the zeolite crust may leave pitted surface causing damage or disintegration of the minerals beneath so best to not remove zeolites overgrowths.

Zeunerite: Micaceous; fragile. Tolerates brief sonication. Treat as Micaceous Mineral and Radioactive Mineral.

Zincite: Crystals in matrix may be fractured so use care when removing supporting matrix. Reinforce with dilute solution of polyvinyl acetate glue before excavating. Attacked by most acids. Remove enclosing calcite with boiling saturated citric acid solution or mechanical means (vibratory impact tools or air abrasion).

Zinkenite: Acicular form very delicate; avoid water which may cause matting. Wash only by swishing in alcohol or acetone. Treat as a Sulfide.

Zinnwaldite: Treat as Micaceous Mineral.

Zippeite: Powdery, radioactive. Treat as Radioactive Mineral.

Zircon: Excellent chemical and mechanical resistance. Clays and other adherents often removed with steel tools, but air abrasion is better. Macleod (1970) recommends avoiding sonication, but many samples have survived this effective cleaning method. Slowly attacked by NH_4HF_2 but luster retained. Use vinegar to extract from carbonate matrix but in such specimens the zircon may be intergrown with calcite; matrix removal may cause disintegration (King 1983, 72).

Zoisite: Tolerates Iron OUT/EDTA and hot oxalic acid. Macleod (1970) recommends against sonication of tanzanite variety.

CHAPTER 5: Further Specimen and Collection Development

Now that your specimen is properly cleaned and prepared what else can be (or needs to be) done to further enhance its aesthetic or scientific value? It is possible to add more meaning and pleasure to your collection at this point? Absolutely! The specimen can be improved by proper labeling and cataloging as well as inclusion into a display. If necessary, it can also be mounted on a stand. Whether displayed or not the specimen must also be properly stored and conserved. Each of these significantly interconnected topics are addressed in this chapter.

Specimens should be properly labeled (Section 5.2) and cataloged (Section 5.3) before being put on display (Section 5.6) hence these topics are discussed in that order. (We all want to hurry to get our latest acquisition on display, but this might occur at the expense of proper labeling and cataloging, with possible future consequences...forgetting locality, loss of information when specimen is deacquisitioned or the collector passes). The overall goals of private and institutional collections are different so there are significant similarities and differences in procedures for both. The discussion in this chapter focuses more on private collections. Excellent references for institutional collections include Brunton, Besterman and Cooper (1984), DeMouthe (2017) and King (1986). These references contain useful advice for private collections as well.

Some ideas in this chapter apply to more than one topic so it is worthwhile to read the entire chapter before engaging in any activity described here.

5.1 Repairs, Restoration and Fakes

A mineral specimen is said to be **repaired** (or less commonly reconstructed) when two or more parts that were together as part of a natural specimen are reattached, usually with glue. A specimen is said to be **restored** when it has been returned to its original appearance when (for example) a missing section has been replaced with natural or synthetic material not part of the original specimen. A specimen constructed or produced in any way to deceive is a **fake**. Fakes may include natural crystals glued onto a matrix or crystals grown in a laboratory.

Repairs are common in the mineral world (Figures 5-1 and 5-2). A specimen may be repaired to improve its aesthetic and economic value. Acceptance of repairs is a matter of personal taste. Specimens in scientific collections are often not repaired, as an unrepaired specimen is more natural than a repaired specimen. Whether for private enjoyment or scientific collection the repair detail (nature of repair with before and after photographs, adhesive used, repair date, etc.) should be noted in the collection catalog.

Commons repairs include damage from a mishandled specimen or reassembly of crystal fragments found separately in the debris of a ruptured or collapsed pocket. For examples see Trinchillo and Pezzotta (2015) and Cornejo and Bartorelli (2009, 501, 518 and 570).

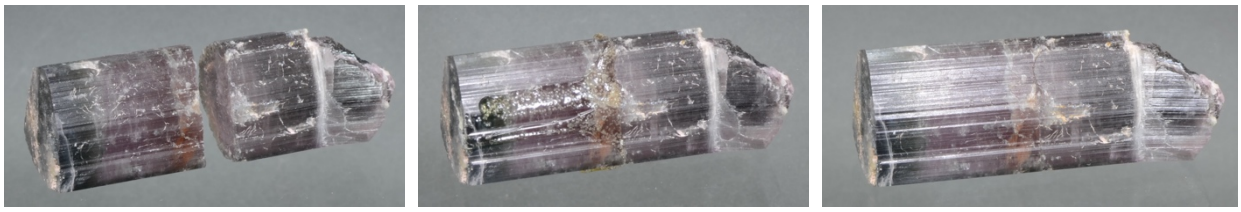


Figure 5-1. Repairing a broken tourmaline crystal. Left: The segments before repair. Center: Repaired using too much Duco cement which has oozed out along the joint. A soak in acetone and wiping the softened adhesive reversed the repair. Left: The same specimen repaired cleanly with the proper amount of adhesive.

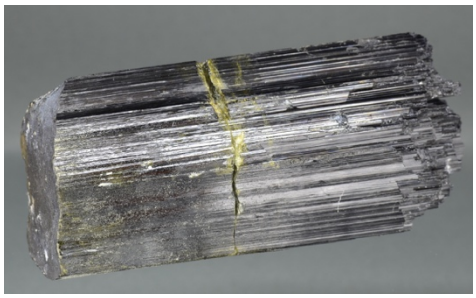


Figure 5-2. This tourmaline was repaired by reattaching the crystal segments, but a ragged gap remains. Restoration could obviate this gap, but the expense is not justified in this case.

The act of repairing a specimen may be as simple as applying a drop of adhesive between two close-fitting sections of a crystal (or crystal and matrix) having a clean break to complex reassembly of material found in pieces at the bottom of a mineral pocket. Multiple repairs of long crystals are quite common (and perhaps even inevitable) and are generally accepted by collectors.

Poor repairs are easily identified by visible glue and misaligned crystal segments (Figure 5-1). Well done repairs should not be immediately obvious, but in many cases will be revealed under magnification by narrow gaps where pieces have been rejoined. Discovering a repair by glue fluorescence under longwave (blacklight) or shortwave ultraviolet light (UV) is commonly suggested, but a specimen's natural fluorescence may sometimes be confused with glue fluorescence. Many older glues, whether water- or organic solvent-based will fluoresce but smart specimen fakers may use one of the more modern adhesives which do not fluoresce. A generally reliable method to test for fakery is to soak the specimen in a solvent and see if it falls apart at the suspected repair point. Try acetone first as this solvent will soften most glues (causing the glue to become hazy or white) and is tolerated by most minerals. If acetone fails, try water but pay attention to water sensitivity (www.mincleandev.com). Avoid trying to twist the specimen apart without softening the glue as this can damage the specimen.

To make a clean repair the areas to be joined must be freed of debris and fit tightly together. In some cases, the break is natural and secondary *in situ* mineral growth has occurred at the break faces. In this case the additional growth should not be removed because it is part of the natural

mineral paragenesis, and no repair should be attempted. A ragged break can be repaired, but the missing matter will make the repair more obvious, and it may be prone to come apart.

Adhesive choice is a critical issue when planning and executing a repair. The adhesive should be sufficiently strong to hold the repair together yet be easily reversible should the repair need to be disassembled. (A repair should never be irreversible.) An adhesive based on an organic solvent (such as Duco cement) is preferable to a water-based adhesive (usually a polyvinyl acetate glue such as Elmer's Glue-All) as the former generally give stronger repairs. In addition, water-based adhesives will degrade water-sensitive minerals (www.mincleandev.com). Use only glues that are transparent (or nearly so) when hardened to minimize drawing attention to the repaired area. (When in doubt allow a sample of the glue to harden on a piece of white paper for 24 hours before using it for a repair.) Rubbery silicone glues should be avoided as some formulations release acetic acid vapors during curing (Flores 2025) which can damage acid-sensitive minerals such as calcite. In addition, once cured silicone glue can be difficult to remove completely causing complications should the specimen need to be disassembled again. Cyanoacrylate (superglue) formulations may set too quickly to allow enough time to properly fit the specimen pieces together. Epoxies are often recommended but some are difficult to soften when cured. If the repaired specimen is to be part of a fluorescent mineral display the repair adhesive should be unreactive to ultraviolet light. (Test this by allowing a small dab to dry thoroughly on a nonfluorescent surface then examine under UV light.) Avoid an adhesive which expands while setting (Gorilla Glue) as these will not give clean repairs. Expanding glue may seep into fractures, expanding the crack and perhaps causing the specimen to split on setting. Avoid hot glues, as these create a thermal shock risk when applied and tend to expand on cooling. There is no general agreement among professional mineral preparators as to what glue brand is best. This author prefers Duco cement. HXTAL NYL-1, "a museum quality epoxy adhesive for laminating, bonding, and repairing glass...a water white (optically clear) adhesive with the same index of refraction as borosilicate glass" has also been recommended (HXTAL 2025) but its reversibility is not documented so it should only be used with caution.

Mineral tack is useful as a temporary support but not for permanent repairs. Some compositions degrade and harden over time, losing their adhesive strength. Colored tacks (especially blue and yellow) are visually obvious resulting in a (pardon the pun) 'tacky', distracting appearance.

To make the repair first verify that the ends to be attached are clean and dry and that the sections fit together snugly. Apply the minimum amount of adhesive to one broken face and bring the pieces together. If excess adhesive oozes out of the joint immediately wipe it away with a lint-free cloth. Figure 5-1 illustrates both a sloppy and clean repair to the same specimen.

Additional adhesive can be applied along cracks on the rear of the matrix for added structural integrity. This rear face adhesive does not need to be as tidy as on the display face but avoid overdoing it. In extreme cases, a thin, rigid plate - perhaps an acrylic mineral stand - can be glued to the back for extra support (Figure 5-42).

Because the preferred adhesives for mineral specimen repair take some time to cure it may be necessary to support the specimen during this process. Such support should be planned before the adhesive is applied. The support must be clean and free of loose fibers to avoid transferring dust and other debris to the curing adhesive. King (1985, 110) suggests supporting the specimen in a tray of fine sand whereas Hanna (2024) suggests a bowl of uncooked rice or barley.

Soft or crumbly matrix material is particularly difficult to repair effectively. Because the cured adhesive is stronger than the matrix the specimen is prone to break again when the matrix fails at a different spot leaving a blob of ineffectual cured adhesive behind. These specimens are best repaired by first stabilizing the matrix achieved by soaking in dilute solution of the stabilizing agent followed by drying overnight. Several soak/dry cycles are usually necessary. The stabilized specimen can now be repaired as described above. Read more on this in Section 5.8E.

The ethics of using an adhesive to fill cracks in a specimen which is otherwise structurally sound is debatable. This should be considered a type of restoration (see below).

The details of any alteration to the specimen including cleaning, trimming and repairs - what pieces were assembled, the adhesive used, date of repair, etc. - should be recorded in the collection catalog and/or on the back of the specimen label. This is especially important for the history and scientific value of a specimen in an institutional collection but unfortunately is only rarely recorded in private collections.

An unrepairable specimen should not be discarded because it still has potential scientific or historical value. Too often such specimens are relegated to faceting rough and their specimen value forever lost. Precious, unrepairable specimens might instead be restored (see below).

Some material is so frequently repaired that a repair is *expected*! Pyrite 'sun' discs on shale matrix from Illinois are a common example (Figure 5-3). Many of these are either found detached from matrix or detach very easily on handling. A sun which has not been reattached to its matrix is uncommon. Be wary of fakes in which the sun is glued onto a matrix that did not originally host it. Obvious glue residue is common with such repairs but usually easily removed by gentle wiping with an acetone-soaked rag. Specimens in which the shale overlaps the pyrite disc are more difficult to repair and are thus more likely to be completely natural. If the sun's 'matrix' contains fern fossils, you're looking at a classic fake.

Figure 5-3. The glue used to attach this pyrite sun to the matrix is faintly visible along the sun's edge. The sun fits well into the matrix depression, so it is likely a sloppy repair and not a fake.

If after reattaching pieces with an appropriate adhesive the specimen is incomplete restoration may be necessary. In a broad sense, restoration includes any alterations designed to return the specimen to its original appearance, including 'restoring' luster via surface coating or filling cracks. See Kile and Wilson (1997). For restoring patina, see Scott (1926, 64–68). For example, the tourmaline segments in Figure 5-2 were glued back together but because the break is ragged (missing chips) the damage remains obvious. To return the specimen to a more complete condition missing tourmaline or other materials would have to be added artificially. This type of work requires much experience and great artistic skill and is usually rather expensive. In the case of Figure 5-2, the cost of restoring this modest specimen was not justified and no restoration was attempted. Should your specimen require restoration consult a professional mineral specimen preparator. Like a repair any restoration work should be recorded on the specimen's label and in the collection catalog. An irreversible restoration should generally be avoided because this can destroy a specimen's scientific value. Unimportant and/or low-quality specimens have little scientific value and intended for educational or aesthetic purposes are an exception. The ethics of mineral specimen restoration are open for debate. For additional reading on repairs and restoration see Sinkankas (1970, 301–304).

Eventually, every collector will encounter mineral specimen fakes (Figures 5-4 and 5-5). These vary widely in composition but in general can be divided into three categories: (a) Laboratory grown crystals (or other synthetic materials) with or without matrix, (b) Specimens assembled from two or more mineral or rock components, usually with an adhesive and (c) Specimens altered by treatment such as heating or irradiation. Our main interest in fakes in this book is how to 'clean' fakes of the second type (that is, disassemble them to salvage their component parts) by using the methods to disassemble repairs (above). For example, the topaz specimen of Figure 5-5 was recognized as a fake by the obvious and excessive glue (sprinkled with some powdered matrix in a poor attempt at disguise) around the base of the authentic topaz crystal. The topaz crystal was authentic and deemed worthy of salvage so the specimen was soaked in acetone until the glue softened and the topaz could be detached without damage.

Figure 5-4. Three fakes. Left: An irradiated aquamarine crystal sold as heliodor. Center: Tourmaline crystals glued to matrix at an unnatural angle. Right: A lab-grown emerald cluster sold as natural material.

Figure 5-5. A fake consisting of a topaz crystal sloppily glued to matrix. The excess glue was not successfully disguised by mixing with powdered matrix before setting.

Some fakes are beautifully constructed works of art. There is a small community of mineral collectors who enjoy accumulating and studying such specimens. These collectors would cringe at the disassembly of a finely crafted fake.

The articles by Kile and Wilson (1997), Dunn and Bentley (1981) and (especially) Dunn, Bentley and Wilson (1981) include much useful detail and philosophical discussions. These articles should be studied by every mineral collector.

5.2 Labeling

A **mineral specimen label** conveys information about the specimen it accompanies. This information usually includes the mineral species present and the locality from which the specimen was collected. A wide variety of other information might be included such as chemical formula, date collected and the name of the person who collected the specimen. ***Of this information, the locality is the most important.*** While the mineral species is routinely included it can always be determined from the specimen itself without any additional information even when the label is lost. Proper labeling and cataloging are critical to prevent 'information damage' (loss of important information about the specimen) which can significantly decrease a specimen's scientific and historical value. Don't assume that you can remember significant details for one specimen (let alone thousands) that you obtained decades ago or that someone handling your collection after you have passed will know (or care) anything about your 'rocks'. Detailed labels and collection catalogs are also critical to obtaining the best sale price or possibility of donation acceptance when disposing of a collection. Numerous articles have been written about proper labeling and other record keeping. See for example Currier (2013) but also Brunton, Besterman and Cooper (1984), Rumrill (2005) and DeMouthe (2017).

The format of labels intended for display varies considerably from handwritten on a scrap of paper to an engraving on a fancy custom-made acrylic stand to information recorded directly on the specimen itself. Consistency in label format - including paper, font size and information presented - is important to give the collection a tidy, professional appearance. Creating a word processor template makes it much easier to maintain this consistency. Labels accompanying minerals for display typically include only the name of the mineral species and the locality. Ideally

a catalog number should also be included on a display label, often on the back. Display labels must be large enough (in size and font) to read easily but not cluttered (record less important information in the collection catalog instead of the display label). Label appearance and required specimen information are especially critical for competition displays. Review the Federation rules (www.amfed.org/contests/Rules) for specifics.

When listing a locality on a label be specific, as recording less detail can cause locality uncertainty. For example, if a specimen is from the Tsumeb Mine give the locality as 'Tsumeb Mine' and not just 'Tsumeb' as the latter might refer to the mine itself or another locality in vicinity of this mine (which is not the mine itself) such as the Tsumeb West Mine.

A catalog number on the label and/or the specimen connects the specimen to a catalog listing where more detail is usually recorded. Labels not physically attached to the specimen tend to become separated from the specimen. Ideally the information is recorded directly on the specimen to minimize (but never completely prevent) its loss. Figure 5-6 illustrates some common label formats with some of the advantages and disadvantages of each in increasing effectiveness at reducing information damage risk.

Considering all these factors, the optimal label type is the **rescue label** (or life-saver label) which includes (at least) the locality and is indelibly written on the specimen itself (Figure 5-6i). Other information which cannot be ascertained from the specimen itself such as the original collector and date of collection is also often included if space permits. Traditionally the rescue label consists of India ink, laundry ink or other durable black ink on a small patch of white paint (enamel is best). (For an interesting study on ink durability see Nancarrow 2023.) However, this requires a sufficiently flat area of the specimen where the label does not obscure anything important. Writing small yet neatly on a somewhat uneven surface can be a significant challenge as well. Paint-and-ink rescue labels tend to be highly resistant to degradation but may be damaged by mechanical or chemical cleaning methods such as the textile gun. White-Out and similar typographical correction fluids are not suitable for the rescue label background as these materials may suffer degradation in water. Coating the label (lacquer, polyurethane, polyvinyl acetate glue, etc.) provides increased damage resistance but care must be taken to select a coating which does not turn yellow, become brittle, soften the paint or blur the ink. Nail polish is convenient for this purpose and is usually packaged with a little brush, but its removal requires acetone which will most probably damage a printed label. Mod Podge has also been recommended for this purpose, but it is known to yellow over time. An alternate rescue label format consists of a small piece of paper glued (Elmer's Glue-All, Duco cement, etc.) directly to the specimen. Allow adequate coating drying (curing) time (24 hours or more) before handling the specimen. Coating a label (one or two layers of lacquer or Duco cement) physically attached to the specimen can protect this label from some mechanical cleaning processes such as brief sonication as well as certain aqueous chemical treatments such as derusting with dithionite.

Rescue labels are not ideal for display purposes, so they are often accompanied by a display label bearing the species name and locality.

Figure 5-6. A spectrum of mineral labels. (a) No label. All specimen information except species lost. The worst possible labeling scenario. (b) Handwritten paper label. Gives a cluttered, unprofessional collection appearance. Easily separated from specimen. (c) Computer generated label. A consistent format creates a professional appearance. Paper may yellow and ink may fade. Easily separated from specimen. (d) Label with specimen photo. Easily separated from specimen but photo assists restoring specimen/label connection. (e) Label attached to stand. Professional appearance. Less risk of separation from specimen but can be expensive to acquire and change. (f) Catalog number on specimen without other information. Useful only if the catalog is also available. (g) Unprotected paper label on specimen. Physical attachment reduces chance of separation. Label subject to fading and other damage over time. (h) Coated paper label on specimen. Coating reduces damage risk. (i) Proper rescue label. Avoids the issues with a label separate from specimen or a paper rescue label.

Chamberlain (2008), whose labels survived a fire and the subsequent firefighting damage, gives the following procedure: typewritten numbers on paper, mounted then coated with Duco cement. Alternately inkjet-printed numbers on cardstock coated first with Krylon colorless protective plastic spray, followed by mounting and overcoating with Sally Hansen Hard as Nails

with Nylon nail polish. Laser printed labels tended to run when coated with the nail polish. The rationale for using cardstock instead of normal paper is not given but being thinner and more flexible the latter may allow for better adhesion due to better molding to an uneven surface.

Avoid mounting a rescue label on an area of the specimen which is dirty or friable, as this will result in poor adhesion. Ideally the label information should be typed or produced electronically (don't assume anyone else can read your handwriting) on archival (acid free) paper. Lesser papers may turn brown or crumble over time. Produce the label with a laser printer and not an inkjet printer as laser printer labels will last far longer. A coating can protect against curling and subsequent detachment. Using a bar code or QR code on a paper label has the advantage storing lots of information in a compact space but the disadvantages of requiring additional technology and expense for reading. In addition, as computer data formats change, a coded label may become undecipherable in the future thus defeating its information protection purpose. To attach the label to the specimen, avoid water-based glues (usually polyvinyl acetate, such as Elmer's Glue-All) with water-sensitive minerals (www.mincleandev.com). Self-adhesive labels are of little value as these rarely stay stuck to a rock for very long. Mineral tack is widely used for attaching paper labels but as noted in Section 5.5B some formulations will leave oily stains while others dry up and lose their adhesiveness. Tack may be the best option for attaching a paper label when no other options are available.

A label accompanying a specimen in its storage box and not intended for display - called a 'tombstone label' (Currier 2013) because it sits vertically at the head of the specimen during storage (Figure 5-30) - usually contains more detail than a display label. Such information might include chemical formula (although this is easily found online), date collected, name of collector, repairs, etc. ***Recording a catalog number on a tombstone label is critical.*** Because tombstone labels are not meant for display their format and content consistency is less critical. To hold the most information a tombstone label should be the maximum size accommodated by the storage box without extending beyond the interior. If the label is folded it may fall apart over time.

When specimens are too small to bear an attached label or a group of specimens is to be labeled together, the label is attached to a container. The Riker mount (Figure 5-7) is a standard box widely used for such a purpose in both the physical and life sciences. These mounts are inexpensive and available in a variety of sizes. They are great for small, sturdy specimens which are not easily crushed (gemstones, etc.) or less sturdy but flat specimens (kunzite crystal shards, etc.). Small cardboard boxes, glass jars and other containers can also be used. Labels for thumbnail specimens can be kept inside the thumbnail box, either attached to the lid or placed in between the stand and the box (Figure 5-7).

Practice label making and material compatibility on some junk rocks before working with precious specimens, as per Guiding Principle 5. Overall, collectors tend to use labels which are a compromise between information protection and preparation simplicity.

Figure 5-7. Left and center: Kunzite shards in a Riker mount, this one bearing a historical W. M. Foote label. Right: A thumbnail specimen label stored between the specimen base and box.

Specimens often accumulate several labels as they move from collection to collection. These labels - even if modern - record some of the specimen's history and should thus be preserved. This subject is discussed in Section 5.9.

Field collected material is often temporarily labeled perhaps with writing on the outside of newspaper wrapping. This critical information can easily be lost when the specimens are not processed quickly due to fading, acidic vapors attacking the paper, water damage (Chamberlain 2008), etc. Such material deserves better treatment so consider more durable labeling.

For more on labeling see Sinkankas (1970, 306–309), Lemkin (2018) and Brunton, Besterman and Cooper (1984). Wight (1993, 137–143) discuss micromount labeling.

5.3 Cataloging

The **collection catalog** records details about individual specimens in a conveniently stored, searchable and sortable format. In many ways a catalog both duplicates and supplements proper specimen labels. Catalog entries are generally more detailed than individual label entries and may (or even should) include a list of all species present (including any varieties), detailed locality information, where the specimen is stored, date collected, name of collector (or name of the person of dealer who supplied the specimen and price paid), size and weight of the specimen, physical description ("deep purple crystals to 2 cm abundant on a massive quartz matrix"), notes about previous labels, luminescence observations (fluorescence and phosphorescence) plus any cleaning and development treatments as well as repairs or restorations. When listing a locality be specific as recording less detail can cause locality uncertainty. When recording a storage location more information is better than less. 'Cabinet 6, drawer 4, row 5, column 2' is better than just 'cabinet 6.' Specimen sizes are given in centimeters in three dimensions. A digital caliper with plastic or foam protectors for the tips to prevent damage is useful. Weights are given in grams and are easily determined with an inexpensive digital scale (Figure 3-29). Remember to update the card's physical description - size and weight - if the specimen is trimmed. Chemical formulas, crystal system, hardness, cleavage and other species-specific information can also be included but these are easily found online (www.mindat.org or handbookofmineralogy.org/pdf-search). More advanced catalogs can include literature references and even specimen photographs (from multiple

angles if possible; photos can also be stored at www.mindat.org) as well as scans or photographs of previous labels. (Some famous collectors drew specimen sketches on their catalog cards. These cards are also collectable!). Specimen specific details such as size, weight and photographs help reunite a specimen and its label or catalog entry should they become separated. Scientific and museum collection catalogs tend to be more detailed than catalogs of private collectors. However, even for the amateur collector more information is better than less. See Figures 5-8 and 5-9.

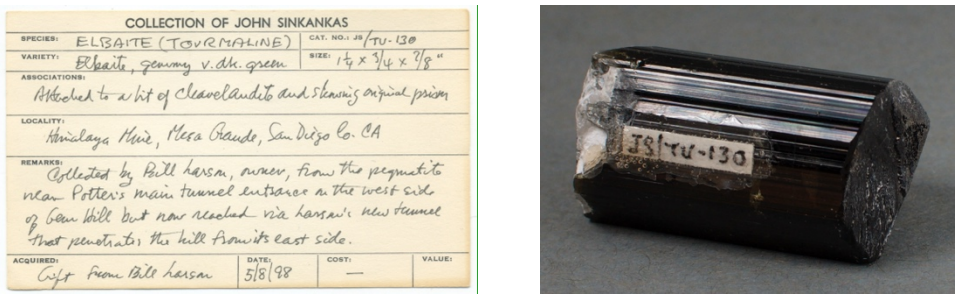


Figure 5-8. Left: A catalog card from the John Sinkankas collection (Wilson 2025). Some cards from this collection include a sketch of the specimen on the back. Right: The associated specimen with its attached catalog number.

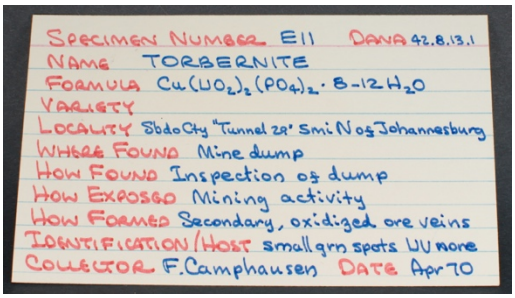


Figure 5-9. A superb, handwritten collection card.

Specimens with published images are said to be *illustrated*. This increases their value and so a proper reference to the publication should be included in the catalog (Figure 5-10).

Preparing a catalog entry is a good time to verify species and locality information. Don't take previous labels for granted (even dealer labels) unless you are highly familiar with the given species and/or locality information. Species can be wrongly identified or discredited, and locality names can change or deliberately made misleading.

Cataloging is often one of the less enjoyable tasks for the collector but don't put it off. You may forget vital information about a specimen that's been sitting on your worktable for a month especially if lots of other specimens lie neglected there as well. (How much did I pay? Is that tourmaline from the Tourmaline Queen Mine or the White Queen Mine?)

Figure 5-10. A photograph of this etched kunzite called 'The Sail' have appeared in Wilson, Olson and Olson (2017, 121), in Menzies and Scovil (2022, 184) and now in this book. These references are included in the specimen's catalog entry because illustration is part of the specimen's history.

Proper and thorough cataloging is critical to obtaining the best sale price or possibility of donation acceptance when disposing of a collection. A potential purchaser can gain quick, useful information about a collection's quality and value from a catalog. In addition, an electronic catalog can easily be emailed to a potential buyer convincing them that the collection may be worth the time to visit in person after all.

Historically catalogs were handwritten in a ledger or on separate cards (Figures 5-8 and 5-9). Historical catalog cards and ledgers are very collectable. Many collectors prefer an electronic format for their catalog using spreadsheet or database software. (Some collectors prefer the retro card catalog.) In either case a backup (photocopy if paper or to an external disc or the cloud if electronic) should be made frequently. For further protection an electronic catalog can also be backed up with a printout. A properly detailed and maintained catalog is a significant insurance policy against information damage.

Each catalog entry should include a unique number to relate the specimen to a catalog entry. ***These numbers must be repeated on any other display or tombstone labels*** but do not alter any historical labels. The format of these catalog numbers varies widely from simple numerical designators ordered corresponding to the sequence in which the specimens were entered into the catalog (such as 44138) to complex alphanumeric codes (often used by dealers) which may include references to the species, subcollection, locality or previous collection. Simpler is generally better to avoid errors and confusion. In Figure 5-8 Sinkankas assigned the number JS/TU-130 to this tourmaline. Avoid recycling catalog numbers of specimens which have left the collection as this can be another source of errors and confusion. For more discussion see Skelton (2024).

Wight (1993, 136–152) provides a good overview of micromount cataloging techniques. For additional reading on mineral specimen cataloging see DeMouthe (2017, 9–18 and 63–67), Sinkankas (1970, 306–309) and Gabriel, N. (2024).

5.4 Mineral Stands

A. Selecting the Best Stand

How your collection looks while on display is nearly as important as the quality of the specimens which comprise the display. Once properly cleaned many specimens can be quite pretty but are much more dramatic when properly mounted and displayed under good lighting. A **stand** (also called a **base**) may be necessary to support a specimen which does not sit by itself at a pleasing or stable display angle. Securely supporting specimens is especially important for collections in seismically active areas; see Kampf (1994). Poor quality stands or a jumble of different stand styles (materials, sizes, etc.) can be a significant detractor to the display's beauty and museum-like appearance. In addition, crooked specimens (mounted at an odd angle perhaps with the termination pointed down) are equally distracting. When a label is part of the stand the issue of labels becoming separated from specimens is mostly obviated. Properly mounted specimens increase the economic value of a collection and can be an important factor when selling. The collection of Figure 5-11 sold for a premium price because every specimen was mounted on its own labeled, acrylic stand and was well displayed.

Figure 5-11. This collection sold for a premium price because of its high quality, professional labeling, mounting and display.

Many specimens easily scratch display cabinet shelves (even glass shelves); stands can reduce or even eliminate this unsightly damage. Small rubber or silicone feet on the bottom of the stand obviates this issue and provides some earthquake protection as well (Kampf 1994).

Some collectors disdain stands of any sort because they impart an unnatural appearance to natural objects. Opinion varies widely at all levels of the hobby as to what is best or correct when it comes to stands. Preferences range from a complete absence of stands at all to minimal, nonintrusive stands to stands custom fitted for each individual specimen. In this section we explore how to select the right stand. Attaching the specimen to the stand (mounting) is discussed in the following Section.

Historically, specimens were either not mounted, or mounts were mostly made of wood (with the specimen secured by wax; Figure 5-12). Half a century ago mounting on a styrofoam block was quite popular but is now considered passé (Figure 3-69). Stands made of **clear acrylic**

(also called **Plexiglass** or **Lucite**) came into fashion in the 1980's or 1990's and remain the most common stand material today (Figure 5-6e). Vintage stands are quite collectable especially when accompanied by the corresponding specimens and vintage labels. The modern collector has a much wider range of stand materials to choose from. But what to choose? Whether considering a single specimen or mounting an entire collection the following paragraphs explore options and help guide your choices through a series of questions.

Figure 5-12. A Norwegian monazite crystal mounted on a wooden pedestal and bearing an A. E. Foote label, dating the specimen to 1875–1895 (Wilson 2025).

Like labeling, consistency in mounting details (stand material, size, etc.) are important to present a clean, professional appearance. When mounting for competition carefully study the American Federation of Mineralogical Societies Uniform Rules for Competitive Display Cases (AMFED 2025) before making any decisions.

Should the specimens be mounted on stands or not? There are a broad range of opinions on this choice. Some collectors prefer to mount every specimen on a stand - even those specimens which are self-standing - for a consistent display appearance while others completely eschew stands. Most display collections are somewhere between these two extremes with some specimens mounted and others not mounted.

Are the stands more for support or more for aesthetics? Stands designed for support often have a lower aesthetic demand (but higher engineering requirements) compared to stands whose main purpose is to enhance the collection's display aesthetics.

What material should the stand be made from? If the mounting is intended to be reversible - there will be no adhesive between the stand and specimen - then ideally the stand should be softer than the mineral to avoid specimen damage (assuming the specimen is more precious than the stand). This is usually not an issue with acrylic (Mohs hardness 2.5; not scratched by gypsum but is scratched by calcite) and wood hardness (varies with tree species). When in doubt, test the relative hardness of the specimen and a scrap of the same material the stand is made from or consult published mineral hardness data (www.mincleandev.com and www.mindat.org).

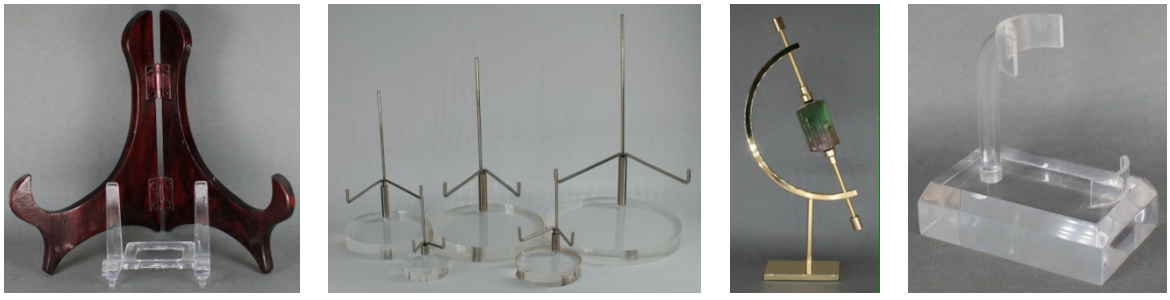
What budget is available? When stands or the materials to make them yourself must be purchased the financial burden of mounting the desired number of specimens must be considered. A small collection to be outfitted with basic stands is within the realm of most collector's budgets

whereas a collection with hundreds of fine specimens, worthy of custom-made acrylic block stands might cost tens of thousands of dollars (or more) to outfit with matching stands.

Should the mounts be permanent, semipermanent or fully detachable? A specimen can be attached to a stand in a way which is intended to be **permanent** (not readily detachable; irreversible), **semipermanent** (glued to the stand but readily detached if needed) or not physically attached to the stand at all (**fully detachable**). The main factor here is how often might the specimen need to be detached from its mounting? Other details about the stands as well as the adhesive used (Section 5.5) further increase or decrease these factors.

Permanent mounting is rarely needed or even desirable and therefore should not be a consideration for the amateur collector. The potential for damage to the specimen should detachment be needed is much too great. An exception can be made for exceptionally rare material for protection against weathering or for public display such as a lunar sample. Completely encasing such a moon rock in acrylic destroys its scientific value but on the other hand if this is the best presentation to help convince a politician to fund a research program or to inspire a budding scientist...

There is a plethora of *fully detachable mounting* choices. Figure 5-13 illustrates just a few of these. Slab stands (Figure 5-13a) come in a wide range of materials (plastic, wood and metal) and are inexpensive but generally only suitable for flat specimens such as sawn slabs and fossil plates. Larger (and therefore more expensive) slab stands may be adjustable. Swing-arm stands (Figure 5-13b) have a round or square acrylic stand with adjustable arms made of steel or brass. The back support can easily be cut if it is too long for your tastes. The metal supports can scratch many mineral species so their tips should be covered with short lengths of clear plastic tubing. Plasti-Dip for coating tool handles has also been suggested for this purpose but avoid yellow and other distracting colors. Fixed-arm stands are also widely available but less useful because they are not adjustable. Caliper stands (Figure 5-13c), usually made of brass or steel, are elegant but expensive and often do not adequately support the specimen without crushing it. A collectable pen/pencil stand (Figure 5-13d) is useful to display long, thin crystals such as tourmaline or stibnite.



(a) (b) (c) (d)

Figure 5-13. Some fully detachable mineral specimen stands.

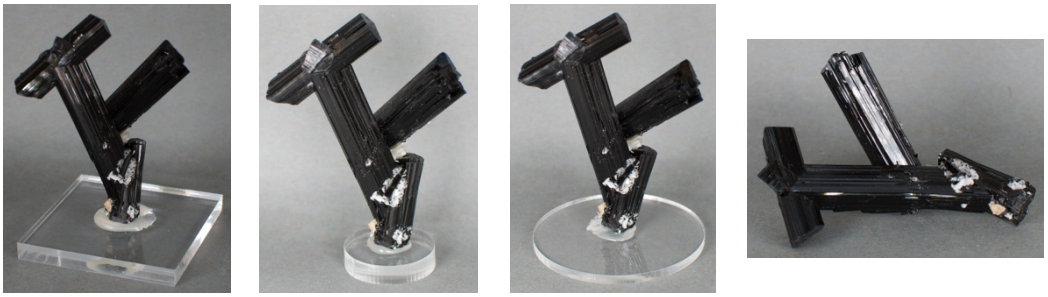
Offenbacher (2001) and Duthaler and Weiß (2024, 124) suggest molding specimen stands from air-drying clay called Das Pro. While inexpensive and easy to prepare such stands may be inconsistent in shape and texture causing the display to have a chaotic, unprofessional, primitive and even childish appearance. In addition, the lifetime of such stands before crumbling is not reported. Imagine hearing your precious specimens clunking hard against glass shelves in the middle of the night... However, some collectors use this material in a more artistic manner and embrace this stand style.

Custom fitted acrylic block stands (Figures 5-6e, 5-10 and 5-11) are the ultimate in mineral specimen display pizzazz and luxury. These are prepared by carving an acrylic block to precisely fit the exact size and shape of the specimen. They provide a professional, museum-quality appearance to the collection but can be quite expensive. However, with minimal do-it-yourself skills any collector can produce these stands on their own (Section 5.4B). Many of the issues which occur when a specimen is glued to a stand are avoided when a custom carved stand is used.

Semipermanent mounting - attaching the specimen to the stand with an adhesive - offers extra protection for handling or against earthquakes (Kampf 1994) but creates a damage risk should the specimen need to be dismounted. These stands are produced commercially in a wide range of sizes, shapes (square, round, etc.) and material. Plastics (especially acrylic) are quite common, but wood and metal stands are also available. Prices range from nearly free to budget unfriendly. Suggestions for choosing the proper material and other considerations for your collection and display needs are discussed below. Uniform materials, shape and other factors across the display makes for a tidier, more professional appearance.

The over-arching question to ask yourself when establishing a display is "what do the other display stands in the collection look like?" Are the stands flat or blocky? Square, rectangular or round? While a square stand is traditional the specimen must be mounted with care to avoid the stand being at an odd angle when the specimen's display face is forward. This can be difficult to achieve especially when the specimen mounted by a dealer and this dealer has numerous specimens to mount and takes less care for achieve perfect alignment. A round stand obviates this issue, as it has no awkward angle (Figure 5-14). A stand must be wide enough to provide adequate support but not overly wide (which is distracting; Figure 5-14).

When the point of attachment is roughly along the specimen's long axis the display looks best when the specimen is mounted in the middle of the stand. When the attachment point is not central to the bottom of the specimen then an off-center mount may be more pleasing to the eye (Figure 5-10). Whether the specimen should be mounted vertical or horizontal is a matter of personal taste (Figure 5-14).



(a) (b) (c) (d)

Figure 5-14. Mounting a tourmaline specimen. (a) The specimen is mounted on a square stand, but the best display face is not parallel to the stand edge, so the stand looks misaligned when the best specimen face is forward. (b) The same specimen mounted on a round stand has no awkward stand angle. This stand is too narrow, risking the specimen's stability. (c) This larger stand provides better stability. (d) The same specimen displayed horizontally without a stand.

Although popular among some collectors, a blocky stand (as opposed to a flat stand) can also be distracting by drawing more attention to the stand and less to the specimen. However, a custom carved stand (Section 5.4B) may have a label attached to its front in which case blocky is necessary. To achieve a riser effect in limited space some displays use thin stands in the front row with blockier stands in the rows behind. Blocky stands may have beveled edges so if you choose to use this type of stand the bevel angle should be the same for all stands to maintain a consistent appearance. Perhaps the best way to ensure equal bevel angles is to buy your beveled edged stands all from the same supplier and in quantity (same manufacturer's lot). Avoid the temptation to cast and then machine your own acrylic blocks because making them perfect and consistent while at the same time not spending hours on the task is difficult.

What material should the stands be made of? Stands are available in a wide variety of materials with plastic (usually acrylic) and wood being most popular. Other materials such as glass or clay may also be encountered. Styrofoam collects dust which can be nearly impossible to remove completely. Mounting on styrofoam was once popular but is now considered tacky and retro (in a bad way). Small glass tiles are inexpensive but like styrofoam do not give an advanced collector appearance to the display. Making your own stands from clay has been discussed above.

For a clean, consistent display look, all stands should be of the same material and the same color. Clear and colorless stands are the least distracting. As above the best way to ensure consistency is to purchase all your stands from the same supplier and in quantity. Flat acrylic stands (square or round) are readily available and generally inexpensive (Figure 5-15). Some manufacturers will cut stands to your specific shape and size needs. Look for laser cut acrylic for smooth edges as saw cut pieces tend to have rough and ragged edges even after flame polishing.

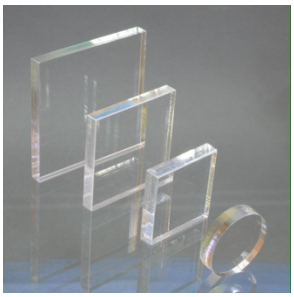


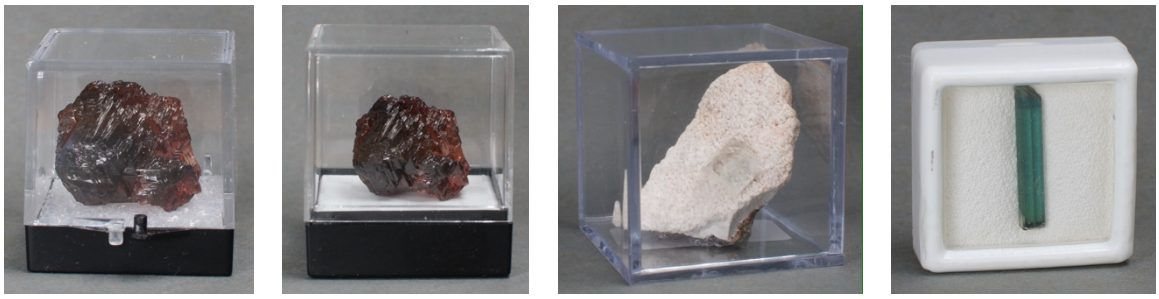
Figure 5-15. Typical flat acrylic stands.

Stands which rotate using an electric motor are popular but (like styrofoam) considered by many collectors to be tacky and tasteless especially when these stands have changing LED lights. However, a fluorite collector recently put forth an idea to light his specimens from beneath with LEDs to emphasize internal colors (Chang 2025).

3D printed stands offer intriguing possibilities and may be the 'wave of the future' but this technology is currently beyond the scope of most amateur collectors. Objects produced by current 3D printing technology are mostly opaque, another factor which will draw attention to the stand and away from the specimen.

Is the mounting for display only or will it be used for storage and conservation as well? Pretty mineral specimens are often fragile and thus need protection against handling damage. The simplest solution is to avoid handling altogether but this is rarely practical. A specimen which may be switched between the display cabinet and storage may have specimen mounting needs with protection from dust and damage, storage and conservation being the main issues. A variety of containers which provide protection and may also be also suitable for display are available. Plastic boxes with hinged or nonhinged lids are widely available in a variety of sizes and designs. (Plastic boxes should be avoided if the display will be illuminated at any time by direct sunlight. Some plastics tend to warp and melt when heated.) Thumbnail specimens can be mounted in a standard 'Perkie' thumbnail box, which is a plastic cube about one inch on each side, with a hinged lid (Figures 5-7, 5-16a and 5-21). This box style was introduced by famed mineral dealer Willard Perkin (Megaw 2013 and Wilson 2025). Perkin's thumbnail labeling and mounting style was unique and is now quite collectable. Inside the Perkie box is a styrofoam or acrylic square to which the specimen is mounted. If this base is also to be used for displaying it should fit snugly in the box but easily removed when needed. The Crystal Showcase thumbnail box (www.openallday.com.au or www.irocks.com) is a more elegant and pricier method than the Perkie box for thumbnail display and storage (Figure 5-16b). With this box the specimen is mounted to the box base instead of the removable base in a Perkie box. The hinged design of the Perkie box limits the size of the specimen it can contain to a bit less than the competition rules maximum for a thumbnail whereas the Crystal Showcase box accommodates this size perfectly. Two-part boxes designed for displaying golf balls and baseballs (Figure 5-16c) may also be useful for protection during storage, but they make a less aesthetic display. Gemstone display boxes (Figure 5-16d) are another useful and inexpensive option for small, sturdy specimens but not for

fragile specimens. Standard micromount boxes are similarly useful but because of the specimen sizes involved do not make for an aesthetic display. A Riker mount (Figure 5-7) may also be useful. All these options provide protection against dust and damage and are easily stored.



(a) (b) (c) (d)

Figure 5-16. Mounts for display and protection. (a) A 'Perkie' (also called 'Perky') thumbnail box with the specimen mounted to a styrofoam base. (b) The same spessartine in a more aesthetic Crystal Showcase thumbnail box. (c) A miniature specimen in a two-part golf ball display box. (d) A small tourmaline crystal in a gemstone display box.

The Jousi box (Figure 5-17) is another option, available in various sizes. A label is attached to one of the clear faces (possibly hindering specimen view unless the box is opened) or on the bottom (requiring the box to be inverted, possibly with specimen damage).

Figure 5-17. A Jousi box showing one possible labelling configuration.

What is the ideal stand size? The ideal stand should be present but not really seen. The best size will be large enough to provide adequate stability but not so large as to draw more attention to itself than to the specimen. Does the stand have enough surface area for the adhesive to provide a strong, secure bond to the specimen? A custom carved acrylic block stand often relieves these issues.

In summary the mount selection depends upon numerous factors including the collection display style, competition rules and your own personal tastes. Maintaining consistency among mounts is important for a neat and professional display.

B. Making Your Own Carved Stands

The ultimate in clean, professional 'museum-quality' mounts are the acrylic block stands, custom carved to provide the specimen with the perfect display angle and firm support (Figures 5-6e, 5-10, 5-11 and 5-18). Several fine minerals dealers offer these stands. These stands add a significant class to a collection and are the elegant standard for competition displays. The cost can be quite significant; at the time of this writing, a *single stand starts at $125*. Most likely not a worthwhile investment for your typical ten-dollar quartz specimen but a drop in the bucket for a 'kilobuck' (thousand dollar) tourmaline. These custom stands have the additional advantage of not needing adhesive and so potential damage from careless mounting and dismounting is avoided. In some cases, a small dab of mineral tack can be useful to ensure the specimen is stable. Many of these stands also have the label laser-engraved onto the front (Figure 5-6e) thus avoiding issues related with specimen/label separation but simultaneously creating another problem. These engraved labels are irreplaceable so if the specimen must be relabeled the entire (expensive) stand must be remanufactured. A custom trophy shop might also be a source of engraved labels. A paper label is easily attached to a custom stand but projects less class and professionalism than an engraved label.

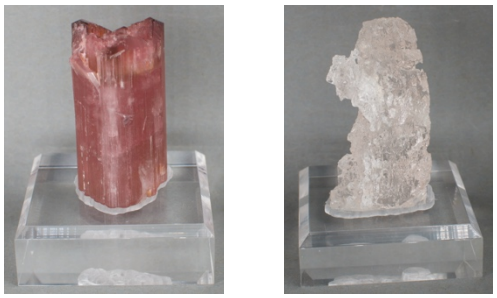


Figure 5-18. A California tourmaline (left) and a Brazilian morganite (right) mounted on custom carved acrylic block stands. Each stand required about 45 minutes to prepare.

To prepare a custom carved stand start by selecting an appropriate acrylic block whose width (ideally) will be about 1.5 to 2 times the width of the bottom of the specimen. A stand which is too large makes the specimen look smaller than it actually is. To center the specimen on the stand, use a Sharpie to draw an X from corner to corner (Figure 5-19). Other ink can be used but it must be easily removed without harming the stand. Mark the stand with a dot to indicate the front face. A similar mark on the specimen marks it's front (blue painter's tape works well). These marks make it easier to check the specimen fit while carving. A rotary tool, preferably having a flexible shaft is outfitted with a cylindrical carving burr (Dremel 194 or similar) is needed. Dremel and Foredom make excellent flexible shaft tools. A foot pedal is useful but not required. The rotary tool is operated at a slow speed. When carving do not push hard but instead let the bit do the work. While carving the stand can be handheld or clamped in a benchtop vise. If clamped pad the vise jaws to avoid scratching the soft plastic. Practice both methods of holding the stand with scrap

material to decide which works best for you. (The author prefers handheld.) Before starting to carve verify that the bit is not bent because the head of a bent bit wobbles and gives less precise control.

Begin carving at the center of the X and slowly work outwards. Make a shallow pit large enough to fit the specimen before contouring the bottom of the pit to create the perfect display angle. The pit should be deep enough to hold the specimen securely without being so deep as to obscure the specimen more than necessary. Remove the acrylic in small bits, about 1 mm or less when close to the correct size. Check the fit frequently. Take care not to scratch any surfaces that will not be carved unless you want to repolish the stand (tedious).

Good lighting is necessary. The carving process is messy, so an apron is a good idea.

When the carving is satisfactory, sonicate the stand briefly to remove residual plastic shavings. Remove the Sharpie makings with a soft cloth dampened with 99% rubbing alcohol (not acetone!). Add vinyl bumpers (feet) to the bottom. The final stand and mounted specimen are shown in Figure 5-19.

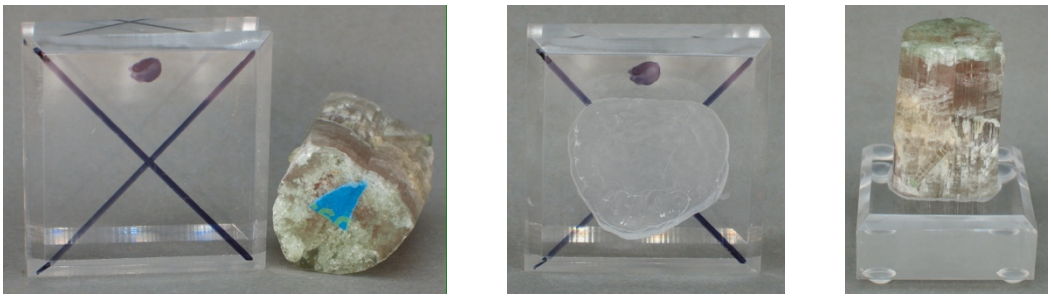


Figure 5-19. Preparing a custom carved acrylic block stand. Left: Ready for carving. Center: Carving completed. Right: Specimen mounted. This stand required 45 minutes to produce.

Don't be discouraged if your first attempt is not perfect. Custom carving an acrylic stand is an art which requires practice and patience to fully develop the technique.

5.5 Mounting the Specimen

In many cases the specimen must be attached to the stand using some sort of adhesive. This section covers what adhesive is best and how to go about joining the specimen and stand using the chosen adhesive. The role of an adhesive to is bond two things together. Not all adhesives are suitable for mounting minerals to a stand and no single adhesive is best for all cases. The following discussion will help you make the right adhesive choice.

A. General Notes: Adhesive Choice and Other Issues

Adhesive properties vary widely and not every adhesive is effective or desirable for attaching a mineral specimen to a stand. The **ideal adhesive** holds the specimen firmly to the stand

without sagging but does not damage the specimen or (less importantly) the stand. You cannot always know if the stand is to be upgraded, the specimen dismounted for photography, etc. A properly executed, removable mounting provides adequate support yet is easily removable with minimal (or preferably no) damage. The adhesive must lack objectionable color or fluorescence. "Because someone suggested it" or "because other people use it" is not an adequate criterion for adhesive selection. The two most common adhesives used for mounting minerals are mineral tack and hot glue; these are discussed below. Read both descriptions before deciding which adhesive is best for your situation.

When **planning to mount the specimen** - regardless of adhesive to be used - start by selecting the proper stand (Section 5.4). A perfectly executed adhesive application is a waste of time and presents an unnecessary risk to the specimen if the stand is inappropriate and the specimen must be remounted.

Any previous stand or adhesive residue should first be removed before mounting the specimen. Mounting over existing glue and mineral tack residues may reduce adhesion of the new adhesive.

Before mounting, study the specimen carefully to determine the best angle for display. A few seconds spent here will save much frustration and possible damage caused by dismounting and remounting. This is of greater concern with hot glue (Section 5.5C) than with mineral tack (Section 5.5B). Adhesive (especially mineral tack) works best on a flat, clean mineral specimen surface and should be applied to be as invisible as is reasonable. Avoid applying adhesive over any existing labels which should be preserved as part of the specimen's history. It may be better to mount without adhesive or even forego mounting altogether to preserve such a label. Adding additional stand material (rod, triangle, etc.) adds extra support for the optimal display angle (Figure 5-20).

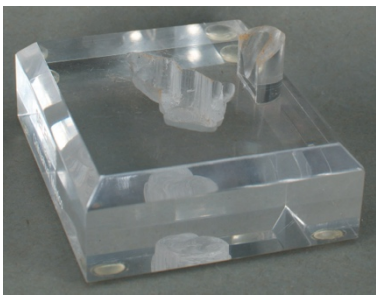


Figure 5-20. Side view of the Figure 5-6(e) stand, showing additional support pedestal.

If hot glue is to be used test mount the specimen with mineral tack first. This helps avoid the issues of Figure 5-14. When you are satisfied that the display angle is optimal photograph the mounted specimen and stand to use as reference when ready to mount the specimen permanently.

Finding the right balance between just enough adhesive to hold the specimen securely but not so much as to make an unsightly blob is challenging and requires practice. This is less of an issue with mineral tack than with hot glue because it is easier to control the amount of tack applied.

Many adhesives do not adhere well to porous or powdery minerals such as the typical Ojuela Mine limonite matrix. In these cases, consider using a mount without adhesive, such as a carved acrylic stand. If an adhesive must be used adhesion can be improved by first coating (or soaking) the area to be attached to the stand with several coats of dilute (~1:10) polyvinyl acetate glue (such as Elmer's Glue-All) in water and allow thorough drying between each coat. A similar result can be achieved with a 1:10 solution of Paraloid B-72 or Duco cement in acetone. This impregnation strengthens the matrix and provides greater adhesion to mineral tack or hot glue. However, areas not infiltrated by the diluted glue solution remain weak and are prone to break away from the reinforced areas. See Blyskal (2024) for more detail.

When mounting an easily cleaved mineral apply the adhesive perpendicular to the cleavage plane. Adhesion parallel to this plane makes for a much weaker mount.

To help them stand out, crystals of just a few millimeters in size can be mounted on a pedestal such as a cork, push pin map tack or clear plastic comb tooth as did Perkin (Figure 5-21). (Always avoid obnoxious colors!) This technique requires much practice and patience to perfect. Spreckels (1965) and Wight (1993) give details useful to macro specimens.

Figure 5-21. A thumbnail specimen mount prepared by Willard Perkin (Wilson 2025) using a colorless comb tine to elevate the specimen above the foam. Megaw (2013) describes how these mounts and their labels were made. Boxes with a Perkin label on the bottom (right) are collectable.

B. Mineral Tack

Mineral tack (Figure 5-22), also called **mineral putty** is an inexpensive adhesive which does not pose a threat to most minerals. This material is nearly ideal as an adhesive as it holds a specimen firmly to a stand but does not routinely damage the specimen itself and at the same time the specimen can be easily dismounted with little to no damage. Tack is available in a range of colors with white, blue and yellow being the most common. Only white should be used as these other colors draw attention away from the specimen and direct it instead towards the unsightly material beneath. Color is also important as tack residues (which can be difficult to remove) have sometimes been misidentified as rare minerals.

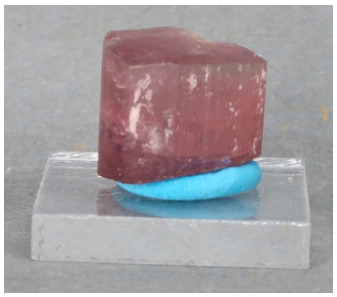


Figure 5-22. Left: Quake Hold. Center: Tourmaline mounted with Quake Hold. Only enough tack is used to hold the specimen at the best display angle. Right: The same tourmaline mounted on the same stand with blue putty. Which tack color looks more natural and less distracting?

The Quake Hold brand is widely available in hardware and home improvement stores. Other brands sold by mineral dealers tend to be more expensive and do not have significantly better properties. Quake Hold retains its 'tack' and suppleness for years without hardening or deforming (flowing) too much at room temperature. (All tacks flow to some extent when warmed by direct sunlight or display case lighting. Some even flow over months just at room temperature.) Some tacks harden or leave oil stains over time whereas Quake Hold tends not to. (Tack recipes vary between manufacturers, as do their properties.) If perfect mounting rigidity is needed - especially for vertically mounted specimens with high centers of gravity - consider using hot glue (Section 5.5C) instead of mineral tack. When mounting the specimen must be *gently* pushed into the tack whereas hot glue requires no force while mounting so hot glue may be a better adhesive choice for very fragile specimens. Unlike hot glue, mineral tack avoids a thermal shock risk and does not require time to become rigid. Quake Hold does not fluoresce under either longwave (blacklight) or shortwave ultraviolet light. These issues must be considered when choosing between mineral tack and another adhesive.

To use mineral tack tear off a small piece and roll into a ball between your palms. Your hands must be clean because even traces of dirt will be transferred to the tack quickly rendering it gray or brown. Apply the tack to the stand and flattened it to about half the ball's original height. Now ***gently*** push the specimen into the tack without rocking. If you are dissatisfied with the specimen's position ***gently*** peel the specimen away from the tack, remove the tack from the stand, prepare a fresh ball of tack and mount again. Tack is sufficiently inexpensive that it does not need to be reused and recycled. It makes an excellent temporary support for mineral photography. It has also been used to attach a label to a specimen when no other labeling options are available (or the dealer/collector is lazy). For further reading about mineral tack see Werner (2023).

C. Hot Glue

In recent years **hot melt adhesive** (commonly called **hot glue**) has become the overwhelming preference to provide a semipermanent attachment to a stand. This adhesive bonds to a wide range of surfaces and to acrylic particularly well. As the name implies this adhesive is

applied in a molten form so thermal shock and other specimen damage is possible. In one experiment the molten glue issuing from the gun tip was at 154ºC, hot enough to melt sulfur (melting point 115ºC), dehydrate chalcanthite (dehydrates at 63ºC) or burn the fingers. Unlike mineral tack hot glue takes a few moments to solidify sufficiently to hold the specimen without being supported by the fingers. When solidified the adhesive is hazy white to pale yellow and has no objectionable color. Unlike mineral tack solidified hot glue remains rigid, preventing the specimen from sagging. In most cases, a specimen or stand is easily removed from solidified hot glue without damage to (Section 3.26). At least one if not all hot glue brands fluoresce under both longwave (blacklight) and shortwave ultraviolet light making this adhesive unsuitable for fluorescent displays. The glue is melted and dispensed with a **hot glue gun**. If you use a cordless air pump with interchangeable battery for removing dust, selecting a cordless hot glue gun of the same brand saves some money.

Mounting a specimen to a stand using hot glue requires some practice to achieve an aesthetic mount without damage to the specimen or stand. Guiding Principle 5 applies here. To avoid the frustration of wasted time and glue caused by mounting errors practice with the gun and brand of glue you intend to use as well as junk rocks on junk stands. Hot glue compositions vary and therefore do not all have the same melting, flowing and solidifying characteristics. When practicing, observe the rate at which the molten glue spreads out. Experiment with the amount of glue needed for a secure amount. Too little glue results in a weak mount whereas too much glue causes an unsightly blob (Figure 5-23). Eichinger (2025) gives a useful introduction to hot glue gun use.

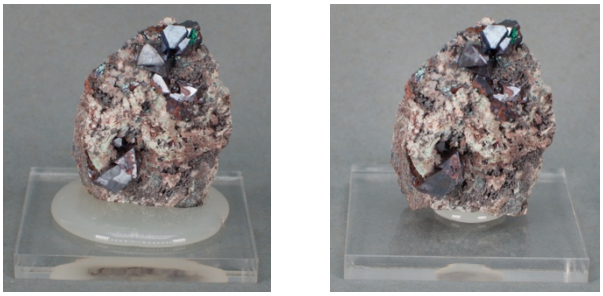


Figure 5-23. Left: A poor mounting job. This mount has more than enough glue to be secure, resulting in an unsightly blob. Right: Remounted with an appropriate amount of glue.

To mount a specimen using hot glue start by cleaning the stand to get the strongest bond between the adhesive and the stand. Cleaning before mounting is also preferable because it is generally harder to clean the stand once a specimen is mounted. If the stand is acrylic, first wipe it with a lint-free cloth dampened with 99% rubbing alcohol then allow it to dry thoroughly. (Do not use acetone as this rapidly attacks acrylic. Water takes longer to dry and may leave unsightly water marks.) Remove any dust and loose debris from the specimen. Place the glue gun and stand over paper to catch any molten glue drippings then turn it on to heat up for a few minutes. For most models the gun is ready when molten glue slowly drips from the tip. (Attempting to mount when

the glue is not hot enough results in poor adhesion.) While the gun is heating, decide where the specimen will contact the stand. In most cases this will be the exact center. Mark this spot on the *backside* of the stand with a marker (typically a Sharpie brand) whose ink is easily removed with rubbing alcohol (not acetone!). This mark will help center the glue and specimen. If the specimen is to be mounted off center (for example when the specimen is highly unsymmetrical) decide where the specimen will meet the stand and make an appropriate mark. With the stand on a flat, level surface and with tip of gun about 1 cm above the stand apply a small dab to desired spot (Figure 5-24). Applying glue to specimen first instead of the stand results in a sloppier and less secure mount.

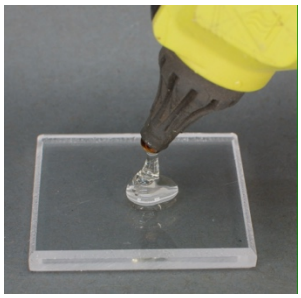


Figure 5-24. Using a hot glue gun to apply molten glue to a stand prior to attaching a specimen.

Place the specimen into the molten glue (unlike mineral tack no force is needed) and hold it steady at the desired display angle until the glue has congealed. Solidification time varies based on the glue composition, glue gun temperature, the glue/stand contact area, the stand thickness and stand material as well as specimen's thermal conductivity (the rate at which specimen draws heat from the hot glue). Metallic minerals such as native copper generally have higher thermal conductivity than nonmetallic minerals such as quartz. The specimen can be repositioned slightly during hardening, which usually takes less than a minute. Hold the specimen still until you are sure it is stable.

An additional glue blob at the back of the specimen may be needed for extra support. When applying this extra glue tilt the stand slightly so the second glue application does not flow forward thereby increasing the size of an otherwise-perfect glue blob. In extreme cases - especially for top heavy specimens - a small, appropriately shaped piece of acrylic glued perpendicular to the stand is necessary for adequate support (Figure 5-20). When the underside of the specimen to be mounted is concave or otherwise has minimal flat surface for the glue to adhere place a ball of glue on the stand first an allow it to solidify. This ball of solid glue can now be used as a pedestal to mount the specimen. Apply more glue to the pedestal and finish mounting as usual.

Even a collector experienced in hot glue mounting has difficulty avoiding fine threads of solidified glue which give the completed mount a sloppy, unprofessional appearance. Examining the completed mount with strong light coming from behind is an effective method to find these sometimes nearly invisible strings. Some of these threads are easily removed with needle-point tweezers. Residual threads are easily removed by gentle wiping with a lint-free cloth dampened

with 99% rubbing alcohol. When mounting doesn't come out quite as you would prefer, disassemble the mounted specimen (Section 3.26) and try again.

Although proper hot glue mounting is quite secure, avoid handling the stand and specimen mounted to it simultaneously. This may cause enough torque to dismount the specimen or in cases where the specimen itself is weaker than its bond to the glue (friable/porous matrix, easily cleaved crystals, thermal shock damage, etc.) the specimen itself may break.

When a hot glue-mounted specimen becomes detached avoid the temptation to reheat the glue blob (often with a lighter) as it remains attached to the specimen or stand. Serious specimen thermal shock damage can occur. The glue blob can be discolored or burnt and the stand damaged. Reheating the hot glue blob often reduces its adhesive strength. For a cleaner appearance it is better to remove the glue residue from the specimen and stand and remount with fresh glue.

D. Other Adhesives

Adhesives other than mineral tack and hot glue should usually be avoided for mineral specimen mounting. Some of these alternates fluoresce. **Epoxies** take too long to set, are often only difficulty reversible and usually attack acrylic. **Silicone glue** can be useful when both mineral tack and hot glue cannot be used. It is easy to apply and provides excellent adhesion, but residues can be difficult to impossible to remove completely. Avoid **sealing caulk** for kitchen and bathroom applications as this material may lose adhesiveness when set and (like silicone glue) residues can be challenging to remove completely. **Clay** and **wax** are historically important adhesives, but these can also have poor adhesiveness and be difficult to remove completely. **Museum wax** and **beeswax** have both been suggested for mounting minerals but their use for this application does not appear to have been investigated much (Werner 2023). **Duco cement** and **Superglue** formulations attack acrylic and unless the points of contact on both specimen and stand are flat, poor adhesion results due to a thin glue layer. **Polyvinyl acetate glues** (Elmer's Glue-All) were commonly used for mounting to styrofoam or wood stands but are no long in general use for mounting minerals. This type of glue is water based and therefore easily removed but no good for minerals which are water sensitive or have a porous matrix. Its lengthy set time is problematic when the specimen must be held in place while the adhesive sets.

E. Micromounts

Preparing micromounts is an art requiring its own unique skill set. Spreckels (1965) and Wight (1993, 109–131) provide useful discussions.

5.6 Displaying

Most collectors are proud of their collections and want to display them in a flattering way. The best-executed displays are planned out before they are assembled. When planning a display,

the most important question is what is the purpose (or theme) of this display? Should it feature the collection's very best specimens? Minerals of a certain color, shape, chemistry or locality? Specimens of gem minerals such as tourmalines and beryls? Perhaps the theme is self-collected specimens, or it is organized by size (thumbnails, miniatures, etc.). For a home display the theme - if one exists at all - is a matter of the collector's taste. Opinions as to what constitutes a perfect display are like specimens in a collection: Everyone has one and none are identical. The available display space (limited or nearly unlimited?), display facilities (cabinets and lighting; Section 5.6A) and specimen mounting should also be considered. Conservation issues (Section 5.8) such as light sensitivity must be considered as well. Planning and assembling a fine display can be a source of personal satisfaction for the collector and adds value to the collection (Figures 5-11 and 5-26).

A. Displaying at Home

When planning a home display there are two overarching decisions to be made. First, what will be the theme of the display (if any)? Secondly, what display facilities (cabinets, floor space and budget for cabinets, etc.) are available? The first issue has been discussed briefly in the preceding paragraph so now we focus on the display facilities. All these decisions are obviously controlled by your budget and creativity. For a nice cross section of mineral displays see Rider (2019). In these displays consider the desirable (labeled acrylic stands, excellent lighting, not overcrowded, etc.) as well as undesirable characteristics (poor lighting, overcrowded, not protected by a cabinet, distracting labels, etc.) as you read the remainder of this Section.

Some collectors prefer to display their specimens in the open on shelves or windowsills. This option is more budget-friendly than acquiring **display cabinets** but allows dust to accumulate. An open display also increases risk of damage especially when small children or cats - both notoriously curious and apt to touch things - are in the household (Figure 5-25).

Figure 5-25. Cats have an insatiable need to knock things on the floor including minerals. Protecting specimens in a display cabinet may cause feline frustration but will save the minerals.

Front opening cabinet doors interfere to some extent with display visibility when the cabinet is closed (Figure 5-26). A cabinet with side doors does not have this sight obstruction but when adding or removing specimens it may be necessary to reach over specimens already in place, creating an avoidable damage risk.

Figure 5-26. This Ikea 'Billie' cabinet makes for a fine display at a reasonable price. Wooden shelves were replaced with custom-cut glass shelves and LED lighting was added with minimal do-it-yourself skills. The collection owner lives in a dusty, semi-arid environment with two playful cats: hence the glass doors.

The price range for new display cases is wide. Ikea (www.ikea.com) offers numerous options starting at $200 or less (Figure 5-26). Ikea may carry a particular style for years making it easier to acquire a matching case when you expand your display. The Billie line shown in Figure 5-26 has been available for about twenty years at the time of this writing. The Waddell line of display cases offers numerous, classy options for mineral collection display at prices up to $5000 per case. A Google search reveals several suppliers. Excalibur Mineral Corporation (www.excaliburmineral.com) offers several styles at discounted prices. The Arkenstone (www.irocks.com/cases) offers a line of exquisite, lighted display cases. It's West Display & Lighting (itswestdisplay.com) offers customs display and lighting solutions designed for mineral displays. If you like an antique or retro look, check used furniture stores where display cabinets may be called 'curio cabinets.' These used cabinets are often expensive because they are sold primarily as collectable antiques. In addition, finding matching furniture when expanding the mineral display can be challenging. Unmatched cabinets produce a distracting, unharmonious appearance and draw attention away from the focus of the display - the minerals themselves. Such cabinets almost always require additional investments in new shelves and lighting. For the collector with significant woodworking skills (and time) building your own cabinets to your own exact specifications and needs can be quite rewarding. Zimmerman (2013) provides an excellent example with detailed discussion. (Zimmerman emphasizes halogen lighting - this was the standard at the time - instead of LED lighting, so the discussion is somewhat dated on this topic.) Hiring a custom cabinetmaker to design and install custom display cabinets is another possibility (when you win the lottery). Choose cabinet materials cautiously as some common materials may emit vapors which are harmful to minerals (Arenstein *et al.* 2022).

Cabinets on top of drawers are another option to be considered. Such an arrangement increases number of specimens available to be viewed but these hidden specimens have no appeal until the drawers are opened. Specimens in drawers often collect dust at a slower rate than those in cabinets, thus requiring less maintenance.

Display cabinet locks can be unsightly and are usually only necessary if there is some reason to enhance specimen security such as small children or visitors with unknown morals.

Some collectors add a background to the cabinet. When nonintrusive this background can enhance the display's aesthetics but an intrusive background (bright colors or a mirror, the latter usually intended to allow specimen backsides to be viewed) can be quite distracting and even downright gawdy. A background which is the same color as the cabinets themselves is best. Remember that the specimens are the main attraction in a mineral display.

Cabinets in the basement or garage should be elevated off the floor and otherwise protected against possible water and insect incursion damage.

Shelving is another detail to consider. Cabinets with fixed position shelves may be somewhat less expensive but reduce flexibility when planning the initial setup or reorganization of a display. Plastic shelves should be avoided as these scratch much too easily, are often too weak to support enough weight and (in some cases) can yellow over time (especially if exposed to constant sunlight or cabinet illumination). Wooden shelves tend to scratch readily and reduce light

getting to specimens on lower shelves. Glass shelves are ideal. The cabinet shelves in Figure 5-26 were custom-cut, tempered glass measuring 6 mm thick and were the greatest single item in the budget for this cabinet. Thinner glass may not have the strength to hold heavy specimens. Tempered glass is treated to make it stronger than annealed glass of the same thickness. It is more expensive than untreated glass but is another one-time investment in your collection's overall safety. Think twice before skimping on the quality of glass shelves as the failure of one shelf can be a calamity for every specimen in the cabinet. Shelves must be supported securely within the cabinet (another issue which may need to be upgraded as part of a used cabinet purchase). This is especially critical when considering protection against earthquake damage (discussed below). Risers provide additional display flexibility (top and middle of Figure 5-26).

Proper **lighting** is necessary to bring out the full beauty of the displayed specimens. Selecting appropriate lighting requires thought and research. Several factors must be considered simultaneously with the cabinet selection. External lighting can provide some display enhancement but will cause glare when the display is behind closed glass doors. Lighting within the cabinet - frequently underneath a shelf or in the corner between the cabinet front and side panels - is immeasurably better than any external lighting. The two can be made to work together so do not automatically eschew external lighting. The internal lighting can be built into a new cabinet or may be something you add yourself. When new cabinets are in your budget consider purchasing cabinets with built-in lighting. Although these are generally more expensive than unlit cabinet, they may be less hassle in terms of time, effort and cost than adding your own lights to an unlit cabinet. Like the need to duplicate cabinet style when adding another cabinet to the display consider also the need to duplicate lighting style for the extra cabinet (if you have do-it-yourself lighting).

When selecting lighting pay attention to six fundamental characteristics: *illumination type* (incandescent, fluorescent, halogen or LED), *color temperature* (essentially a measure of the colors emitted), *color balance* (how evenly are the various colors emitted; daylight balanced - simulating natural sunlight - is often better than cool or warm), *intensity* (measured in lumens), *heat produced* and *cost*.

Direct sunlight has excellent (if not ideal) color temperature and color balance and is affordable. Specimens often look better in direct sunlight than under any artificial light source. However, sunlight is generally not adjustable nor is it available on demand. Sunlight also includes some ultraviolet which must be considered unless the cabinet glass effectively blocks it.

Incandescent (tungsten) lighting generally has insufficient color temperature and color balance to illuminate minerals to their best advantage. Much of the energy consumed by an incandescent bulb is released as heat causing the display cabinet to become warm and potentially damage some minerals. Incandescent lighting is not a good choice for a mineral display.

Fluorescent lighting, once widely popular as CFL (compact fluorescent lighting) has better color temperature and color balance than incandescent lighting but can easily become warm. Fairly energy-efficient, but LEDs are a better choice.

Halogen lighting was until 10–20 years ago the standard for lighting exhibits of all kinds. Excellent color temperature and color balance were available. However, the bulbs tended to be expensive, often had short lifetimes and produced much heat, making their use in an enclosed display cabinet problematic. In one case a cabinet illuminated by halogen lights increased by almost 4°C in just 13 minutes whereas a similar cabinet illuminated by LED lights (Figure 5-26) warmed by less than 1°C in 90 minutes.

Light emitting diodes (LEDs) are the modern standard. Once expensive, these have become widely available and sufficiently inexpensive to be installed even in large displays. Available in a range of color temperatures, 5000K (very close to natural sunlight) is generally best for mineral displays. Tunable color temperature is available at a somewhat higher price. Color balance tends to be better in more expensive units. LEDS have excellent energy efficiency and produce very little heat allowing the display cabinet to be illuminated continuously without concerns for potential thermal damage. Available in various configurations and usually requiring only minimal do-it-yourself skills to install. LED lights (strip lights in particular) are composed of numerous, point light sources. This allows light to reflect off multiple crystal faces simultaneously compared to the more diffuse sources mentioned above which often cause the specimens to appear less 'lively'. Specimens lacking distinct crystal faces - such as botryoidal prehnite - may appear better under a more diffuse light, in which case the LED output can be diffused with a translucent, white plastic cover. Dimmable LEDs are also readily available and only modestly more expensive than similar, undimmable units. In summary, when purchasing LED lighting look for 5000K units which are dimmable and tunable (if the budget allows). Betts (2025b) states that color temperatures above 5000K "makes gold look greenish" and anything lower "won't render blues [or] purples." LED lighting has a very long lifetime and thus usually never needs to be replaced.

The *cost* of proper lighting will be a significant portion of your mineral display budget. However, poor lighting will negate all other positive aspects of a well-planned display. Although you can start with less costly lighting and upgrade later this may not be a trivial task and is a waste of the money spent on 'start up' lighting. Thus, it is a good idea to invest in the very best lighting from the start. Your budget and your minerals will thank you and your visitors will be impressed.

Another factor to consider is the number of light sources. As mentioned above multiple point sources illuminate a specimen more effectively than a single (even brighter) source. LED spotlights whose position can be adjusted are a nice add-on especially in combination with (nonadjustable) strip lights. Some collectors like strip lights inside the cabinet and bright halogen spotlights outside the cabinet (where heating is not an issue) but these external lights can create glare on cabinet doors (Mason 2024). The best light position within the cabinet - mounted to a shelf above the specimens, directed from behind, etc. - depends on what you are displaying. In a typical mineral display, the light source will be above and/or in front of the specimens causing the specimens to be seen in reflected light. Translucent and transparent specimens (colorful tourmalines, pallasite meteorite slices, etc.) often appear more colorful when lit from above and (even more so) from behind (Figure 5-27). (Pallasite slices are often displayed lying on a light box.) Opaque specimens usually do not benefit from backlighting whereas transparent gem

specimens and slabs may be 'livelier' when lit from behind and/or beneath. If backlighting is used glare is blocked by diffusing the light with translucent white plastic, etched glass or some other material (Burns 1941, 171).

Figure 5-27. Left: A smoky quartz crystal lit from the front thus seen in reflected light. Right: The same crystal lit from behind.

For more detailed discussions of mineral display cabinet lighting consider the advice of John Betts, who has extensive experience in exhibit design for museums (Betts 2025b). The discussion initiated by Szarka (2018) gives some insight into color temperature for mineral displays.

Other details include a carpeted floor (which may reduce damage when a specimen is dropped) and good temperature control in the display room (but avoid heating or air condition currents blowing directly on to minerals and cabinets). A vent fan is a good idea for cabinets where halogen or other hot light sources are used and replacement with LED lighting is not feasible.

Protection against earthquakes should be considered especially for collectors who live in seismically active areas. Like paying for insurance no one wants to put out the extra expense but if a quake does occur you will be very glad you did. Additional motivation for earthquake security might be gained by reading the gut-wrenching accounts of earthquake damage to the collections of Jack Halpern (Halpern 2001), Willard Perkin (Megaw 2013) and others (Wilson and Currier 2001). Kampf (1994) provides an excellent overview of problems and solutions concerning mineral collections and earthquakes. Simple yet effective earthquake damage mitigation actions include adding small rubber feet (vinyl bumpers) to mineral stands (so specimens are less prone to slide around), using firm yet reversible adhesion to secure specimens to their stands, securely strapping cabinets to the wall (don't assume that a cabinet is so heavy that it cannot be toppled, especially tall cabinets), installing secure cabinet door latches (to keep specimens from sliding off the shelf onto the floor) and using shelf supports which prevent the shelf from bouncing up and down (Hardinger 2023c). Mineral collection insurance is usually expensive and requires a professional appraisal (another significant cost) and is thus impractical for all but the most valuable collections. Interested collectors should consult their insurance agent for more details. Halpern discusses collection insurance in the context of recovering from his calamity mentioned above and recommends securing specimens to the shelf with Quake Wax for added earthquake security (Halpern 2001).

B. Setting Up or Reorganizing a Display

Once the display cabinets, shelves and lighting have been installed, where and how to install the specimens? If not already done now is the time to decide on the display's theme or organization if any. It is much easier to figure out which specimen goes where before placing any specimens in the cabinet instead of constantly moving specimens in, out and around with subsequent risk of damage. Display theme possibilities are as broad as your imagination. Examples include organization by color, mineral species or mineralogical classification (Dana, Strunz, etc.), locality, shape, size, self-collected to mention a few. Read Backner (2024) for even more ideas. Every collector wants to maximize the number of specimens to show off in a display but overcrowding makes the display cluttered and unprofessional. Selecting just the right number of specimens can also help you carefully evaluate what fits into the cabinet's theme. Practice and review your planned organization outside the cabinet (perhaps on the kitchen table) where there is more room to maneuver compared to the sometimes-cramped quarters inside the display cabinet. Consider best viewing angle (straight on versus from above) when deciding on which shelf to place each specimen. For example, a terminated crystal might be placed somewhat below line of sight to allow inspection of the termination. Place gem crystals directly in line of sight so they will receive some backlighting to emphasize their color and clarity. Larger specimens and lower quality specimens generally look better on lower shelves (and are safer there as well).

When it is time to begin placing specimens into the cabinet don a pair of well-fitting cotton gloves. These gloves provide some protection against handling damage and prevent fingerprint transfers (imagine having to unload an entire display cabinet shelf to clean that one fingerprint that seems to suddenly appear, marring an otherwise perfect display). Cotton gloves are generally cheap enough to be disposable and some should always be kept on hand for future cabinet cleaning and display reorganization. Form-fitting gloves provide the surest fit and therefore least chance of an accident.

Remove the worst of the dust with a small, handheld vacuum cleaner such as the type used for computer keyboards. This is better than blowing with compressed gas electronics cleaner because such dusting in a semi-enclosed space tends to just shift the dust and debris around more than blow it out of the cabinet. Removing dust and tiny mineral specimen debris before wiping helps prevent scratching the shelves. Scratches are an easily avoidable flaw in an otherwise pristine display.

Only after removing dust thoroughly clean the inside of the cabinet and top and bottom of all shelves using a soft, lint-free cloth and a glass cleaning product (such as Windex) which evaporates without leaving any residue. It is often easier to remove the shelves and clean them outside the cabinet before returning them to the cabinet. Clean any stands needing attention.

When transferring specimens to their planned positions within the cabinet pay attention to their mounting. Don't assume there is a strong (or even any) adhesion to the stand. It is best to handle by the specimen or (less satisfactory) the stand alone unless the specimen is very fragile in which case handing by stand only is better. Avoid grabbing the specimen and stand simultaneously

as even minor torque can dismount a specimen and/or cause damage. Place specimens at the back of the shelf before adding more to the front to minimize potential damage caused by reaching over specimens to locate another specimen behind. When unloading the shelf take specimens in the front before those in the back. When the shelf is complete take a step back and review your work. It is easier and less frustrating to reorganize one problematic shelf instead of having to unload and rework the entire cabinet.

Sinkankas (1970, 309–326) provides additional thoughts concerning collection displays.

C. Cleaning the Display

Over time the display cabinet will collect dust, mineral specimen bits and other debris which makes the collection look uncared for. This is one of those things which cannot be avoided (blame entropy) especially in dry environments where static electricity is an issue. Cleaning is in order and for this the tools described in the previous section for setup are used.

Start by clearing adequate space on a kitchen table, etc. to receive the specimens as they are removed from the cabinet. While wearing cotton gloves unload the shelves by removing specimens in front before those in the rear. Using window cleaner solution and a soft, lint-free cloth clean each shelf with only after it is completely emptied of specimens. If shelves are even slightly insecure unload the entire cabinet before cleaning. The shelves are freed of dust and other loose debris as described in the previous section.

Specimens attached to stands or specimens without stands are cleaned of dust and other loose debris as described in Section 3.1. In most cases this will consist of gentle dusting with compressed gas followed by carefully wiping residual dust from the stand with a soft cloth *dampened with rubbing alcohol*. (Dust can be abrasive, so wiping with a dry cloth of any material can cause scratches. Avoid acetone as this instantly attacks acrylic.) When the specimen is attached to the stand gentle work with a soft toothbrush may be useful to remove dust close to the specimen. A gentle water rinse may also be useful; use distilled water (avoids water spots on drying) or rinse with 99% rubbing alcohol immediately after the water rinse. Specimens not mounted to a stand should remain on the stand until it is each specimen's turn to be cleaned to avoid having to puzzle out which stand belongs to which specimen.

An acrylic stand which does become scratched can be polished to remove these scratches. If the stand is a common square or flat stand of the type shown in Figure 5-15 it is easier to just replace the stand. Thicker acrylic block stands (especially when custom carved) can be repolished; numerous procedures can be found online. If the custom stand was carved professionally then the original supplier may be able to repolish it for you.

Examine specimens mounted with mineral tack to see if the tack is 'creeping' (flowing), drying out or losing its adhesiveness. Replace any failing tack as needed or remount with hot glue.

Remove all specimens showing sign of disintegration (especially oxidative decomposition; Section 5.8D), as this rot can 'infect' other specimens in the same cabinet as well as the cabinet

itself. Conservation measures for rotting specimens, other specimens in the cabinet or the cabinet itself may be needed (Section 5.8).

D. Competitive Display

Preparing a competitive display is a fundamentally different task than a home display. Whether competing at a local, regional or national level start by thoroughly studying and understanding the rules, especially those published by the American Federation of Mineralogical Societies (AFMS; https://www.amfed.org). Visit shows which host competitive displays and study (if available) the detailed judging results. Judging comments can be quite nit-picky but this is the nature of mineral display competition especially at the highest levels. For future reference take photos of the judging notes and corresponding exhibits. Then set your hopes high!

5.7 Storage

Rare is the collector who has adequate space, funds and time to display all the specimens in a collection. Specimens not on display need to be properly stored. Poor storage frequently results in specimen damage or information loss. A collection needing minimal storage space is easily accommodated and adjustments to this storage readily made as needed. However, storage for larger collections (or those anticipated to become large) should be carefully planned to avoid constant and tedious storage reorganization and expansion. Broad decisions need to be made, the most important of these being are the specimens to be stored in cabinets (with drawers) or in flats or some combination of these? Fiscal, space and other limitations frequently force a mixture of the two. Some concepts relating to display (previous section) and conservation (Sections 5.8 and 5.9) apply to storage so these sections should be reviewed in conjunction with planning mineral storage.

Placement of specimens within individual drawers or flats can be organized by mineral species, locality, size or any other suitable theme or the placement need not follow any particular order. It is critical, however, to update the specimen catalog immediately after any storage or display location changes are made. Hunting through thousands of specimens to find a certain one because the catalog is outdated is a low-fun activity. Re-inventorying the entire collection because storage location information is inaccurate is another activity lacking entertainment value. In the collection catalog a generalized specimen storage location such as 'drawer 6' is less useful than a more specific location such as 'cabinet 3, drawer 6, row 8, column 2.'

Much has been written about mineral storage. Discussions intended for institutional and academic collections may be more detailed than necessary for the typical amateur collector but often contain useful information. King (1986), Brunton, Besterman and Cooper (1984), DeMouthe (2017, 33–46 and 63–67) and AMNH (2023 and 2025; the latter discusses fossils but still applicable) are worth reading. The Wilson and Currier (2001) mineral mortality article should also be studied.

Whether stored in cabinet drawers, individual boxes or flats, stored specimens need **protective padding** of some sort. The traditional mineral specimen padding choice is *white cotton*

batting. This material is usually inexpensive, readily available in many sizes and easily cut to fit as needed. Multiple layers can be used where extra protection is needed. The white color provides an undistracting background for viewing specimens. However, cotton tends to turn brown over time at a rate depending upon its manufacture and the specimens in its environment. Browning may be accelerated by (or even become rot) when exposed to vapors from some minerals, most notably acidic vapors released by decaying sulfides (Section 5.8D). It can be frustratingly difficult to remove all cotton fibers from a specimen, especially so when observing longwave UV fluoresce as these fibers fluoresce a brilliant bluish white. *Polyester fiberfill* (also called polyfill or Poly-Fil) has been used as a cheaper alternative to natural cotton but it is less pleasant to employ than the former. It is stringier than cotton, tends to snag on minerals and dry skin and presents the same residual fiber fluorescence issue as cotton, but does not appear to discolor over time. Fiberfill should be replaced with natural cotton or some other more suitable protective material.

Polyethylene dry cleaning bags, available by the pre-perforated roll from numerous online suppliers, are ideal for padding mineral specimens. They are soft, have excellent chemical resistance, do not discolor over time, do not shed fluorescent fibers and can be cut or folded to any size or thickness needed. A full sheet in an 8 x 9 cm box or a half to third sheet in a 6.5 x 6.5 cm box works well. Easily reusable multiple times, the bags are inexpensive costing $50 to $100 per roll of a few hundred bags at the time of this writing. *Grocery store produce bags* are also useful in this role.

When storing specimens to be photographed avoid cotton or fiberfill padding as these materials tend to transfer threads and fuzz to specimens, requiring tedious removal before the specimen is camera ready. Such specimens should also be stored in closed boxes (even if in drawers) to avoid accumulation of dust (Beckham 2023). Minerals which gain or lose water to the atmosphere tend to fuse fuzz and dust to their surface and thus should be padded with dry cleaner or produce bags instead of cotton or fiberfill.

DeMouthe (2017, 40) includes tables of "good" and "bad storage materials."

The **space in which specimens are stored** - be it a spare bedroom, garage, basement or outside shed - should have certain characteristics to best protect the collection. In many cases a poor storage environment damages the storage cabinets and boxes first and this in turn causes specimen damage. Wood and cardboard tend to be poorly tolerant of a wet environment so the space should be water resistant. Where necessary elevate storage containers off the floor, cover them with tarps and install a dehumidifier. Temperature should be reasonably stable. Avoid areas which become too hot or too cold (for example, sulfur can crack at temperatures as low as body temperature), including areas close to household heating systems. A moderate, stable humidity level is preferred. Rodents and insects will chew and nest in cardboard and wood so precautions to control or exclude these critters are important. Consider fire prevention measures from the start. The efforts of Chamberlain (2008) to recover his collection from fire and subsequent firefighting damage should convince you to invest the effort. Install fire resistant or fireproof materials, fire suppression (but sprinklers create a water damage problem), smoke detectors etc. Additional storage issues are discussed in Section 5.8.

When selecting appropriate **storage cabinets** several factors must be considered. Unless the cabinets are in the collection display area aesthetics are less important than sturdiness and function. Cabinets made of wood are generally better than those made of metal. If wooden cabinets become warped by water damage and unable to be opened specimens can still be accessed by disassembling the cabinet whereas a metal cabinet rusted shut presents a greater challenge to open without damaging the specimens inside. Wood is a poorer conductor of heat than metal and thus wood provides better short-term protection against fire damage. However, some woods can emit damaging fumes, especially when improperly aged or sealed (King 1986 and Arenstein *et al.* 2022). Overall, the cabinet needs to be sufficiently sturdy to support the weight of specimens it is expected to contain and must be rigid enough to handle opening and closing (sometimes not too gently) of heavy, mineral-laden drawers. Assemble-at-home cabinets are appealing but often need reinforcement to be sufficiently rigid. Ikea (www.ikea.com) sells numerous cabinet styles which can be adapted for mineral display (Figure 5-26) and storage (Figure 5-28). Some Ikea models have been available for numerous years, making it easier to match existing cabinets when expanding the storage area. Used furniture stores are another source of storage cabinets but can be expensive because such stores are directed more for the antique market than for mineral collector interests. Map or blueprint storage cabinets are popular for mineral collection storage. A lockable cabinet - either with a single lock securing the entire cabinet or one lock per drawer - may also be needed as security against earthquakes or inquisitive children. Some issues applying to display cabinets also apply here.

Figure 5-28. An Ikea cabinet used for mineral storage, with uniform individual specimen boxes.

Small wooden cabinets, often of oak and with or without drawers, were used in commercially produced mineralogy kits produced by several famous dealers (Foote, English, Tammen, etc.). Today, these sets are highly collectable (Figure 5-29). For some examples of excellent modern wooden cabinets see White (2024).

Figure 5-29. Three Foote Mineral Company boxed sets from the 1909 catalog. Left: Elementary school crystal set. Center: A chest set. Left: A set in a small, ten-drawer cabinet (Foote 1909).

When selecting a mineral storage cabinet, the **drawers** must also be considered. Drawers must slide smoothly especially when heavily loaded. A drawer which must be forcibly yanked open is a potential source of specimen damage. Wood drawers tend to be less prone to seizing than metal drawers in this way. Sticky drawers can sometimes be cured by thoroughly cleaning the drawer and its tracks then applying a light layer of beeswax or paraffin wax before reinstalling and loading with heavy rocks. Select drawers with ball bearing drawer slides installed if possible. The drawers should not come all the way out easily which can lead to the drawer and its contents falling onto the floor. Drawers which open too readily - often because they are not level and slant slightly forward - can be an issue during an earthquake, so drawers which can be latched or locked are ideal. If multiple drawers tend to open by themselves check to see if the entire cabinet is level and apply leveling shims as needed. The drawer bottoms must be strong as sagging can cause the drawer to become stuck to the point where cabinet disassembly is needed to access its contents. The drawers must be deep enough to avoid damage the specimens. When cabinet shopping take along a box (next paragraph) to judge the drawer depth. Wooden dividers within the drawers may be useful for sturdy specimens but even with padding, may cause harm to more fragile minerals. Boxes are usually better than wooden drawer dividers.

Carboard **mineral flats** (Figure 5-30) are an economical alternative for mineral storage. A standard flat is a box with matching lid, approximately 41 cm x 28 cm and varying in depth from 2.5 to 15 cm. The exact dimensions vary with manufacturer, with flats from Denver Box (www.denverrockbox.com) designed to exactly fit their matching individual specimen boxes. Selecting flats of a consistent size allows for more efficient use of available storage space. New, unassembled flats must be stapled together using a heavy-duty stapler. (A stapler designed for a few sheets of paper may not pierce the cardboard fully resulting in a weaker assembled flat.) Flats are conveniently stacked but such stacks are still prone to earthquake damage. For storage a latched cabinet is preferable to open shelves. Flats are relatively resistant to crushing - especially when filled with individual boxes of the same depth as the flat - but can still fail if the load on top is too much. Therefore avoid (even temporarily) making tall stacks of mineral-laden flats.

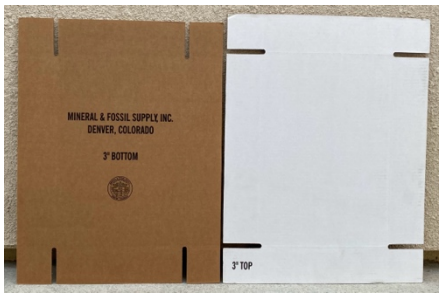


Figure 5-30. Left: An unassembled, 7.5 cm deep flat. Right: A 5 cm flat holding 12 individual specimen boxes with associated tombstone labels and padding in each box.

Regardless of whether the collection is stored in cabinets or flats (or most commonly a mixture of the two) the collection needs protective yet flexible storage for individual specimens. Ideally, **boxes** which fit exactly into the available drawer or flat space (without leaving any empty space) are ideal for this (Figures 5-28 and 5-30). Such boxes are available from a variety of sources. Those for jewelry tend to be less expensive but harder to fit efficiently into a standard flat although they may be well-suited for drawers. Denver Box sells boxes in quantity that fit perfectly into the company's matching flats (Figure 5-30) and are the standard for many mineral collectors and dealers. Small cardboard boxes have some flexibility and are therefore less prone to damage specimens than rigid wooden drawer dividers. It is convenient to keep a selection of boxes in a few different sizes on hand. The ideal specimen storage box is big enough to allow a little space between the box and specimen (which can be filled with padding) but not so big to allow the specimen to rattle around too much and break. Fold-up boxes (Figure 5-31) are also available in a variety of size and are cheaper than Denver Box boxes (hence favored by some dealers) but offer much less specimen protection especially in the absence of padding. Fold-up boxes should be considered for temporary storage only except for the most rugged or least precious specimens. Egg cartons have been recommended as an inexpensive mineral storage solution, but these provide only minimal physical protection even with added padding.

Figure 5-31. A typical fold-up box showing the common fate of a specimen stored therein.

Rigid plastic food storage containers are ideal for well-protected storage of specimens which do not easily fit into standard mineral boxes as well as for exceptionally fragile specimens (Figure 5-32). Such boxes are inexpensive and available in a wide range of sizes.

Figure 5-32. This very fragile, acicular golden rutile with hematite on a friable, dried mud matrix is stored in a rigid food container supplied with plenty of dry cleaner bag padding.

Any pressure applied to a mounted specimen increases the chance of the specimen becoming dismounted. Store specimens unmounted when possible. When mounted specimens are stored, store them upright if space allows. When stored on its side place more padding under the specimen than under the stand to reduce the torque on the specimen-adhesive-stand interface (Figure 5-33). When the stand is wider than the specimen, padding is placed only under the specimen and not under the stand.

Figure 5-33. Storing a mounted specimen. The padding is placed so that the specimen is level to minimize the force on the glue joint. Dry cleaner or produce bags provide adequate padding.

To reduce chances of specimens becoming separated from their labels keep all labels together with the specimen in the same box (Figure 5-30). Any historical specimen labels should receive extra protection as needed (Section 5.9).

Micromount collections are easily stored in either cabinets or flats (or both). Such collections can easily contain 10,000 or more tiny boxes so keep track of each mount's location with appropriate catalog entries. Collectors interested in micromount storage should read Gabriel, N. (2024) and Wight (1993, 235–239).

5.8 Mineral Specimen Conservation

Even the longest-lived mineral collector is merely the temporary guardian of the collection as most specimens (with appropriate care) easily outlast multiple human lifetimes. Therefore, it is the responsibility of each collector to conserve (protect and care for) their specimens for the benefit

of future generations. Conservation of minerals includes not only the protection of their physical state but also any associated historical and scientific information, as well as reversal of damage where possible. Minerals may be damaged by light (Section 5.8A), loss or gain of water (Section 5.8B), tarnish (Section 5.8C) and oxidative decay ('pyrite disease;' Section 5.8D). A friable matrix may need stabilization and special protection during display or storage (Section 5.8E). Other specimens needing special conservation considerations include minerals which are toxic (Section 5.8F), asbestiform (Section 5.8G) or radioactive (Section 5.8H). Scientific or historical information may be lost when labels and other mineralogical ephemera are damaged (Section 5.9).

Many mineral species such as quartz, tourmaline and feldspars have excellent physical and chemical stability and therefore require minimal conservation efforts. However, it is best to develop an 'everything is fragile and precious' attitude and thus extend thoughtful conservation, preservation, display and storage efforts to all specimens. Understanding and applying proper mineral conservation requirements will reduce the chance of damage to your collection.

For general reading on mineral preservation and conservation see AMNH (2025), Brunton, Besterman and Cooper (1984), DeMouthe (2017), Duthaler and Weiß (2024), Howie (1992), Wight (1993) and Wilson and Currier (2001). See also specific mineral species in Chapter 4 and at www.mincleandev.com.

5.8A Photosensitive Minerals

Some chemical changes can be initiated by visible or ultraviolet (UV) light. These changes are mostly due to reshuffling of electrons and changes in atomic oxidation states. For example, in black and white film photography absorption of visible light by colorless silver chloride (AgCl) on the film reduces this compound to metallic silver (Ag^0) which now appears black. The study of the interaction of light with matter (including chemical changes) is called *photochemistry*. A substance which may be changed in some way by light is *photosensitive*. Light-induced color changes may be reversible (in which case the substance is called *photochromic*) or irreversible.

A complete list of minerals known to be photosensitive is too long to give here, but examples include proustite, pyrargyrite and some other deep ruby red silver minerals ('ruby silver') which alter from gemmy red to opaque and dark. Cinnabar changes in a similar manner (Rapil 2024). Silver halides such as chlorargyrite and iodargyrite darken. Colored spodumene crystals (kunzite and triphane) change to a different color (green and blue to pink) or fade altogether (become bleached). Pale morganite becomes more intensely colored in sunlight. Vivianite alters from green to blue and then to bluish black and splits apart (accelerated by evil; Petrov 2023). Red realgar is converted to orange pararealgar (Figure 5-34; Douglass, Shing and Wang 1992). For photosensitivity of specific minerals see www.mincleandev.com.

Figure 5-34. Sun light exposure on the mine dumps as converted the realgar (was deep red) on this specimen to orange pararealgar. The white matrix is ulexite.

There is no simple correlation between a mineral's photosensitivity and its chemical formula. For example, many but not all silver and mercury minerals are photosensitive. Some correlations may be discovered upon comparing minerals at www.mincleandev.com. Sensitivity to photochemical changes is often inconsistent within specimens of the same mineral species or even the same species from separate localities (King 1985, 107). For example, pink kunzite from the Pala Mining District in San Diego County, California tends to be less resistant to bleaching in sunlight compared to the same material from Afghanistan. When change does occur the rate of change can vary widely, from minutes to decades, depending upon the mineral species, locality, and type and intensity of light.

Protection of photosensitive minerals against both light-induced changes in simple: Avoid light. All light sources used to illuminate minerals produce visible and ultraviolet light. The UV intensity from white LEDs is negligible and can for practical purposes be ignored. Thus, a photosensitive specimen is best conserved by storing it in a closed box. (In most cases unboxing the specimen to impress show it is perfectly safe. Some specimens will fade over time, even in a closed box.) When a photosensitive specimen is to be part of a display use only LED lights for illumination. Avoid any exposure to sunlight, or if this is not feasible, a cabinet glass which blocks UV should be used.

For general discussions of mineral photosensitivity see Duthaler and Weiß (2024, 109) and Howie (1992, Chapter 2).

5.8B Minerals Sensitive to Humidity or Prone to Dehydration

Interaction with water is an important issue in mineral specimen conservation. Some minerals dissolve partially or wholly in water. Halite (NaCl; same formula as table salt) is a familiar example. Some minerals which already have one or more molecules of water within their crystal structure (*hydrates*) can lose water to the air (a process called *dehydration*). For example, borax readily loses water to become tincalconite (Equation 5-1 and Figure 3-74). (Review the "•xH_2O" notation in Section 3.14.) Sometimes tiny, fragile crystals of the dehydrated species form on the specimen's surface as solutions carrying salts rise to the surface and evaporate. This coating is called *efflorescence*. (In older literature the term 'efflorescence' was sometimes used

synonymously with 'dehydration.' To a modern chemist 'efflorescence' is the surface deposit and 'dehydration' means 'loss of water'.)

$$\underset{\text{Borax}}{Na_2B_4O_5(OH)_4 \bullet 8H_2O} \rightarrow \underset{\text{Tincalconite}}{Na_2B_4O_5(OH)_4 \bullet 3H_2O} + H_2O$$

Equation 5-1

Minerals which spontaneously gain water from the air are *hygroscopic*. A *deliquescent* mineral absorbs so much water that goes into solution. Although hygroscopic compounds are common in the laboratory, hygroscopic minerals are much less common in nature than minerals which dehydrate.

A substance lacking water in its chemical structure is *anhydrous*.

When a mineral can lose one or more molecules of water, and the dehydrated form is visually indistinguishable from the more hydrated species the dehydrated form is often indicated with a 'meta' prefix. For example, a torbernite - copper uranyl phosphate mineral - can lose four molecules of water to form metatorbernite (Equation 5-2 and Figure 5-35). Torbernite and metatorbernite are visually indistinguishable and require chemical analysis to determine which species is present. 'Meta' may also indicate an isomeric form of a mineral, such as cinnabar and metacinnabar. This duplicate meaning of the same terminology can be somewhat confusing.)

$$\underset{\text{Torbernite}}{Cu(UO_2)_2(PO_4)_2 \bullet 12H_2O} \rightarrow \underset{\text{Metatorbernite}}{Cu(UO_2)_2(PO_4)_2 \bullet 8H_2O} + 4\ H_2O$$

Equation 5-2

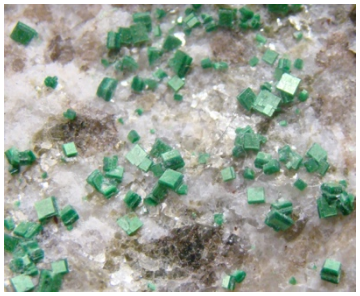


Figure 5-35. Torbernite and metatorbernite cannot be distinguished visually so without chemical analysis we cannot say if the mineral seen here is torbernite or metatorbernite (or even a mixture of the two).

When molecules of water are gained or lost from the crystal structure changes may be obvious or go completely undetected until chemical analysis is conducted. For example, borax starts as water-clear crystals but becomes opaque and chalky when it absorbs water and is converted to tincalconite (Figure 3-71) whereas torbernite and its dehydration product metatorbernite are visually indistinguishable (Figure 5-35). Other phenomena may be observed when water is gained or lost. For example, the color of deep blue chalcanthite ($CuSO_4 \bullet 5H_2O$) fades

to almost colorless as it dehydrates to anhydrous $CuSO_4$. Cracking, peeling and ultimately complete disintegration into powder is another common, water-related change.

A change in hydration may be reversible but the damage caused by such a change is generally not (although it can sometimes be hidden by oiling; see below).

Alternation crusts can often be removed by gentle brushing with a *soft* toothbrush, as mineral species discussed in this section are typically rather soft. Tougher crusts may be attacked with a wooden toothpick, bamboo sliver or plastic brush but with harder tools greater care must be exercised to avoid damage. Extreme cases of crust removal might require air abrasion with a *soft* blasting medium. When conversion is partial the crust will lie only on the surface and removal may reveal a good crystal beneath (Figure 5-36). However, when conversion is complete no amount of crust removal will reveal the original mineral species. Like removing chlorite from quartz, removal of an alteration crust may leave a rough surface.

Wear gloves when handling water-sensitive minerals to prevent damage from skin moisture.

Figure 5-36. Left: Despite storage in a well-sealed jar this thénardite (Na_2SO_4) crystal has absorbed water from the air causing a loss of transparency and formation of a white crust (likely $Na_2SO_4 \bullet 10H_2O$). Right: After gentle brushing with a soft toothbrush.

Prevention of water loss or gain is necessary for preservation of the types of minerals covered in this section. The propensity for a mineral to lose water increases with lower relative humidity whereas the propensity for a mineral to absorb water from the atmosphere increases with increasing relative humidity. The most obvious way to conserve these minerals is to keep them in very low or very high humidity environments, usually in a well-sealed container. A jar with tight fitting lid provides better protection than a plastic freezer bag. Sealing the lid with electrical tape (Figure 3-26) provides further (but imperfect) resistance to the incursion of moisture. Sealing the container with glue is not ideal as such seals are permeable over time and make it more difficult to access the specimen later. For specimens which tend to dehydrate over time a sealed container also helps keep the atmosphere within saturated with water, but again this is an imperfect preservation technique.

For specimens best stored in a low humidity environment a water-absorbing material (a *desiccant*) should also be included. Silica gel (the 'do not eat' packet) can be used but one can only guess if the desiccant has any remaining water absorption capacity. *Indicating Drierite* is a cost-

effective desiccant whose remaining capacity can be judged by its color. This material is composed of calcium sulfate ($CaSO_4$; the actual desiccant) pellets combined with cobalt chloride (a colored indicator). The cobalt salt turns from blue ($CoCl_2$ when anhydrous) to pink ($CoCl_2 \bullet 6H_2O$ when spent) providing a simple visual method of accessing the desiccant's status (Equation 5-3 and Figure 5-37). When the Drierite is all pink replace it with fresh Drierite. Spent Indicating Drierite is easily regenerated by heating for a few minutes on a hot plate or in a conventional microwave oven. Avoid white Drierite as it lacks the useful color-changing indicator.

$$\underset{\text{Blue}}{CaSO_4 + CoCl_2 + H_2O} \rightleftarrows \underset{\text{Pink}}{CaSO_4 \bullet 2H_2O + CoCl_2 \bullet 6H_2O}$$

Equation 5-3

Figure 5-37. Left: The cleaned thénardite crystal of Figure 5-36 stored in a well-sealed jar over fresh (blue) Drierite. Center: Time to replace the (pink) Drierite. Right: The same crystal stored under silicone oil.

Humidity within the storage environment is conveniently monitored with an electronic hygrometer. Modern hygrometers can even be monitored via a smartphone.

Coating with oil is also useful for preservation. Oiling also makes a nonopaque specimen appear more translucent to transparent. For preservation use a silicone oil or a mineral oil and not a cooking oil (such as olive oil or PAM) as cooking oils inevitably become rancid with time. Hair spray has also been recommended but compositions vary widely between brands, and some may contain chemicals harmful to minerals. A sprayable oil is easier to apply than a thicker (more viscous) oil which must be brushed on. Any oil coating is somewhat permeable to air, so it provides imperfect protection against absorption or loss of water. Oiled specimens tend to collect dust unless stored in a closed container. To apply oil simply coat the specimen with a thin layer of oil (dipping is often useful) then blot any excess. Storing in a humidity-controlled environment in conjunction with a surface coating provides significantly better protection than either method alone.

Complete immersion in oil (Figure 5-37) provides better protection than a sprayed oil coating and generally avoids the dust issue. For immersion select an oil which is dispensed by pouring instead of spraying because spraying sufficient oil for immersion can be tedious and messy. An oil of low viscosity (lower centistokes - cSt; more watery and less syrupy) is better than a high viscosity oil.

If a specimen is obtained with an unknown oil coating it is best to assure the highest level of protection by removing the coating and replacing it with a fresh mineral or silicone oil coating. To remove an oil coating first remove as much as possible with a dry, soft cloth then rinse with 99% rubbing alcohol or (less suitable) dry acetone. (Hexane, petroleum ether, gasoline and kerosine are often recommended as well but these should be avoided because they are toxic.) Rubbing alcohol and acetone evaporate quickly and become cold as they do, causing water vapor to condense on the specimen, so blot *immediately after* the solvent rinse.

Reducing water loss or absorption by coating with material such as lacquer, polyurethane, Paraloid B-72 or Duco cement is also useful, but like oil, such coatings are somewhat permeable to water vapor and thus are not foolproof conservation methods. If the specimen is to be coated select a coating which does not yellow over time and is removable with an organic solvent such as acetone or rubbing alcohol. Applying a water-based coating or a coating which needs water for removal defeats the purpose of applying a coating to protect against water.

When stored in boxes some water sensitive specimens such as halite, trona and hanskite tend to 'fuse' with fibers of the cotton or fiberfill cushioning, especially in more humid environments. In such cases insert a layer of folded dry cleaner or produce bag between the specimen and the cushioning. This is critical for specimens to be displayed or photographed as complete removal of fused fibers can be *very* tedious.

For more on preserving and conserving minerals prone to hydration, dehydration or which are soluble in water see Allington-Jones (2017, 4), Duthaler and Weiß (2024, 136–140), Howie (1992, Chapter 3) and King (1985). For the potential sensitivity of individual mineral species to water and humidity see Chapter 4 and www.mincleandev.com.

5.8C Tarnish

Tarnish is a thin layer of corrosion on a material's surface, often only a few atoms thick. (A corrosion layer of visible thickness usually called a crust instead of tarnish. Iron rust is an example of a crust.) Tarnish is usually an oxide or less commonly a sulfide, formed when the surface encounters oxygen (O_2), sulfur dioxide (SO_2) or hydrogen sulfide (H_2S). Water may be necessary in some cases such as formation of rust. Color depends on thickness; very thin layers are colorful (often iridescent) and thicker layers brown to dark gray to black. Sometimes tarnish formation is only observed as a reduction in the mineral's natural luster (typical for pyrite, marcasite and pyrrhotite). Observable tarnishing is a phenomenon common to many native metals, sulfides, sulfosalts and other minerals having a metallic luster. For the sensitivity of individual mineral species see www.mincleandev.com.

A housewife disdains tarnish but the mineral collector should not. In some species tarnish forms a protective layer which stops further degradation. In general tarnish should not be removed as it will simply reform unless protective conservation measures are taken. Tarnish removal can make a specimen look unnaturally bright, especially native copper and native silver. Some specimens, such as lab grown bismuth crystals (Figure 5-38) have an aesthetic iridescence when

tarnished. NH_4HF_2 treatment appears widely effective for tarnish removal, probably by removing a surface coating, with the tarnish returning in hours in some cases but permanently expelled in others. For tarnish removal from some specific mineral species see Chapter 4.

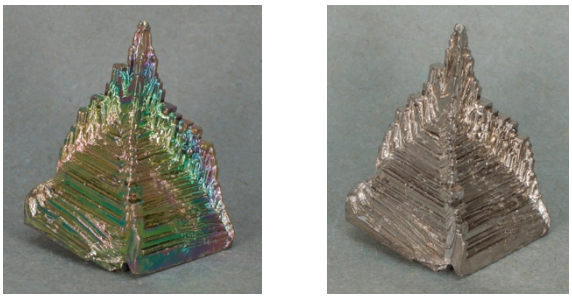


Figure 5-38. Left: A lab grown bismuth crystal, whose rainbow colors are due to an oxide layer formed while hot. Right: The same specimen after a 30-second dip in NH_4HF_2 solution.

The most effective method to prevent tarnish or stop its spread is to store the specimen in a sealed container in an atmosphere (usually pure nitrogen or argon) devoid of oxygen, sulfur dioxide and hydrogen sulfide. For the amateur this is usually not practical and so tarnish will form eventually. A specimen might also be coated with (for example) polyurethane but as mentioned above such coatings are not completely impervious to atmospheric incursion (and may also appear unnatural). Methods for conservation of some individual mineral species prone to tarnishing are given in Chapter 4.

For a technical discussion of mineral tarnishing see Howie (1992, Chapters 4 and 5).

5.8D Oxidative Decomposition ('Pyrite Disease')

Many sulfide minerals are prone to oxidation by atmospheric oxygen resulting in minor changes such as tarnish to disastrous damage including cracking and crumbling as oxidation products expand (occupy more space than the unchanged mineral; Figure 5-39) and force the specimen apart.

Figure 5-39. A sample is so heavily decomposed that is no longer recognizable as marcasite.

The chemical details of this process are complex and vary somewhat between mineral species. Equation 5-4 gives a simplified version of the process, in which pyrite (FeS_2) is oxidized by atmospheric oxygen (O_2) in the presence of water to form iron sulfate ($FeSO_4$), sulfuric acid (H_2SO_4) and sulfur dioxide (SO_2). In some cases, white $FeSO_4$ crystals sprout from the specimen (efflorescence). Bacterial action may also be involved when the relative humidity is high. Larkin (2011) notes that decay may set in when the relative humidity is as low as 60%. Decomposition causes a distinct sulfurous, metallic odor, an important indicator that decomposition has begun even if there are no visual signs such as cracking or efflorescent growth.

$$FeS_2 + O_2 + H_2O \rightarrow FeSO_4 + H_2SO_4 + SO_2 \qquad \textbf{Equation 5-4}$$

The acidic products of sulfide decomposition can spread to other materials in the vicinity including other specimens, labels and cabinet components causing these to become damaged as well. That this decomposition is most encountered with pyrite and that other materials may become 'infected' lead to the term *pyrite disease* or *pyrite rot.* Pyrite disease is not limited to just pyrite as it can also strike marcasite (FeS_2) and pyrrhotite (~FeS) as well as other sulfides such as galena (PbS; Figure 5-40). (In the case of galena, the decay may be from pyrite or marcasite inclusions and not the galena itself.) Alabandite (MnS), arsenopyrite (FeAsS), gersdorffite (NiAsS) and safflorite ($CoAs_2$) are also potential victims of oxidative decomposition (King 1985, 103). Because this decay is not limited to pyrite it is sometimes also called *sulfide rot*.

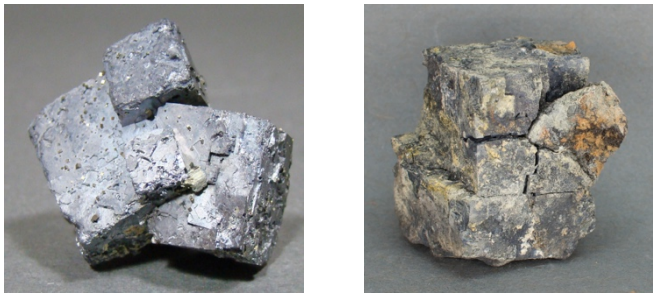


Figure 5-40. Pyrite disease it not limited to pyrite. Left: A galena crystal cluster free of rot. Right: A galena crystal afflicted by sulfide rot (probably due to pyrite or marcasite inclusions).

The propensity to decompose varies widely with locality and even within specimens from the same locality. Pearl (1982) lists some localities whose pyrite (page 47) and marcasite (page 51) specimens frequently rot. King (1985, 103) notes: "The most important factors determining stability is crystal morphology, since oxidation begins at exposed surfaces and inter-crystalline boundaries. Thus, stability is related to the genetic environment of the material and therefore to locality. Large crystals from metamorphic or hydrothermal situations are less likely to be affected by oxidation than fine-grained polycrystalline material, such as sedimentary pyrite or marcasite nodules." Storage in high humidity environments appears to be another contributing factor.

More has been written about the treatment and prevention of oxidative decomposition of pyrite and marcasite than of any other minerals due to the abundance of these minerals on Earth (and hence the number of specimens in collections) combined with their propensity to decompose. Much of this literature is aimed at mineralogical and museum professionals. The amateur interested in more detail should see DeMouthe (2017, 27), Duthaler and Weiß (2024, 131), Howie (1992, Chapter 6), King (1985), Kolesar (1996, 94–95), Larkin (2011), Shinya and Bergwall (2007) and Waller (1987). For writings on pyrite disease in fossils (also applicable to mineral specimens) see Davidson and Brown (2012). A recent comprehensive review of the science by Tacker (2020) is worth reading.

Water (even atmospheric moisture) sometimes initiates or accelerates oxidative decomposition in specimens which otherwise appear to be stable. Thus, if no signs of decay exist use only dry methods such as gentle brushing or compressed gas for cleaning. If the specimen exhibits any signs of decay steps should be taken to slow the decay. Oxidative decomposition damage is irreversible.

Oxidative decomposition can generally be slowed but not completely stopped. Specimen destruction is usually inevitable, occurring in months to decades. While specimens with signs of sulfide rot can be conserved in most cases it is better for the rest of the collection to simply discard the problematic specimen. When the specimen is sufficiently precious, apply the conservation measures described below. Even when it shows no signs of decay (yet) minerals from localities known to produce decay-prone specimens should be considered for preemptive conservation measures.

When handling decomposed pyrite, marcasite and similar materials wear gloves, as the peculiar, sulfurous odors of this material persist on the skin even after thorough washing with soap and water. In addition, acidic decomposition products are likely to irritate sensitive skin.

The mineral cleaning literature contains numerous recipes for treating oxidative decomposition. Some of these methods require facilities or chemicals not readily accessible to the amateur and some are downright comical. A simple and effective method used by this author and based on Sinkankas (1972, 263) is as follows. Remove any loose debris by dry methods then soak overnight sequentially in household NH_3, clean water and finally acetone or 99% rubbing alcohol. Allow the specimen to dry at room temperature overnight. If after *thorough* drying the sulfurous odor persists either repeat the treatment or discard the specimen.

Older mineral cleaning literature generally suggests that after treatment and drying the problematic specimen should be given a coating of some sort such as polyvinyl acetate, Paraloid B-72, lacquer or oil. However, more recent reports have brought the protective value of such coatings into question as no coating is completely impervious to atmospheric oxygen or moisture. Coatings may slow the decay but cannot completely prevent the process. For example, a study of several synthetic resins found that none provided complete protection against decay (Costagliola, Cipriani and Manganelli 1997).

Storing the treated specimen in a closed container with a desiccant such as Indicating Drierite will further prolong its life. Although no studies appear to exist using an alkaline desiccant

such as calcium oxide (CaO; lime), sodium hydroxide (NaOH; lye) or potassium hydroxide (KOH; caustic potash) may slow decomposition by absorbing both moisture and acidic vapors.

Pezzotta (2022) reports that storage of sulfides sensitive to oxidative decay in hermetically sealed containers seems to *promote rather than hinder decomposition*. Storage in a *ventilated environment* such as an open box is preferred. He further suggests that coating "actually activates and/or accelerates the alteration processes."

Any specimen which continues to show symptoms of decay after NH_3 treatment and storage in a low humidity environment is likely beyond the resources of the typical amateur to preserve indefinitely. If such a specimen is sufficiently precious contact a professional for expert conservation.

When a specimen is to be retained replace its label and box (even if seemingly undamaged) as these may also harbor acidic fumes which may lead to their eventual destruction, and which may spread to other specimens. When cleaning or reorganizing the display specimens should be examined for indicators of oxidative decay even if these specimens have always appeared to be stable in the past (much like a person should get an annual physical exam, even if they have always appeared healthy in the past).

Related to 'pyrite disease' is Byne's disease, in which calcareous specimens such as fossils are attacked by acidic vapors released by wood components of display cabinets (and presumably other sources such as decaying sulfide minerals) resulting in efflorescence of calcium salts on the 'infected' specimen (Shelton 2008).

For additional information on cleaning and conserving specific mineral species prone to sulfide rot see individual listings in Chapter 4. For the potential sensitivity of individual mineral species to oxidative decay see www.mincleandev.com.

5.8E Minerals with Friable Matrix

Handling a specimen with a thin, fragile or friable (crumbly or spongy) matrix can cause the specimen to shed crystals or even fully disintegrate. Techniques to stabilize or reinforce the specimen against such disintegration or to stabilize it for development operations such as trimming are useful. These methods should be easily applied, not impart an unnatural appearance to the specimen and (if possible) should be reversible. Obscuring interesting crystals should be minimized. Stabilization of the backside alone should be considered before immersing the entire specimen in the stabilizer solution. Some examples of specimens which may benefit from matrix stabilization include boleite on gypsum/anglesite matrix (Amelia Mine, Baja California Sur, Mexico; Figure 5-41), crocoite in gibbsite matrix (Adelaide Mine, Tasmania, Australia), kunzite on montmorillonite clay (Pala Mining District, San Diego County, California) and various species on fine-grained, powdery limonite (Ojuela Mine, Durango, Mexico).

Figure 5-41. Left: This specimen of boleite on a crumbly mud/gypsum matrix is in danger of disintegration unless the matrix is impregnated with a stabilizing agent. Right: This nonporous, thin, fragile gypsum and fluorite plate benefits from reinforcement (Figure 5-42).

A thin, fragile matrix can be reinforced by applying a generous patch of a removeable adhesive such as hot glue or Duco cement across the back then allowing it to harden (Figure 5-42). Alternately, a solid supporting material such as a thin acrylic stand can also be used (Figure 5-42). In either case the applied reinforcement should be reversible in the event it must be removed. Backside reinforcement is useful when there are no crystals on this face to be obscured.

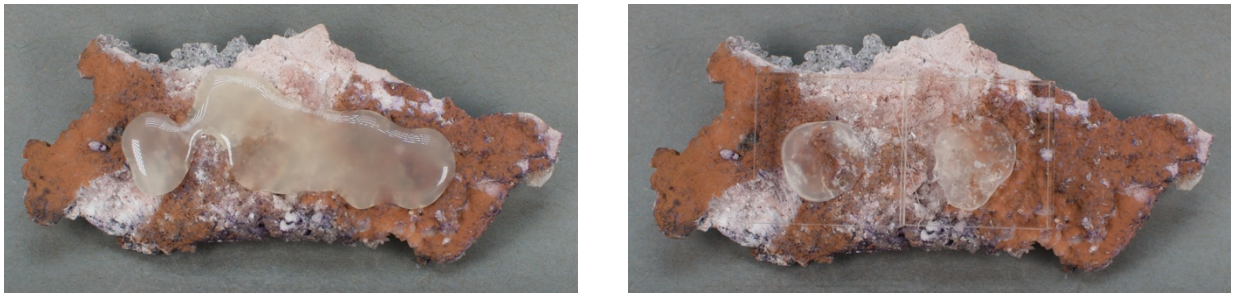


Figure 5-42. Reinforcing the back side of the thin matrix plate shown in Figure 5-41. Left: With a hot glue alone. Right: With two thin acrylic stands attached with hot glue. In both cases the reinforcement is not visible on the display face.

A friable, crumby matrix will not adhere well to the type of supports used in Figure 5-42 so the matrix must be reinforced by impregnation with a stabilizing agent. This requires the matrix to be sufficient porous and the stabilizer to be in an absorbable form, usually as a dilute solution. The stabilizing agent should not expand while drying, be transparent and colorless when dry, not turn yellow over time and be easily removable if possible. Polyvinyl acetate glue (Elmer's Glue-All) and Duco cement both meet all these requirements except the last, as once polyvinyl acetate glue is dried it is not removable. Polyvinyl acetate glue may also leave white spots where the stabilizing solution has not been completely absorbed into the matrix. Despite this, polyvinyl acetate glues and Duco cement are frequently used for this purpose as they are inexpensive, easily applied and highly reliable. Paraloid B-72 is an acetone-soluble, thermoplastic resin which can be applied to most minerals and is easily removed by soaking in acetone (Davidson and Brown 2012 and Zoic Palaeotech 2025a). Older mineral preparation literature suggests coatings or

impregnation agents such as lacquer, shellac or gum arabic but these are not ideal choices as their application is usually irreversible.

Using a sprayable stabilizing agent is sometimes recommended, but such application may not allow deep matrix penetration, nor can it generally be applied only to a small area if needed.

To stabilize with polyvinyl acetate glue, 5 mL of Elmer's Glue-All (measure with a disposable syringe) is added to one liter of water. (Higher concentrations are used by some workers. A higher concentration results in a more viscous solution which may not penetrate the matrix well. Experiment to find out what works best in your case. Other polyvinyl acetate glues may not work as well.) Stir briefly to produce a milky suspension then immerse the specimen overnight. Gloves are not needed. Rinse the specimen briefly in clean water then allow to drain and dry for several days on a wire screen mesh to minimize contact with the specimen and facilitate drying the underside. (The milky suspension turns clear when dry.) Vacuum chamber treatment may enhance the drying process. Several additional immersions are often needed to obtain the best balance between stabilization and too much glue on the specimen. How many cycles are needed is just a best guess. The glue stock solution can be stored for weeks or longer in a well-sealed container. Gently shake or stir before use. Before applying an aqueous glue stabilizer check the mineral's potential water sensitivity at www.mincleandev.com.

To stabilize with Duco cement, select a sealable, graduated container more than large enough to hold the specimen. Add the specimen then enough water to fully immerse the specimen. Remove the specimen, note the water volume left in the container, then discard the water and thoroughly dry the container and specimen. Prepare the solution by placing the container on a scale then add about 5 grams (exact amount not critical) of Duco cement per 100 mL of measured water volume. Now add the measured volume of acetone. The Duco dissolves quickly with a little stirring. Add the specimen and close the lid. After standing overnight, remove the specimen, give it a quick rinse in fresh acetone then allow to dry. Repeat the immersion/drying cycle several times as needed until the desired stabilization is achieved (an educated guess). This Duco solution does not store well so it should be prepared immediately before use.

To stabilize with Paraloid B-72 use about 5 grams Paraloid solid (exact amount not critical) to 100 mL acetone. Apply the Paraloid solution in the same way as the Duco solution. The Paraloid solution is viable for several weeks or longer after preparation if stored in a tightly sealed container.

To remove Duco or Paraloid impregnation, soak the specimen in clean acetone overnight then allow to dry. Allow the bath to evaporate at room temperature (flammable! do not heat!) and notice the residue. Repeat the soak/evaporate cycle until little or no stabilizing agent is extracted.

Any stabilization treatment should be applied only after all chemical treatments have been completed (if possible) because stabilizers may react with cleaning chemicals. Polyvinyl acetate glue softens in water and Duco cement softs and dissolves in acetone. Paraloid B-72 is softened and dissolved partially to completely in acetone or 99% rubbing alcohol and becomes hazy in concentrated H_3PO_4 but is stable to Iron OUT/EDTA. Other, yet undiscovered instabilities should be expected.

5.8F Toxic Minerals

The presence of certain chemical elements such as arsenic (As), lead (Pb) or mercury (Hg) implies toxicity. Many minerals include these elements such as realgar (AsS), galena (PbS) and cinnabar (HgS). However, whether a substance is toxic or not depends on more than just its chemical formula as there are numerous biological factors as well. A certain mineral may be nontoxic (or have low toxicity) through one route of human exposure but be highly toxic by another. Howie (1992, 116–118) provides a table of "moderate to highly toxic" minerals. King's "Minerals with toxic potential" table (1986, 139–142) gives details about each mineral's degree and mode of toxicity. DeMouthe (2017, 85) also includes a toxic minerals list. Additional information may be found at www.mincleandev.com. *Minerals not on these lists should not be assumed to be nontoxic.*

Routine, short-term handling of mineral specimens usually does not pose a serious health risk. Prolonged exposure, perhaps by a mineral in jewelry rubbing against the skin or (especially) to dust from lapidary work or mining, general poses a higher risk. The special situations presented by asbestiform minerals (Section 5.8G) and radioactive minerals (Section 5.8H) are discussed in the corresponding sections below.

Toxic minerals do not require any special conservation procedures simply due to their toxicity. However, gloves should always be worn when handling such minerals and the hands are washed immediately thereafter. Never lick minerals despite what any old timer may say! Do not use minerals to make potions, etc. **As a general precaution, treat all minerals as toxic unless known otherwise**. *Recall Guiding Principle 1. Safety is paramount!*

5.8G Asbestiform Minerals

Asbestos is a collective term for certain silicate minerals forming long, hairlike fibers (*asbestiform*; Figure 5-43). Minerals which may exhibit asbestiform crystallization include chrysotile (a serpentine mineral and the most common form of asbestos) amphiboles including amosite (fibrous grunerite, also called brown asbestos), the anthophyllite group, crocidolite (a fibrous form of riebeckite or magnesioriebeckite; also called blue asbestos), tremolite, richterite and winchite. Not every sample of these minerals will exhibit asbestiform character. Vermiculite and talc may be contaminated with fibers of asbestiform minerals so exercise caution when handling these minerals. Other minerals which may have a fibrous morphology and thus may cause asbestosis or related diseases include erionite and palygorskite (mountain leather).

Long term exposure to asbestos fibers has been shown to cause asbestosis, a scarring of the lungs due to asbestos inhalation. Short term, occasional exposure is unlikely to be an issue but appropriate precautions (wear gloves, work outdoors and wash hands thoroughly when finished) should always be taken when handling these minerals. *This is another application of Guiding Principle 1. Safety is paramount!* Asbestiform mineral specimens are often stored in a well-sealed container to minimize dispersal of fine fibers.

Figure 5-43. Left: Asbestiform chrysotile having a bad hair day. Right: Tremolite exhibiting a compact (not asbestiform) morphology.

5.8H Radioactive Minerals

Mention radioactivity and many nonscience people will envision explosion of nuclear weapons or death by horrible lingering disease. However, with some basic precautions radioactive minerals can be a safe and enjoyable aspect of the mineral hobby.

The word *radioactivity* was coined in 1898 by Marie and Pierre Curie to describe emissions produced by uranium (and later other elements such as radium and thorium). These emissions, all types of ionizing radiation, include alpha particles, beta particles and gamma rays. Considered simply, all radioactive minerals produce these radiations to some extent. Alpha particles are easily blocked by a few sheets of paper or a few inches of air. Beta particles have more penetrating power, being stopped by about a meter of air or a few millimeters of aluminum. Gamma rays have extreme penetrating power, requiring inches or more of lead to be fully absorbed. These emissions can be detected with a Geiger counter, a tool which should be owned by every collector who handles radioactive minerals (Figure 5-44).

Figure 5-44. Left: A 1950's Geiger counter. Center: A classic Victoreen Civil Defense Geiger counter. Right: A modern digital Geiger counter.

Minerals containing uranium (U) or thorium (Th) are radioactive. There are many such minerals including uraninite - UO_2, thorite - $ThSiO_4$ and torbernite - $Cu(UO_2)_2(PO_4)_2 \cdot 12H_2O$. Minerals which do not have U or Th as a primary element in their formula can be radioactive due to substitutions. For example, Th may substitute for Ce in monazite ($CePO_4$). For lists of inherently

or potentially radioactive minerals see www.mincleandev.com as well as Howie (1992, 115–116), King (1986, 143–145) and Rowan (2017).

Some radioactive minerals are unremarkable in appearance while others (mostly uranium minerals) are quite colorful, adding to their popularity among collectors (Figures 3-13, 5-35 and 5-45). Many stunning uranium mineral photographs can be seen at www.mindat.org.

Figure 5-45. Crystals of boltwoodite, a uranyl silicate - $(K,Na)(UO_2)(SiO_3OH)•1.5H_2O$.

The potential hazards posed by radioactive minerals are caused by the ionizing radiation emissions, radon gas and dust inhalation. Occasional, brief exposure to low levels of ionizing radiation is unlikely to cause a significant health risk, but steps should be taken to further mitigate these risks. The only way to completely avoid the risks posed by radioactive minerals is to completely avoid such minerals. However, radiation is still present, albeit weakly, in the natural environment and therefore cannot be completely avoided. A few, small specimens which are not intensely radioactive can be placed in the display cabinet, but large groups or large specimens should not be. If radioactivity can be detected outside of the closed flat or drawer which contains one or more specimens these specimens should be stored away from the living area (in the garage, basement or outdoor shed). Radioactive dust can be particularly hazardous, as particles which become lodged deep in the lungs will not be easily exhaled, causing lung tissue to be exposed to a constant radiation dose.

In addition to ionizing radiation, radioactive minerals also continuously release radon, a radioactive gas. Radon is denser than air and can accumulate in basements, the bottom of boxes and other low points. Because radon is radioactive it does not accumulate indefinitely but decays away, resulting in an equilibrium situation which maintains a certain fixed level of radioactivity. Radon is generally not an issue for mineral collections unless the collection contains a plethora of specimens or too many large specimens. When in doubt, monitor your radioactive mineral display and storage spaces with a detector specifically designed to detect radon (not just a Geiger counter), available at hardware stores or online. Radon decay products are radioactive solids which may accumulate on boxes and packing material so check these for radioactivity if they are to be used for other purposes.

Powdery or friable radioactive minerals such as carnotite or zippeite (Figure 3-72) pose a greater dust risk than massive minerals such as uraninite or pitchblende. A specimen which poses a small dust risk may pose a larger ionizing radiation risk, so check with a Geiger counter. Work

in a well-ventilated space (preferably outdoors) and wear gloves. Working inside a box to catch small bits which may fall off will reduce the risk of contaminating the workspace. Wash your hands with soap and water thoroughly afterwards. Some experts recommend against examining radioactive specimens with a hand lens as this brings the radiation source close to the eyes, which can be very sensitive to radiation damage. A microscope puts greater distance between your eyes and the specimen. Do not eat, drink or smoke/vape while working with radioactive minerals. All radioactive minerals should be treated as toxic. To avoid dust hazards do not clean radioactive minerals, but if cleaning is necessary review Section 3.29 first. Include the international radioactive material symbol (a trefoil enclosed in a circle; Figure 5-46) on the labels of all radioactive specimens so they can be quickly identified.

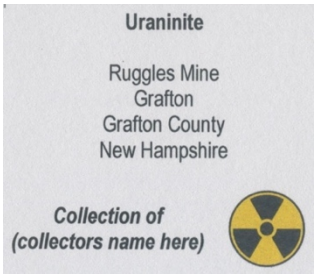
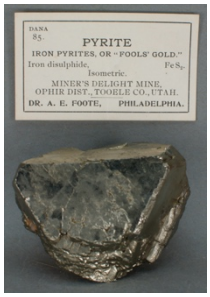


Figure 5-46. A collection label bearing the international radioactive material symbol.

Collectors who handle radioactive minerals should read Rowan (2017). Additional information can be found in Duthaler and Weiß (2024, 135), Hicks (1983), Howie (1992, 115–116), King (1986, 143–145), McDonald (2006), Price, Horack and Faithfull (2013), Rowan (2018) and von Philipsborn (1996).

5.9 Conservation of Labels and Other Mineralogical Ephemera

Ephemera such as labels, catalogs and photographs are also important parts of a mineral collection (Figures 5-47 and 5-48). Although rarely saved purchase receipts also provide valuable historical information, giving the date and amount of purchase as well as the name of the previous owner (usually a dealer). Such ephemera provides specimen context, enhancing its geological, historical and scientific value in the same way that a GIA certificate can enhance a gemstone's value. All mineralogical ephemera is potentially useful to some collector or institution and therefore should be conserved. If it does not fit into your collection seek a collector who values the item.



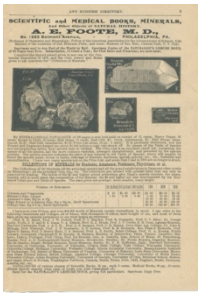


Figure 5-47. A. E. Foote ephemera. Left: A label attached to a specimen. Foote occupied the Belmont Avenue address from 1877 to 1890. Center: A printed label and associated specimen. Right: An advertisement from 1877.

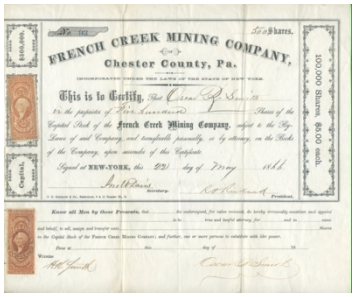


Figure 5-48. Left and center: Mineralogically-related stock certificates. Right: A 1900 Paris Exhibition award medallion.

The most common mineralogical ephemera items are paper. These are best stored with special protection and (if possible) kept with the specimen in its display space or storage box. If keeping these items together is not practical the ephemera can be stored in a separate notebook or other filing system and their location noted in the collection catalog as well as on the back of the display label and the rescue label if feasible. A photograph of the item should also be added to the specimen's entry in the collection catalog if possible. *Do not fold, tape, staple, paper clip, glue, write on or otherwise alter vintage labels or other ephemera. Make any necessary notations only on your self-printed labels.*

If stored apart from the specimen the ephemera should have sufficiently rigid support to resist bending. Glassine envelopes, stock books and other material intended for the stamp collector generally offer good protection for paper and can be useful to the mineral collector. Polypropylene sleeves and binder pages intended for sports cards can also be useful. Avoid polyvinyl chloride (PVC) as this tends to degrade and damage its contents.

All labels associated with a specimen, from vintage to modern, should be retained. These can provide important information about the specimen's history, locality and provenance, even if only recent in origin. For example, a specimen that was owned by Washington Roebling (1837 – 1926) - the engineer who supervised construction of the Brooklyn Bridge and amassed an excellent mineral collection, now in the Smithsonian's National Gem and Mineral Collection - has greater historical and scientific value than a similar specimen without this provenance. Similarly, A. E.

Foote (1846–1895) was a Philadelphia mineral dealer whose labels often included the store's address, giving a date range for the specimen (Figure 5-49). Price information recorded on such labels can be especially interesting. The Mineralogical Record Bibliographical and Label Archive (Wilson 2025) includes numerous images of vintage dealer labels. Collectors unconvinced about the "power of provenance" should read Trinchillo (2024).

Figure 5-49. Left: A dirty rock bearing a historically important A. E. Foote label. To clean or not to clean? Right: An orange 'something interesting here' arrow.

Old labels can be quite fragile and are best handled with tweezers designed for the stamp collector. Labels which are wrinkled or creased can be improved somewhat by dry pressing with a standard clothes iron on low setting. Pencil marks and light soiling can often be removed by gentle work with a clean, new (not old and hardened) pencil eraser. A nonabrasive paper cleaner product called Groomstick may also be useful. One moldy label can infect other labels so mold should be mitigated by the procedure recommended by Chamberlain (2008). The label is cleaned with a soft cloth slightly dampened with Lysol spray disinfectant then exposed to sunlight for several days. Avoid bleach as this may decolorize some inks.

Old labels are frequently printed on acidic paper in which residual acids introduced during paper production will cause the paper and its markings to fade and decay over time. There is no practical way for the amateur to stop this although sufficiently precious mineralogical paper objects can be sent to a professional conservator. The paper's lifetime can be prolonged by use of acid-free materials for storage as well as limiting light exposure.

A dirty specimen with an attached label or a 'something interesting but tiny here' arrow creates a cleaning paradox (Figure 5-49). Should the specimen be cleaned if the cleaning process damages the label? Or should the specimen be left uncleaned, perhaps leaving it less aesthetic or obscuring some crystals but assuring the label is preserved? Perhaps the label can be coated so it survives treatment after which the coating can be removed? Or will a cleaning method which poses no risk to the label (such as compressed gas) be adequate? What if the label is already heavily damaged? Opinions vary widely among collectors, but the consensus is aligned with Guiding Principle 4: "When unsure...don't (clean the specimen)." See Hardinger (2024c) and M. (2024) for discussions.

A similar case occurs when a specimen to be divided into two or more smaller specimens bears a single, historical label. Is it better to divide the specimen, keeping the original label with

the best daughter specimen and supply copies for the lesser specimens or should the specimen be kept intact (perhaps with reduced value) for the sake of the original label? The decision is more difficult when the original label is attached to the specimen. Once again, opinions vary.

Numerous print and online resources for conservation of paper and related materials are available. See for example Asiarta Foundation (2025), Burns (1941, 119–121) and Government of Canada (2020).

CHAPTER 6: Cleaning and Development Case Studies

This chapter covers the cleaning and development of actual specimens. Each example includes a description of the specimen's issues, the treatment steps used to resolve these issues and in many cases the rationale for these operations. Photos before and after treatment are also included in most cases. If the treatment resulted in no obvious change or destroyed the specimen only a before photo is shown. Most attempts listed here were successful, but some were not. Not every specimen could be improved by mechanical or chemical methods and some surprises occurred in other cases. These failures are equally as enlightening as the successes. In some cases, evaluation of a 'dirty' specimen revealed that it was actually not dirty, and no work was needed. Some cases involve a single mineral species (making treatment easier) whereas other cases involved multiple species or multiple problems adding to the complexity of the preparation decisions and procedure. For details on procedures used in this Chapter consult the Table of Contents and the Index.

Topaz (Tepetate, San Luis Potosí, Mexico)

A typical specimen for the locality, with a crusty rhyolite matrix. Treated with the textile gun followed by NH_4HF_2. Overall change was minor because much of the rhyolite is included within the topaz.

Sphalerite (Central Stone Company Potosi Quarry, Washington County, Missouri)

Dark, massive to crystalline sphalerite with a patch of a massive, uninteresting material, probably baryte (it gave no reaction with 5% HCl). Baryte has excellent chemical resistance and would need a mechanical method (most likely air abrasion) for removal.

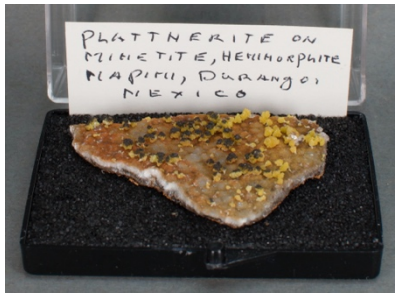
Quartz variety Grape Agate ("Grape Agate" mines, West Sulawesi Province, Indonesia)

Quartz variety grape agate (amethyst) with a disfiguring secondary crust. This crust is not a carbonate as it is inert to HCl. Textile gun treatment failed to change the specimen whereas three-hour soak in NH_4HF_2 followed by textile gun treatment resulted in definite improvement.

Goethite replacing Pyrite (Pelican Point area, Utah County, Utah)

Faithful replacement of goethite after a sharp pyrite cluster, with some impacted sandy clay. Textile gun treatment quickly removed this clay without damage.

Plattnerite, Hemimorphite and Mimetite (Ojuela Mine, Durango, Mexico)



A thin matrix plate hosting colorless hemimorphite crystals, yellow mimetite and black plattnerite crystals, mounted on an ugly spray painted styrofoam base. Considering the likely fragility of both the matrix and the plattnerite the specimen was not dismounted. The handwritten label was upgraded with a more detailed, laser printed label.

Quartz (Big Bertha Mine, La Paz County, Arizona)

A muddy and rusty quartz cluster with hints of rock crystal clarity. Textile gun treatment removed some of the compacted mud. Hot oxalic acid treatment completed the cleaning resulting in a rather nice specimen.

Quartz, Albite and Microcline (California Blue Mine, San Bernardino County, California)

The specimen might benefit from some trimming but cracks in the matrix perpendicular to display face suggest that any trim may propagate these cracks and split the specimen. Without the trim the matrix also makes a perfect natural stand for a great display angle. The specimen received no treatment.

Quartz, Muscovite and Feldspar (Elizabeth R Mine, San Diego County, California)

Sandy, decomposed feldspar with muscovite on quartz. No improvement occurred upon textile gun treatment. Treatment with NH_4HF_2 followed by the textile gun, KOH/TKPP, textile gun, NH_4HF_2 and finally the textile gun again removed much of the decomposed feldspar while leaving the muscovite and quartz untouched. Overall, a modest improvement.

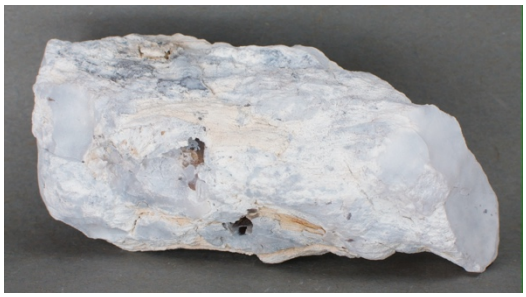
Red Quartz (Red Feather Lakes, Larimer County, Colorado)

The specimen was treated hoping that the rust could be removed without reducing the intense color. Textile gun treatment gave no change. The coating was too thick for Iron OUT, so it was treated with hot oxalic acid which caused noticeable loss of color. Examination under the microscope shows incomplete removal of the surface rust. The specimen is becoming too pale for the client's wishes, so treatment was terminated.

Quartz variety Agate (Rancho Coyamito, Chihuahua, Mexico)

A sawn and polished agate sample having some rust on a central cavity as well as sticker residue on the back. The sticker remnants were removed by soaking in 99% rubbing alcohol followed by textile gun treatment. Overnight Iron OUT/EDTA treatment did not affect the rust. Examination under the microscope revealed that at least some of the rust to be a surface deposit and not an inclusion. Hot oxalic acid treatment provided partial cleaning. Examination again under magnification revealed the remaining rust to be included.

Quartz variety Chalcedony Limb Cast (Texas)



A chalcedony limb cast having a light brown, sandy coating and minor rust. No improvement was seen when treated with the textile gun. Treatment with hot oxalic acid followed by the textile gun derusted the sample and removed much of the coating. NH_4HF_2 treatment with subsequent textile gun treatment followed by KOH/TKPP and another round of textile gun work removed most of the residual coating and all the rust. The sample became colorless, but the wood structure is more obvious.

Quartz with Inclusions (Ksar Tassemente, Drâa-Tafilalet Region, Morocco)

A translucent tabular quartz crystal, quite rusty and muddy, with inclusions difficult to identify while dirty. Textile gun treatment removed some coating, but cleaning was incomplete. Due to quartz's excellent chemical resistance and the absence of other mineral species on the surface the specimen was treated with hot oxalic acid followed by sonication and thorough drying resulting in satisfactory cleaning. The inclusions were then seen to be green and visually identified as a chlorite group mineral.

Quartz (Maple Lode Mine, San Diego County, California)

Slightly milky, lightly frosted quartz crystal with an unidentified white coating of small, tabular crystals. Aggressive chemical treatment possible here due to the high (short term) chemical stability of quartz and desire to remove the coating. Not improved by treatment with the textile gun alone or by chemical treatment (concentrated HCl, NH_4HF_2 or hot KOH/TKPP) followed by the textile gun. The coating is probably not cookeite, montmorillonite, calcite or a zeolite; a feldspar is likely. Needs air abrasion for further improvement.

Quartz with Limonite (Teanaway basalt, Kittikas County, Washington)

Quartz crystals deposited over an unsightly limonite matrix much of which was removed with the Dremel 290. Treatment with hot oxalic acid removed more, but not all the limonite, leaving the remaining limonite somewhat softened. Most of remaining limonite was removed with another Dremel 290/hot oxalic acid cycle. Thorough drying produced yellow stains (from residual limonite) which was removed by soaking overnight in dilute HCl followed by sonication. Minor limonite remained which was not removed by textile gun treatment. Yellow staining did not reappear after drying overnight.

Quartz (Himalaya Mine, San Diego County, California)

A lightly smoky quartz point with unidentified rusty coating. Scraping with an Xacto knife quickly and nearly completely cleaned of the flat faces but not where contoured. The surface beneath was lightly frosted. (With a similar specimen the textile gun was less successful than scraping.) Sonication gave some improvement but still incomplete. Overnight treatment with NH_4HF_2 removes all remaining crust except where overgrown by quartz. Textile gun treatment dislodged a chip which was repaired with Duco cement before the photo. The coating on a similar specimen from the same locality was nearly completely removed and without reducing the specimen's luster by treatment for three hours with hot KOH/TKPP followed by final cleaning with the textile gun.

Quartz (Locality unknown)

A rusty, crusty and muddy quartz point having a rough surface. Examination under magnification shows no additional minerals present. Textile gun treatment removed much (but not all) of the mud. Treatment with hot oxalic acid provided further improvement but the cleaning remained incomplete. Additional treatment with NH_4HF_2 followed by thorough textile gun work provided additional significant improvement but some rust remained. Hot alkali treatment gave no further improvement. The last rust traces were removed with Iron OUT/EDTA. Excess massive, shattered quartz matrix was trimmed by first cutting a shallow kerf in the back with a rotary tool and diamond cutoff blade. The trim was completed on the Zuber MP-5. Finished with a custom carved acrylic block stand.

Rose Quartz (Taquaral, Minas Gerais, Brazil)

Two crystalline rose quartz specimens glued to a wood stand with a paper label underneath. The stand is unaesthetic so a water soak is needed to soften the glue, but this will likely compromise the paper label. The label was removed by carefully sliding a sharp knife beneath it. An overnight water soak softened the glue to allow easy separation of the specimen and stand. The textile gun removed glue residues as well as some loose debris. One specimen retained some debris between crystals suggesting further chemical treatment was needed but examination under magnification revealed the presence of a small but fine beryllonite crystal. Cleaning was terminated at this point to avoid potential damage to this rare association. The wooden stand is part of the specimen's history and thus was retained.

Quartz with Goethite replacing Siderite/Dolomite (Morocco)

A cluster of quartz points bearing abundant rhombohedrons of an unverified mineral (siderite? dolomite? goethite replacement?) with a heavy rusty/muddy coating some of which was removed with the textile gun. Oxalic acid treatment followed by textile gun and sonication removed the remainder of the coating and revealed that the rhombs are sublustrous but unetched and have a gray color. That the rhombohedral crystals survive oxalic acid treatment suggests they are not a carbonate species but instead are more likely a replacement of a carbonate species by goethite although the gray color is unusual for such a replacement. In retrospect the rhombs should have been tested further before subjecting them to aggressive chemical treatment.

Quartz (Locality unknown)

A truly ugly quartz cluster with more incomplete than complete crystals, normally of insignificant value and not worth the effort to clean unless perhaps you need some practice. However, a single 'obelisk' crystal with a nicely symmetric, trigonal termination was observed and deemed worthy of the effort. Some nondescript gypsum was also noted and deemed sacrificial. Cleaning began with removal of the bulk of the limonite matrix with the textile gun. Two cycles with hot oxalic acid solution removed much of the remaining limonite and rust and caused the cluster to disintegrate. The remaining stubborn bits of limonite were removed with an overnight soak in concentrated HCl (which turned dark brown due to dissolved iron) followed by thorough rinsing with the textile gun. This HCl immersion produced mild effervescence suggesting that a carbonate mineral - unseen during initial examination - was also present. Interesting to note this carbonate survived the hot oxalic acid to some extent. After prolonged drying a pale yellow staining appeared which was removed by standard Iron OUT/EDTA treatment. The final product is doubly terminated and nearly water clear. The residual staining seen is due to hematite inclusions which are not removable by any chemical treatment which would not also destroy the specimen.

Quartz, Albite, Microcline and Tourmaline (Himalaya Mine, San Diego County, California)

The specimen is partially coated with rusty, sandy-looking material. A '96' in black ink on white paint is present tying it to an accompanying catalog card of minor historical importance. Fairly common material of low scientific or historical value. Preservation of the label must be balanced against improving the specimen. Because its area of effect can be controlled, air abrasion may be useful here but would be tedious. In the absence of the label and given the good chemical stability of the minerals present hot oxalic acid would normally be used but this would most likely destroy the label. Is it possible to coat the label with some agent to resist chemical attack then remove this coating afterwards without damaging the label? A suitable coating (Paraloid B-72, lacquer, epoxy, etc.) would most likely be applied by and then removed by an organic solvent which begs the question: Will the label survive an organic solvent, most likely acetone? A spot test indicates both and paint are unstable to acetone. Therefore, it was decided to sacrifice the original label, repaint it after cleaning and record the change on the associated catalog card. Textile gun treatment removed much of the mud, clay and decomposed feldspar but did not completely clean the specimen. Hot oxalic acid treatment followed by work with the textile gun resulted in significant improvement by removing the rust but not the sandy material. This sandy material was also not significantly removed with NH_4HF_2 or hot KOH/TKPP. Rust reappeared after the later treatment; this was removed by an additional hot oxalic acid treatment followed by thorough air drying. A photo of the specimen before cleaning as well as details about the cleaning were added to the collection catalog card.

Babingtonite (Chester, Hampden County, Massachusetts)

Dried hard white mineral tack on a grainy matrix. Some tack residue removed with the tip of sharp knife and the rest with a few seconds work with textile gun. Finish up with sonication.

Dravite (Yinnietharra, Western Australia, Australia)

A complete but rusty dravite crystal, free of matrix. Treatment with the textile gun or overnight with Iron OUT/EDTA failed to improve the specimen. Hot oxalic acid successfully derusted the specimen revealing a gray micaceous mineral (perhaps muscovite or decolored chlorite). Removal of the micaceous material would most likely require air abrasion.

Rhodonite, Willemite and Franklinite (Franklin, Sussex County, New Jersey)

Massive rhodonite with a brown coating. Willemite (detected by shortwave UV fluorescence) and small franklinite crystals also noted. Alkaline $NaHSO_3$ did not alter the coating whereas cleaning was successful in less than two hours with $HONH_2$•HCl.

Cobaltoan Dolomite (Aghbar Mine, Drâa-Tafilalet Region, Morocco)

Needs only minimal derusting and trimming. Treatment with Jacquard Hydro (instead of Iron OUT/EDTA because this is a carbonate) followed by a minor trim of barren matrix completed the work.

Fluorite (Fluorite occurrence, Amoron'i Mania, Madagascar)

Deep green fluorite partially coated with a white crusty material. The crust was removed successfully with the textile gun which also broke through a thin crust of 'massive' fluorite matrix to reveal white material (decomposed feldspar?) underneath. The resulting specimen is somewhat friable and temptation to over-prepare it was resisted.

Fluorite, Quartz and Baryte (Superior Mine, Benue, Nigeria)

A gray, translucent fluorite crystal with each complete face partially to fully coated by a quartz druse crust. Brown, microcrystalline baryte covers the quartz on two faces. The brown material appears to be included within the baryte and provides a nice contrast. The fluorite faces are dull so removing the quartz would not improve the aesthetics and would destroy the paragenesis record. Specimen needs no work.

Fluorite and Calcite with Bitumen (Annabel Lee Mine, Hardin County, Illinois)

Gemmy fluorite cubes with a heavy but incomplete bitumen coating. Acids avoided to preserve the calcite. Brief sonication has little effect. Treatment with KOH in 99% rubbing alcohol for 24 hours followed by sonication removes all the bitumen. A little rust on the back was removed

by overnight treatment with Jacquard Hydro followed by brief sonication. Iron OUT/EDTA was avoided because of the calcite. A bit of mineral tack residue was removed by 'prod and blot' with a fresh ball of tack. Textile gun treatment was deemed too risky on this thin specimen.

Quartz and Fluorite (Rock Candy Mine, British Columbia, Canada)

A nondescript green and brown fluorite mass overgrown with white crystalline quartz. The fluorite is cleaved with no distinct crystal faces evident. A hollow, translucent quartz epimorph was deemed more interesting than the specimen's current state. Air abrasion maybe effective but probably more tedious. The fluorite was excavated over one hour with the Dremel 290 and the Paleo tips, starting with the chisel point followed by the longer conical point for finish work in the recesses. Occasionally rinsed to remove debris which obscures the work area. No damage to quartz interior was seen. The remaining brown stains are quartz veins, deposited between fluorite generations or into cracks of fluorite. These stains did not yield to any derusting method.

Fluorite and Quartz (Morocco)

Yellow fluorite with a somewhat dull luster, a partial quartz crust and much rust. Treatment with Jacquard Hydro (instead of Iron OUT to avoid chelators) caused minimal change as much of the rust is under the quartz coating. Three hours in NH_4HF_2 solution followed by textile gun treatment provided some derusting and partial removal of the quartz crust. Extended NH_4HF_2 treatment (two weeks) resulted in little further improvement. Examination under magnification revealed a significant amount of the remaining rust is under a fluorite layer and thus not removeable. Minor etching was also noted.

Fluorite and Quartz (Morocco)

Several yellow fluorite cubes, partially coated with rusty microcrystalline quartz crust, on a quartz-rich matrix. Initial textile gun treatment removed some crust to reveal the fluorite crystals were better quality than first thought. Attempted derusting with Jacquard Hydro (instead of Iron OUT to avoid chelators) was unsuccessful as was an overnight soak in 85% H_3PO_4. Treatment with NH_4HF_2 overnight to loosen and weaken quartz crusts followed by textile gun treatment resulted in significant but incomplete crust and rust removal. A second NH_4HF_2/textile gun cycle completed the cleaning. A similar specimen having a thicker quartz crust was only partially cleaned by this same procedure and showed no further improvement even after three NH_4HF_2 treatments.

Fluorite with Bitumen (Cave-in-Rock, Hardin County, Illinois)

A glossy, translucent to transparent fluorite cluster having a partial dark coating. Observation under magnification verified that the coating is bituminous and not a dark outer fluorite zone. Textile gun treatment provided only minimal improvement. The specimen was immersed in a magnetically stirred KOH/rubbing alcohol bath for eleven weeks with textile gun treatment approximately every seven days. The solution was replaced every two weeks as it became dark brown. When bitumen dissolution appeared stalled the specimen received a thorough water rinse. Some bitumen remained. When examined under magnification as well as by immersion in a fluid of nearly equal refractive index this residual bitumen was seen to be included within the fluorite (or within deep cracks) and therefore not removeable.

Fluorite and Quartz (Okorusu Mine, Otjozondjupa Region, Namibia)

Blue fluorite heavily enrobed in translucent to opaque quartz points having an unknown white coating (a second quartz generation?). The fluorite itself is clean. Minor clay present which was removed with the textile gun. A three-hour NH_4HF_2 treatment provided minor improvement to the quartz while the fluorite remained glossy. A second NH_4HF_2 bath caused no additional changes. Treatment with hot KOH/TKPP was ruled out due to thermal shock concerns especially at the quartz/fluorite junctures.

Fluorite (Rogerley Mine, County Durham, England)

Minty green fluorite cubes, ranging from lustrous to dull, with corroded galena and minor quartz. The galena is encrusted with dark decomposition products, quite typical for the locality. NH_4HF_2 treatment to remove the quartz may leave the fluorite with a pitted surface (due to intergrowth) and further attack the galena (although the resultant surface may be brightened) so it was avoided. The specimen might be oiled to improve the fluorite luster. Little can be done to significantly improve this sample.

Baryte and Calcite (Juanita Mine, Socorro County, New Mexico)

Bladed baryte with unsightly, damaged calcite, which was removed with 30% acetic acid and magnetic stirring. Three days were required for complete calcite removal. Avoided HCl which may etch the baryte. Finished with sonication to remove the last traces of acid.

Prehnite and Calcite (Paterson, Passaic County, New Jersey)

Damaged, dingy calcite obscuring a translucent, light minty green prehnite plate. The calcite was removed with 30% acetic acid, replaced every two to three days as needed. (Vibratory impact tool treatment would probably damage prehnite surface, as would HCl.) The resulting thin calcite residue was easily removed with the textile gun but the prehnite plate disintegrated due to preexisting cracks or calcite seams in prehnite (which were weakened or dissolved by the acid treatment).

Fluorite and Calcite (Illinois)

A large, transparent fluorite crystal with excellent color and significant internal cleavage fractures bearing a heavy coating of dull, damaged calcite. Removing the calcite should allow the fluorite color and transparency to be better displayed but may cause the specimen to disintegrate. The calcite was removed by soaking in 30% acetic acid for two to three days, at which point the acetic acid was regenerated every 24 hours by addition of 25 mL concentrated HCl per liter of initial acetic acid volume. After two regeneration cycles the acid solution was discarded and replaced with fresh 30% acetic acid. The process was repeated until all the calcite was removed (about three weeks). During this process and with subsequent handling the specimen suffered significant disintegration to the point where repair was fruitless. The specimen might have survived if it had been reinforced some way prior to acid treatment but significant cracking would still be evident in the final specimen.

Gypsum on Rhodochrosite (Santa Eulalia Mining District, Chihuahua, Mexico)

Damaged gypsum partially coating crystalline rhodochrosite. Ten days in the toilet tank removed the gypsum but caused a light rust coating to form. Derusting with Jacquard Hydro returned the bright pink color. Iron OUT was avoided due to uncertain rhodochrosite compatibility with chelators.

Gypsum on Rhodochrosite (Santa Eulalia Mining District, Chihuahua, Mexico)

A damaged gypsum crust partially covering rhodochrosite with quartz. Removed most of the gypsum with Dremel 290 and aluminum tip, working carefully to avoid damaging the rhodochrosite. The remaining gypsum was removed using the ion exchange resin procedure, replacing the water every few days (because water is cheaper than resin). The Dremel 290 and resin treatments were alternated every few days until the gypsum was completely gone.

Inesite (Hale Creek Mine, Trinity County, California)

Black stains treated with equal parts 12% H_2O_2 and 3% acetic acid. Slow effervescence occurred with minor change ceasing after two days (starch-iodide paper test indicated peroxide

remained). Brief sonication removed chemical residues. The excess massive inesite matrix could be trimmed but at the expense of some potentially important labeling on the backside.

Crocoite (Adelaide Mine, Tasmania, Australia)

A cluster of crocoite crystals with a brown, crusty overgrowth (rusty gibbsite?) and numerous small but gemmy second-generation crocoite needles. Removing the crust would cause loss of the aesthetic second-generation crocoite so the specimen was not treated.

Crocoite (Adelaide Mine, Tasmania, Australia)

Somewhat dull crocoite intergrown with dark matrix. Very fragile; handled in a cheesecloth sling during all treatments. Treated with equal parts of 12% H_2O_2 and 30% acetic acid for one hour (initial vigorous effervescence) then stirred overnight in clean water. Sonicated briefly then dried thoroughly. Gibbsite matrix removal by H_3PO_4 treatment was deemed an unnecessary risk due to possible crystal loss.

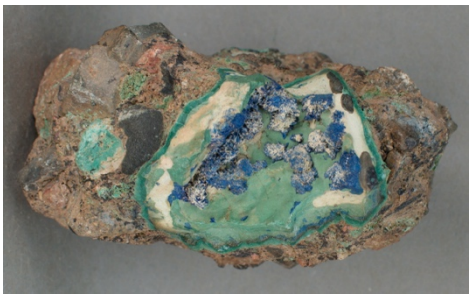
Crocoite (Adelaide Mine, Tasmania, Australia)

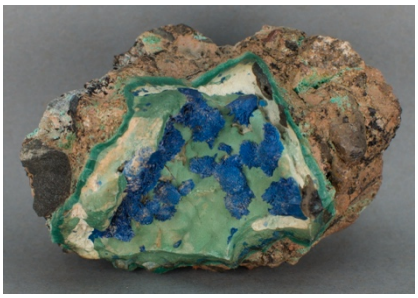
A cluster of crocoite crystals partially coated with a thin to thick, light to dark brown crust (gibbsite and limonite and/or manganese hydroxides/oxides?). Held in cheesecloth sling while treated with equal parts of 12% H_2O_2 and 30% acetic acid produces immediate vigorous effervescence. When bubbling ceased the specimen was sonicated briefly then air dried. Jacquard Hydro treatment lightened the brown coloration somewhat but not completely. More (but not all) the gibbsite was removed by a two-hour soak in 85% H_3PO_4 followed stirring overnight in clean water, brief sonication and thorough air drying. Small, inconsequential fragments were dislodged during cleaning with a larger fragment lost by gentle handing afterwards (deemed unrepairable). Perhaps less gibbsite should have been removed or the attachment of the larger fragment was only tenuous, and loss was inevitable.

Dolomite variety Teruelite in Gypsum (Nabo Ravine, Aragon, Spain)

The specimen has too much matrix and some of the dolomite crystals could be better exposed. Trims easily as desired with the Zuber MP-5. The dolomite crystals were excavated with the Dremel 290 and aluminum tip. A ten second sonication removed residual tool marks but reveals internal fractures in the dolomites suggesting any further trimming is likely to lead to disintegration.

Azurite and Malachite (Apex Mine, Washington County, Utah)





Abundant, deep blue crystal rosettes with dull luster in a cleft with excess matrix. Contaminated with sandy dirt. Trims nicely with Zuber MP-5 making the specimen self-standing at a good display angle. Textile gun removed the sandy material. Azurite luster not altered during this process.

Magnetite and Clinochlore (Zelentsovskaya Pit, Chelyabinsk Oblast, Russia)

A well-formed magnetite crystal on a rusty, muddy clinochlore-rich matrix. Trimmed with the Zuber MP-5 and nippers to reduce excess matrix and make the specimen self-standing. The textile gun removed some impacted mud. Iron OUT/EDTA followed by textile gun treatment (two cycles) finished the specimen.

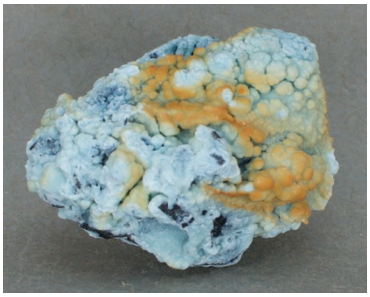
Calcite, Sphalerite, Chalcopyrite and Marcasite (Mid-Continent Mine, Cherokee County, Kansas)

Somewhat rusty. Treatment with Jacquard Hydro (to avoid calcite etch) made the calcite somewhat whiter, derusted the chalcopyrite and improved the sphalerite iridescence somewhat.

Bastnäsite (Zagi Mountain, Khyber Pakhtunkhwa Province, Pakistan)

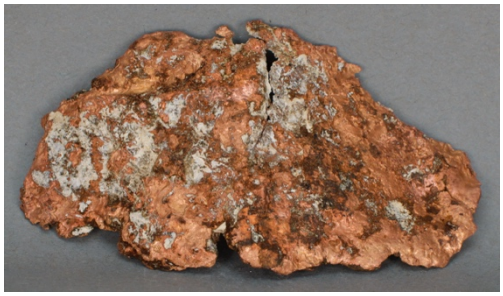
A single, brown and moderately lustrous bastnäsite crystal on rusty matrix. The matrix is crumbly with a 'grain' suggesting Zuber MP-5 trimming might be unpredictable. Trimmed instead with the Dremel 290. Matrix tends to flake perpendicular to bastnäsite during trimming. Derusted with Jacquard Hydro as bastnäsite tolerance to Iron OUT/EDTA unknown.

Gibbsite (Xianghualing Mine, Hunan, China)



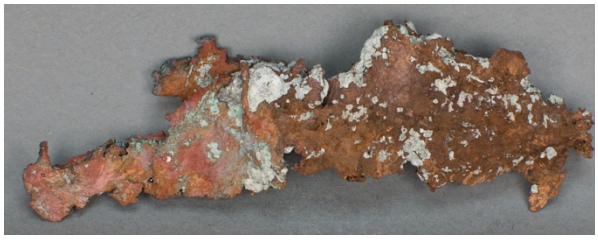
Pale blue, rusty gibbsite. Gibbsite tolerance to dithionite is unknown so try the mildest derusting method first. Jacquard Hydro treatment overnight gave no change. Microscopic examination revealed the rust to be on the surface but its resistance to dithionite suggests it may not be rust or may lie just beneath the surface. No further cleaning attempted.

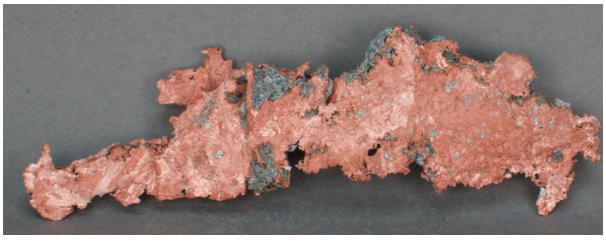
Copper (Michigan)



Sheet copper with a dark patina. No change when treated with the textile gun. Thirty minutes immersion in Heinz 57 ketchup produced no obvious change until textile gun treatment, which revealed an unnaturally bright surface. Patina was restored by immersion in 12% H_2O_2 for 30 minutes.

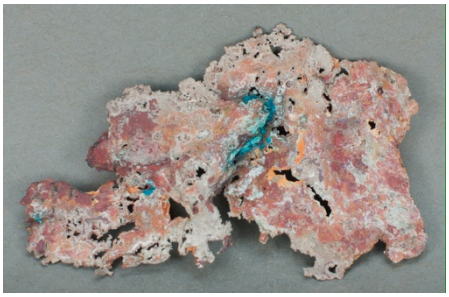
Copper (Michigan)





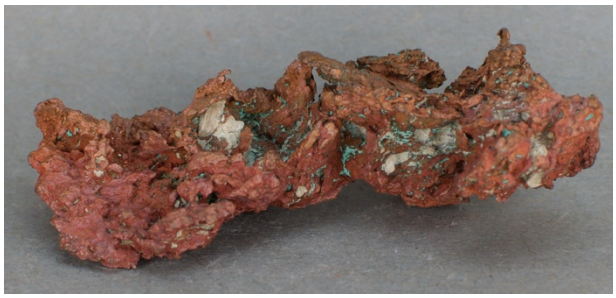
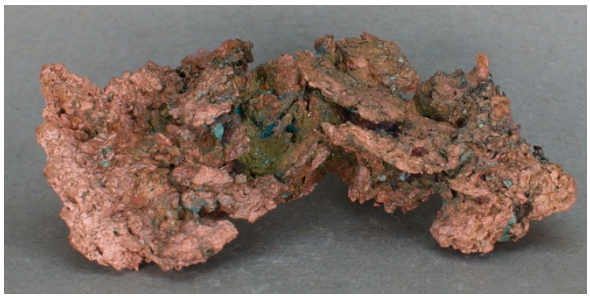
Copper with minor matrix and dark patina. No change when treated with the textile gun. Treatment with NH_4HF_2 followed by the textile gun removed the dark coating producing an unnaturally bright luster and distinct crystalline structure. Further treatment with 12% H_2O_2 dulled the patina producing a more natural but still distinctly crystalline appearance.

Silver, Copper, Cuprite and Malachite (Cashin Mine, Montrose County, Colorado)



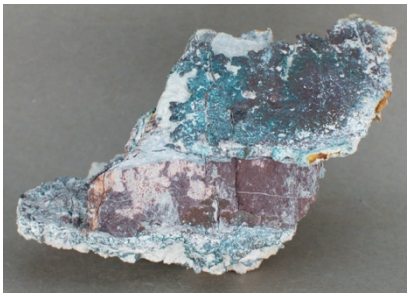
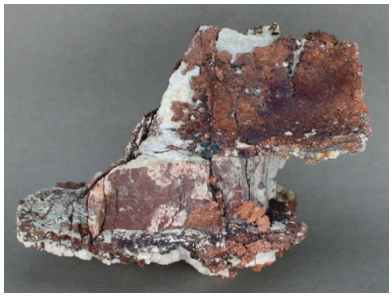
Sheet copper with a crust of blue green malachite and minor cuprite. Old label states silver also present but not seen under magnification. The copper might be so heavily corroded so that very little remains, and cleaning may cause disintegration. As it is, the specimen is ugly and of limited value. Worth risking disintegration if silver really is present. Treated with 30% acetic acid overnight followed by brief sonication and thorough drying. Crud removed. Silver now very evident. Patina mostly retained. Much improved aesthetics and scientific value.

Copper (Ray Mine, Pinal County, Arizona)

Dusty and corroded with useless paint label residue. Textile gun treatment removes some crud but not the paint. Sonicate in acetone for 30 minutes to soften the paint which was then easily removed with the textile gun but left a lighter spot where the paint was. After a one-hour soak in 30% acetic acid the solution turned blue, and the crud was partially removed. Textile gun treatment nicely removed some darker surface coating. The lighter spot where label was is now same color as rest of specimen. Some brightening has occurred (but not unnaturally so) but the patina is somewhat uneven. After drying overnight some crud remains and the patina has darkened a bit but still appears natural.

Copper (United Verde Mine, Yavapai County, Arizona)

Dark, crystalline sheet copper on/in cracks of decomposing matrix. Minor, uninteresting copper secondaries (malachite, cuprite) also present. Rusty. Textile gun treatment removed much decomposed matrix and other loose debris as well as minor damage to exposed sheet copper. One hour in 5% acetic acid caused the copper to be nicely coppery but not obnoxiously so. Copper patina response to Iron OUT/EDTA uncertain so it was treated with Jacquard Hydro overnight. A dark, fine precipitate formed on the specimen but was easily removed with mild textile gun treatment. Rust decolored but reappears (a bit less intense) on drying. Repeating the Jacquard Hydro/textile gun sequence gave minor improvement but at the expense of some copper and matrix. Considering the balance between further improvement and degradation of specimen integrity work was halted.

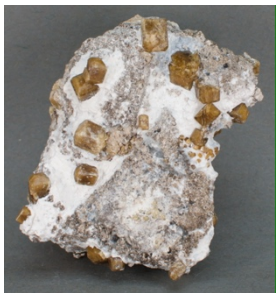
Neptunite (California State Gem Mine, San Benito County, California)

A doubly terminated neptunite crystal etched from a natrolite/crossite matrix. Poor luster due to silica residues leftover from the tech process. Excess, unaesthetic and crumbly matrix. NH_4HF_2 brightened the neptunite considerably. Excess matrix trimmed with tile nippers. Lower neptunite termination is buried in natrolite but seen to be broken on the backside, so it was not further revealed.

Galena (Tri-state Mining District, Kansas-Missouri-Oklahoma)

Dull, crusty galena on matrix. Briefly sonicated then treated with stirred EDTA solution overnight. This removed the crust leaving unaltered but still dull galena. When a similar specimen having 'ruby jack' sphalerite was treated in a similar manner the sphalerite luster was not altered.

Vesuvianite (Sierra de Cruces, Coahuila, Mexico)



Vesuvianite crystals, partially etched from calcite and rhyolite matrix. Some of the vesuvianites could be better exposed and the matrix is unnecessarily ragged in spots. Work with the Dremel 290 mostly resolved these issues with some broken and/or smaller vesuvianites sacrificed to better reveal larger, more perfect crystals. Matrix dust and residual tool marks were removed by a twenty second immersion in a solution of six parts water and one part concentrated HCl followed by brief sonication and thorough drying.

Tourmaline (Himalaya Mine, San Diego County, California)

A terminated tourmaline crystal having a dull, thin dark green skin over a colorless core. The termination is overgrown with sandy, fine-grained muscovite which was removed by textile

gun treatment. The rust which appeared beneath was removed with Iron OUT/EDTA followed by sonication. The treatment process also improved the tourmaline luster.

Tourmaline (Himalaya Mine, San Diego County, California)

A crude tourmaline crystal with abundant, tiny acicular tourmaline needles and a scrap of microcline matrix, contaminated with rusty mud. The textile gun was avoided to prevent damage to the delicate tourmaline needles. Soaking in Iron OUT/EDTA overnight followed by sonication and thorough drying was adequate to clean the specimen.

Tourmaline (Maine)

In-situ fragmented tourmaline cemented together by muscovite/cookeite. A bit rusty. Blue mineral tack residue. Treatment with NH_4HF_2 for three hours loosened and/or dissolved some muscovite/cookeite. More coating and the last of the tack residue removed by careful textile gun treatment but enough coating remained to maintain specimen integrity. Derusted with Iron OUT/EDTA.

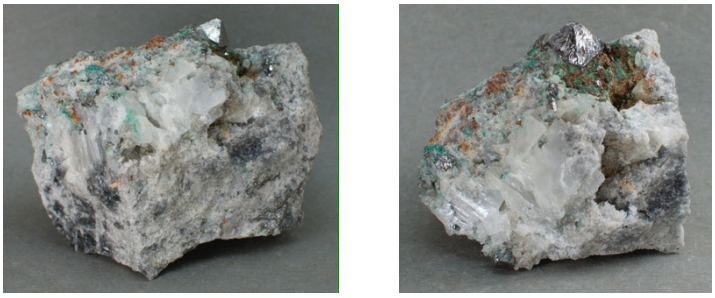
Tourmaline, Microcline and Albite (Himalaya Mine, San Diego County, California)

A light green, gemmy tourmaline crystal lies across one face of a partial microcline crystal. Minor but gemmy albite variety cleavelandite in tabular crystals also present. Dusty, slightly rusty and coated with a little decomposed feldspar. Very gentle treatment with the textile gun removed the loose debris and decomposed feldspar while retaining much of the fine, acicular tourmaline. An overnight soak in Iron OUT/EDTA solution followed by sonication and thorough drying removed the rust and brightened the feldspar somewhat. No yellow stains appeared on the porous microcline matrix after drying.

Tourmaline with Albite (Himalaya Mine, San Diego County, California)

A large, multicolored tourmaline crystal with patches of albite variety cleavelandite and unidentified white material (cookeite? montmorillonite? decomposed feldspar?). Tourmaline and albite both have excellent chemical resistance whereas the unidentified crust will (presumably) be weakened (or removed) chemical attack. Textile gun treatment resulted in significant improvement but incomplete crust removal. NH_4HF_2 treatment followed by textile gun treatment then KOH/TKPP treatment (again followed by the textile gun) completed removal of the unknown crust while leaving the cleavelandite intact. Overall luster was improved.

Carrollite (Kamoya South II Mine, Katanga, DR Congo)



Specimen has excess matrix. Carrollite has a reputation for breakage or becoming dislodged by trimming so support the carrollite with a large wad of mineral tack during trimming. Several trims with Zuber MP-5 then nippers for finer work. Behaved well during trimming. Two more tiny but perfect carrollite crystals were revealed in pockets during trimming.

Beryl with Tourmaline and Muscovite (Minas Gerais, Brazil)

Rusty clay in/on surface. Some muscovite is damaged. Textile gun treatment and hot oxalic acid (heat slowly - thermal shock risk) each caused only minor improvement. Surface clay and some damaged muscovite were removed by the latter procedure, but much included clay remained. Tourmaline and etch pits both a little better exposed but overall improvement was minimal.

Hanksite (Searles Lake, San Bernardino County, California)

A heavily decomposed hanskite crystal whose white crust is probably tincalconite (borax is a common association at this locality). Crust removal, first with a soft toothbrush then wooden toothpick and finally plastic brush in rotary tool was incomplete. Air abrasion might be effective to complete the task. A *quick* water rinse to remove residual dust then immediately blotted dry. Silicone oil applied.

Microcline variety Amazonite (Crystal Peak, Teller County, Colorado)

A microcline crystal group with a little mud and rust, some of which is included. Porous, so yellow stains on drying a possibility. Textile gun treatment gave minor improvement. Hot oxalic acid treatment yielded major improvement. Avoided dithionite because of feldspar's broad

chemical stability. Some rust remained. Yellow stains formed on drying were removed by soaking in concentrated HCl overnight, but the rust still lingered and the yellow formed again on drying. Two Iron OUT/EDTA treatments were needed to prevent further yellow staining when completely dry.

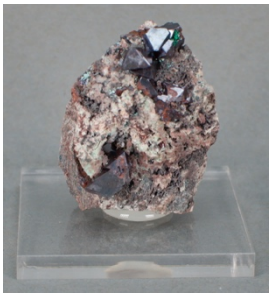
Leucite (Roccamonfina Volcanic Complex, Campania, Italy)

Dingy leucite crystals partly exposed in a seemingly friable basalt matrix. Not self-standing. Textile gun work removed dust but not matrix (which is less friable than it appeared). Dremel 290 further excavated (but not overexposed) the leucites and the base flattened to make the specimen self-standing. Brief sonication removed dust and tool marks. The leucite is dingy due to its naturally rough porcelaneous surface and further luster improvement is not possible.

Pyrrhotite, Sphalerite, Calcite and Dolomite (Santa Eulalia Mining District, Chihuahua, Mexico)

Dingy, damaged calcite crystals on a matrix of crystalline pyrrhotite and sphalerite. Calcite removed by soaking in 30% acetic acid for a few hours. When effervescence ceased some white crystalline material remained where the calcite had been. Examination under magnification revealed this to be a patch of crystalline dolomite which was retained because it is undamaged and produces a pleasant contrast.

Cuprite, Copper, Malachite and Chrysocolla (Mashamba West Mine, Lualaba, DR Congo)



Several dull cuprite crystals on matrix which under transmitted light are intense ruby red. Accompanied by minor malachite and unattractive pale green chrysocolla. Can cuprite be made more brilliant (probably at expense of copper secondaries)? One hour treatment with ammonium acetate/EDTA (solution turns blue) removes malachite but most of the chrysocolla remains. Cuprite luster improved but transparency has not. Copper not brightened. Trimmed with tile nippers for best vertical mounted display then mounted on a thin acrylic base for best display angle.

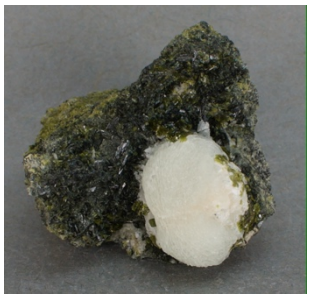
Albite, Lepidolite, Tourmaline and Microcline (Himalaya Mine, San Diego County, California)

One face of a microcline matrix bears abundant, bladed and somewhat fragile albite variety cleavelandite along with minor lepidolite and tourmaline. Muddy, rusty and partially coated with decomposed feldspar. Careful work with the textile gun removed some of the mud and decomposed feldspar. For additional derusting and mud removal hot oxalic acid was employed because all species present tolerate this treatment. Some decomposed feldspar remained which was removed with NH_4HF_2.

Smithsonite (Choix, Sinaloa, Mexico)

Gray blue smithsonite with a dull luster, dusty and with a rusty matrix, unreadable paper label and mineral tack residue. The dust, label and mineral tack residue were easily removed with the textile gun, but this did not improve the luster (even when wet!). An overnight soak in Jacquard Hydro solution followed by sonication and thorough drying finished the process. Iron OUT was avoided because of potential Zn^{2+} chelation which might further reduce the luster.

Prehnite and Epidote (Imilchil, Drâa-Tafilalet Region, Morocco)



Rusty and muddy, porous to massive and crystalline epidote matrix. The prehnite ball is off center. Textile gun treatment removed some of the mud and rust. Iron OUT/EDTA completed the process. Trimmed with the Zuber MP-5 to better center the prehnite. The newly revealed matrix face was clean around the rim but rusty at the center. Cleaning was completed with a second Iron OUT/EDTA bath followed by drying overnight.

Quartz, Baryte and Hematite (Morocco)

A plate of lustrous, terminated quartz crystals with abundant but heavily damaged baryte blades. The quartz was worth salvaging so the baryte was removed efficiently with the Dremel 290 using the chisel tip for the bulk of the work and the fine-point tip for the crevasses. The quartz was not damaged by this process. Scattered, microcrystalline hematite was visible at this point. Traces of baryte remained but were not deemed worthy of the effort for removal.

Monazite-(Ce) (Brown Derby Mine, Gunnison County, Colorado)

Monazite crystals, two terminated but partially buried and numerous partial crystals, slightly rusty, off center in a partially barren matrix. No cracks are seen running through the two largest terminated monazite crystals. Trimmed barren matrix with the Zuber MP-5 guided by existing cracks followed by cleanup with tile nippers. Excavated terminated monazite crystals with the Dremel 290 once again taking advantage of existing cracks but also taking care not to propagate these cracks any further. Finished with Iron OUT/EDTA, sonication and thorough drying.

Topaz and Muscovite on Albite (Khoroshiv Raion, Zhytomyr Oblast, Ukraine)

Two large translucent topaz crystals with matted, dark muscovite on a rusty albite variety cleavelandite matrix with impacted mud. The textile gun removed much mud and some decomposed feldspar. Iron Out/EDTA followed by textile gun treatment resulted in little improvement. Hot oxalic acid provided significant improvement (heated slowly due to topaz thermal shock concerns). The feldspar is somewhat porous, so the oxalic acid bath was followed by overnight soak in dilute HCl as a pre-emptive treatment for yellow iron stains. After sonication and thorough drying minor yellow staining removed with Iron OUT/EDTA. Some unremovable muddy inclusions remain in the otherwise lustrous topaz.

Baryte, Quartz, Fluorite and Chalcopyrite (Morocco)

Lamellar baryte with a sandy white crust (more baryte?) between the blades, on a crystalline quartz matrix. Scattered, crusty and iridescent chalcopyrite crystals and minor, small and somewhat corroded fluorite also present. Gentle textile gun treatment removed some of the sandy material. Sonication and Jacquard Hydro treatment provided no significant improvement. (The baryte is already sublustrous so Iron OUT/EDTA was probably a safe alternate to Jacquard Hydro.) Soaking in NH_4HF_2 solution followed by the textile gun gave some minor improvement although the chalcopyrites were not brightened. No further work was conducted.

Magnesite and Chalcedony (Casper Mountain, Laramie Mountains, Wyoming)

Specimen is rusty and has a bit too much matrix. A sluggish reaction with 5% HCl supports the identification of the massive white material as magnesite and not calcite or aragonite. The somewhat friable matrix was cautiously trimmed with tile nippers followed by fine work with the textile gun. Derusting was achieved by overnight treatment with Jacquard Hydro followed by brief sonication and thorough drying. Even though the magnesite has a rough texture, Jacquard Hydro was selected over Iron OUT to avoid chelation and possible etching by the citrate present in Iron OUT.

Orthoclase, Magnetite and Zircon (Imilchil, Drâa-Tafilalet Region, Morocco)

A muddy, rusty orthoclase crystal featuring a 'battlements' growth pattern and studded with tiny magnetite crystals. Careful work with the textile gun removed much of the clay but minor magnetite was also lost. Derusted with Iron OUT/EDTA which left residual clay with a green color that faded upon thorough drying. Treated again with the textile gun followed by Iron OUT/EDTA left the orthoclase with a sickly gray color. Examination under the microscope revealed several tiny (< 1 mm) zircons not seen before cleaning as well as several equally small, gemmy, water-clear prisms (not quartz...topaz?).

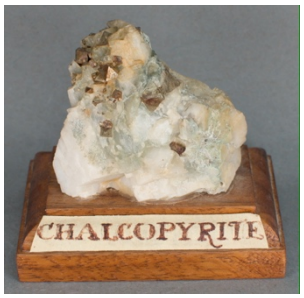
Mimetite variety Campylite (Dry Gill Mine, Cumbria, England)

Lustrous mimetite with a partial black coating. Trimming the excess, massive quartz matrix will sacrifice some mimetite but make the specimen self-standing. Because this specimen is of low scientific value pleasing appearance was judged to be more important. Overnight treatment with a 1:1 mixture of 12% H_2O_2 and 30% acetic acid removed most of the black coating while retaining the mimetite luster. Trimming with tile nippers rendered the specimen self-standing and better center the mimetite patch.

Anthraxolite/Pyrobitumen on Quartz (Fonda, Montgomery County New York)

'Herkimer diamond' quartz on a silicified limestone matrix contaminated with brittle, dark organic material (anthraxolite? pyrobitumen?) having a melted plastic appearance. Much of this contamination was removed with the Dremel 290 using an aluminum tip to minimize damage risk to the surrounding quartz. The specimen was then soaked in a KOH/rubbing alcohol bath for four weeks. During this time the bath acquired a light brown color but had small to no effect on the black material. Soaking in acetone for an addition week was ineffective. A chlorinated organic solvent might be useful but was avoided due to the significant hazards presented by such solvents.

Pyrite and Calcite (French Creek Mines, Chester County, Pennsylvania)



Octahedral pyrite and minor acicular actinolite in calcite, acid etched by previous owner to better reveal the pyrite. Glued to a wooden stand with a paper label underneath. The stand is unaesthetic so a water soak is needed to soften the glue, but this will likely compromise the paper label. The label was removed first by carefully sliding a sharp knife beneath it. An overnight water soak softened the glue allowed easy separation of the specimen and base. Glue reside was removed from the bottom of the specimen with the textile gun. The original paper label and wood stand are part of the specimen's history and thus were retained.

Red Beryl (Ruby Violet claims, Beaver County, Utah)

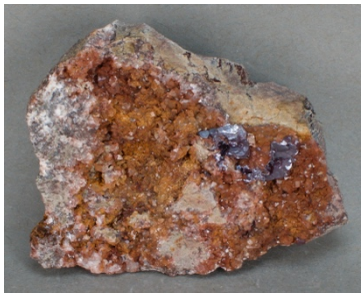
A red beryl crystal on a rusty rhyolite matrix with a sawn face and obvious tool marks. The specimen was temporarily mounted before work to better visualize the desired outcome. The Dremel 290 was used to remove tool marks, roughen and round off the flat, sawn faces and to slightly increase the red beryl exposure. Now self-standing but not yet a perfect display angle. Derusted with Iron OUT/EDTA followed by sonication and thorough drying. Rust does not reappear. To trim the matrix and make the beryl more central with best face forward the specimen was mounted on a flat, round acrylic stand with hot glue before trimming slightly with the Dremel 290. Brief sonication removed dust and minor tool marks. The beryl is now at a pleasing angle. The final trimming revealed more rust which was removed with another Iron OUT/EDTA treatment. A brief soak in 99% rubbing alcohol softened the hot glue adhesive and allowed facile removal of the temporary stand.

Red Beryl and Hematite (Thomas Range, Juab County, Utah)

A tiny but perfect red beryl crystal on an overwhelming large white rhyolite matrix with interesting swirls (preserve these if possible). Abundant but tiny colorless topaz also present, mostly on the swirl. Very minor hematite can be sacrificed in exchange for enhancement of the more desirable red beryl. Trimmed with Zuber MP-5. The matrix breaks easily but somewhat unpredictably; swirl mostly lost. Dremel 290 finishes the trim. Brief sonication to remove dust and

tool marks. Trimming with a saw or the Dremel 290 may have been a better choice. Plenty of hematite remains near the beryl.

Cuprite and Dolomite (Mashamba West Mine, Lualaba, DR Congo)



Crystalline cuprite with rusty dolomite on an oversized matrix. The matrix is too thick for the Zuber MP-5 to trim so excess matrix was removed first by sawing roughly perpendicular to the display face but in a way that saw marks would not be visible from this face. The thinned matrix was then easily trimmed with the Zuber MP-5. Under magnification the rust can be seen to lie on the surface of the dolomite. This rust cannot be removed with oxalic acid or any dithionite recipe as the cuprite would also be attacked. Textile gun treatment and prolonged sonication failed to remove any of this coating, so no further treatment was conducted.

Natrolite and Analcime (Mont Saint-Hilaire, Québec, Canada)

A spray of natrolite needles (mostly not terminated), lustrous analcime and other unidentified species with a dark coating. Treatment with 12% H_2O_2 (no acetic acid) produced vigorous effervescence and mild warming. After sonication and textile gun treatment, however, there was no obvious improvement. Treated with Jacquard Hydro (instead of Iron OUT due to unknown tolerances), alkaline $HONH_2$•HCl or alkaline $NaHSO_3$ all yielded no obvious improvement. Significant improvement was obtained by treatment with a 1:1 mixture of 12% H_2O_2 and 30% acetic acid which removed much black crusty material, did not alter the natrolite or analcime and revealed distinct albite and aegirine crystals. A white crust formed upon drying but dissolved when soaked in clean water. Some dark coating remained which was further reduced (but not completely removed) by treatment with acidic $HONH_2$•HCl followed by acidic $NaHSO_3$. Would display better on a custom carved stand, but this low-quality specimen is not worth the effort.

Hemimorphite and Calcite (Ojuela Mine, Durango, Mexico)

Crystalline calcite and hemimorphite abundant on one face of a thick limonite matrix. Thin this matrix to improve aesthetics without compromising specimen integrity. Matrix too tough for textile gun. Air abrasion probably effective but will consume large volume of medium. Saw cannot make fine enough cuts and will leave unnaturally flat surface. The matrix was reduced to about one-quarter of its original thickness with the Dremel 290 over four hours. Numerous massive hemimorphite veins were encountered which are tougher than the limonite. Avoided prying as this applies force to both the matrix side and crystalline face side of the lever which might cause the weakened matrix to break. The specimen was handled carefully to avoid damaging the fragile crystallized face. The process was finished with the textile gun then sonication to remove dust and tool marks.

Genthelvite and Magnetite (Huanggang Fe-Sn deposit, Inner Mongolia, China)

A sharp genthelvite crystal partially obscured with a fine-grained quartz (?) coating. Massive magnetite on the back. Air abrasion is unsuitable to remove the harder quartz from the softer genthelvite. Careful work with the Dremel 290 only partially excavated the genthelvite; further, more aggressive work risked damage. Treatment with NH_4HF_2 followed by the textile gun (three cycles total) removed nearly all the residual coating. The genthelvite remained lustrous but the magnetite luster (considered sacrificial) was reduced. Hot KOH/TKPP followed by another NH_4HF_2 treatment yielded no further progress.

Fluorapatite and Diopside in Calcite (Yates Mine, Québec, Canada)

Several fluorapatite crystals with minor (mostly incomplete) diopside crystals in an orange calcite matrix. As received, a one inch, doubly terminated fluorapatite crystal in two equal fragments is detached from the matrix. The Dremel 290 was used to further excavate the fluorapatite crystals from matrix with simultaneous loss of some inconsequential, broken diopside crystals. This tool is particularly effective against the easily cleaved matrix. Additional Dremel 290 work rendered the specimen self-standing. Residual tool marks were removed by a 30-minute soak in dilute HCl (5 mL concentrated HCl in 500 mL water) followed by sonication. (Acetic acid is less inclined to attack the fluorapatite but would take much longer than HCl. The fluorapatites are already naturally rounded so brief HCl treatment should not cause any noticeable changes.) Water-based glue residue in the base of the specimen became white after sonication and was removed with the textile gun. The broken fluorapatite crystal was cleanly repaired and reattached to its place on the matrix (lower right) with Duco cement.

Montmorillonite replacing Spodumene with Quartz and Tourmaline (Elizabeth R Mine, San Diego County, California)

Friable and soft montmorillonite replacing spodumene on a matrix of heavily fractured massive quartz with minor black tourmaline and black stains. The matrix should be reduced a bit to emphasize the pseudomorph, but care must be taken to preserve integrity of the entire specimen. Some of the black patches are tourmaline while others appear to be manganese hydroxides/oxides. Excess matrix was removed with the Dremel 290 by carefully opening existing cracks in the quartz matrix, taking care to avoid cracks which propagate into the pseudomorphed portion. Black stains were removed by treatment with 12% H_2O_2 which produced immediate but mild effervescence and loosened some debris but had little notable cleaning effect. The specimen was next treated with a 1:1 mixture of 12% H_2O_2 and 30% acetic acid. Mild effervescence was again observed. An overnight soak was followed by thorough rinsing, brief sonication and overnight air drying. The

manganese stains were reduced but the montmorillonite color has suffered minor fading. Cleaning was somewhat more effective than the photographs suggest.

Anatase and Brookite (Magnet Cove, Hot Spring County, Arkansas)

Anatase, brookite and other unidentified minerals on a quartz matrix under a thick limonite coating. Work with the Dremel 290 easily removed most of this limonite. A brass tip was used to minimize possible collateral damage. Poorly crystalline quartz and an unknown micaceous mineral were revealed with the latter having been damaged by the vibratory impact tool. Additional limonite was removed with the textile gun. Chemical treatment (hot oxalic acid, Iron OUT/EDTA, NH_4HF_2 or hot KOH/TKPP) did not further attack the limonite. Yellow staining appeared upon drying after oxalic acid or Iron OUT treatment. This staining was quite persistent (because limonite was still present and because the matrix is somewhat porous) and even after multiple chemical treatment cycles was never fully obviated. Minor trims were affected with tile nippers.

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