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Handling of Processes Involving Mineral Acids

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Science Education Title: Handling of Processes Involving Mineral Acids

Overview:
A mineral acid (or inorganic acid) is defined as a water-soluble acid derived from inorganic minerals by chemical reaction as opposed to organic acids (*e.g.* acetic acid, formic acid). Examples of mineral acids include:

- Boric acid (CAS No.10043-35-3)
- Chromic acid (CAS No.1333-82-0)
- Hydrochloric acid (CAS No.7647-01-0)
- Hydrofluoric acid (CAS No. 7664-39-3)
- Nitric acid (CAS No. 7697-37-2)
- Perchloric acid (CAS No. 7601-90-3)
- Phosphoric acid (CAS No.7664-38-2)
- Sulfuric acid (CAS No.7664-93-9)

Mineral acids are commonly found in research laboratories and their corrosive nature makes them a significant safety risk. Since they are important reagents in the research laboratory and often do not have substitutes, it is important that they are handled properly and with care. Some acids are even shock sensitive and under certain condition may cause explosions (*i.e.*, salts of perchloric acid).

Principles:
Mineral acids are corrosive in nature. If acids are inhaled, they can be destructive to mucous membrane tissues and the upper respiratory tract, cause burning of the throat and nose, coughing, wheezing, shortness of breath, and pulmonary edema (water retention). Skin contact causes burns and eye contact may even cause blindness. Ingestion may cause permanent damage to the digestive tract. Contact with skin, eyes, respiratory tract, and digestive tract causes burns and irritation.

When diluting acids, add the acid to water slowly and in small amounts to avoid large amounts of heat release during mixing~~being released~~. Never use hot water or add water to acid. Large amounts of heat may be released, causing the solution to boil vigorously and splash acid out of the container. Wear appropriate PPE when mixing or diluting an acid.

This document provides a general guideline for the use and handling of mineral acids by hazard class only and does not apply to the safe handling of hydrofluoric acid where special directions approved by the principal investigator must be followed. Extra care must be taken when handling and using hydrofluoric acid because 1) it dissolves most materials including glass and ceramics so it should be stored using polyethylene and 2) ~~it is very~~highly toxic causing severe burns, where painful or visible symptoms may be delayed by 8 h or longer.

Nitric acid is a strong oxidizer that reacts with most metals evolving either hydrogen gas or nitrogen oxides depending on the concentration and the metal. It does not dissolve gold or

Commented [ASW1]: HF is unique because of 1) its reactivity with glass and 2) its health hazards. Include a discussion on this topic. Also, the "adding water to acid, not the other way around" idea would be good here.

platinum. Sulfuric acid is water reactive and acid mists containing sulfuric acid can cause cancer. Concentrated sulfuric acid also reacts violently with many organic chemicals leading to gas evolution. Hydrochloric acid reacts with nitric acid to form aqua regia, which causes brown fumes to evolve consisting of toxic nitrogen oxides.

In some cases, multiple guidelines may apply for the use of a chemical (*e.g.* precautionary use of benzene as a flammable liquid and a carcinogen would apply). Refer to the safety data sheet (SDS) for the specific mineral acid before using it. If it is not possible to follow the guidelines mentioned in this document, the principal investigator must develop an alternative standard operating procedure that provides an equivalent level of safety. There may be cases when the level of safety will need to be even more rigorous.

Procedures:

~~1. Potential Hazards~~

~~1.1. Corrosive: If acids are inhaled, they can be destructive to mucous membrane tissues and the upper respiratory tract, cause burning of the throat and nose, coughing, wheezing, shortness of breath, and pulmonary edema (water retention). Skin contact causes burns and eye contact may even cause blindness. Ingestion may cause permanent damage to the digestive tract.~~

~~1.2. Irritant: Contact with skin, eyes, respiratory tract, and digestive tract causes burns and irritation.~~

~~1.3. Additional Comments:~~

~~1.3.1. Nitric acid is a strong oxidizer that reacts with most metals evolving either hydrogen gas or nitrogen oxides depending on the concentration and the metal. It does not dissolve gold or platinum.~~

~~1.3.2. Sulfuric acid is water reactive and acid mists containing sulfuric acid can cause cancer. Concentrated sulfuric acid also reacts violently with many organic chemicals leading to gas evolution.~~

~~1.3.3. Hydrochloric acid reacts with nitric acid to form aqua regia, which causes brown fumes to evolve consisting of toxic nitrogen oxides.~~

~~1.3.4. Hydrofluoric acid is very toxic causing severe burns. Painful or visible symptoms may be delayed by 8 hours or longer.~~

Commented [ASW2]: These ideas are more conceptual, and would be difficult to film. Move them to the Principles.

1. Engineering Controls

1.1. Mineral acids should be handled in a chemical fume hood with the sash pulled down between the chest and what is being worked with in the hood. The height of the sash should be that which provides optimal safety while allowing one to execute tasks in an unencumbered manner.

1.2. Concentration of 3 M (M = molar) or less may be handled on a bench top remembering that they are still corrosive.

1.3. Use secondary containers when possible.

2. Personal Protective Equipment (PPE)

2.1. Chemical splash goggles and/or face shield must be worn if working outside a fume hood or if the sash is not pulled down to the properly height due to experimental setup reasons.

2.2. When using hydrofluoric acid, use neoprene, or thick butyl rubber gloves. For other acids use double nitrile, neoprene, or PVC (vinyl) gloves. Replace gloves whenever a splash occurs.

2.3. Wear a reusable or disposable chemical resistant apron/smock/lab coat (rubber, neoprene, or PVC). Traditional cotton-polyester white lab coats readily collects/absorbs compounds and are not recommended.

2.4. Protective clothing with long sleeves and full-length pants should be worn along with closed-toed footwear.

3. Additional Precautions

~~3.1. When diluting acids, add the acid to water slowly and in small amounts to avoid large amounts of heat being released. Never use hot water or add water to acid. Large amounts of heat may be released, causing the solution to boil vigorously and splash acid out of the container. Wear appropriate PPE when mixing or diluting an acid.~~

Commented [ASW3]: This would be a good topic to explain in the principles.

~~3.2.~~ 3.1. Reactions with metals generate hydrogen gas, which may be flammable and potentially explosive.

~~3.3.~~ 3.2. Do not mix nitric acid with organics, which may cause an explosion or fire.

~~3.4.~~ 3.3. Skin contact with hydrofluoric acid causes severe tissue damage and corrosive chemical burns. In the case of hydrofluoric acid coming into contact with skin or tissue, flush contact area with tepid water for 5 min, apply calcium gluconate to counter the effects, and then seek medical attention. The onset of effect(s) from hydrofluoric acid can be delayed by as much as 8 h. It is especially important to seek medical attention for any HF burn because these delayed effects. HF essentially dissolves your bone structure causing it to be handled with great care.

Commented [ASW4]: What are the effects? What makes HF unique from other mineral acids.

4. Storage

4.1. Mineral acid containers should be stored together in an acid (corrosive) cabinet. This cabinet should be clearly labeled as containing acids. ~~Minimal a~~Acid amounts of less than ~~of acid~~ 1 L should be stored at any one time.

Commented [ASW5]: Is this quantifiable?

4.2. Mineral acids are chemically incompatible with bases, oxidizing agents, organic materials, and combustibles, and should be stored separately. Nitric acid—being a strong oxidizer—should be stored in a chemically resistant secondary container separate from other acids. The secondary container should be constructed of polyethylene, PYREX, or Nalgene.

4.3. Strong mineral acids ~~and ammonium hydroxide~~ should not be stored in the same cabinet. ~~Fumes from ammonium hydroxide combining with acid fumes may form ammonium salts, which are mildly acidic and over time can degrade labels and both wood and metal storage shelves.~~

Commented [ASW6]: Why are you singling out this specific base?

4.4. Avoid storing acids on metal shelves or use secondary containers made of plastic or in case of hydrofluoric acid, polyethylene.

4.5. If mineral acids must be transferred to smaller working containers, make sure the container is compatible with the acid and must be labeled with all of the required information that is on the permanent or manufacturers' container labels. The permanent or manufacturers' container label must meet OSHA's Hazard Communication standard [29 CFR 1910.1200(f)(1)] by providing the following information:

- Chemical identity and appropriate hazard warnings.
- Hazard warnings must provide immediate recognition of the primary health and/or physical hazard(s) using pictograms, signal words, and precautionary statements. The hazard label must also be permanent, legible, and written in English.
- The name, address, and telephone number of the chemical manufacturer, importer, or other responsible party.

4.6. Avoid over-purchasing and only purchase what can be stored safely in the laboratory.

4.7. Always handle mineral acids in a properly functioning chemical fume hood. Ensure that the sash is working properly, exhaust management is appropriate, and recently verified. Additionally, practice good housekeeping in the hood prior to utilizing the mineral acid. Remove incompatible materials and ensure clutter in the hood is reduced or eliminated to a level that enables safe handling and manipulation.

4.8. Containers should be kept upright and tightly closed in a dry and well-ventilated place. When opened, containers must be resealed to prevent spills.

4.9. Store and handle away from ignition sources and avoid heat and shock or friction.

5. Emergency Procedures

5.1. Exposures/Unintended Contact

5.1.1. In case of skin contact, immediately remove contaminated clothing and rinse thoroughly with water for at least 15 min.

5.1.2. In case of eye exposure, immediately rinse eyes with copious amount of water for at least 15 min and then promptly seek medical attention.

5.1.3. In the case of large amounts of vapor inhalation, move person to fresh air and then seek medical attention.

5.1.4. In the case of ingestion, immediately seek medical attention.

5.2. Spills

5.2.1. In the case of a chemical spill, the sooner it is controlled, the less damage it can cause. As the spill is controlled, the spill should also be contained in an as small as possible area and prevented from spreading further.

5.2.2. The spill must be cleaned immediately. Laboratories requiring the handling of mineral acids should have spill kits readily available.

5.2.3. Decontamination or neutralization may be required for which solid sodium bicarbonate or calcium carbonate is recommended. The spill may be covered with the acid neutralizer and then swept up with absorbent pads or a broom. If this is to be handled by a laboratory investigator, consultation as to the appropriate level of PPE is recommended. A standard operating procedure (SOP) should be developed to handle these kind of safety issues in the laboratory prior to any experimental work requiring mineral acid usage.

5.2.4. In case of a large spill, evacuate the area immediately alerting others, and call 911. Make sure someone is near the scene to provide information to the responders. Have the product information and the safety data sheet (SDS) available.

5.2.5. All spills, minor or large, must be reported to the proper regulatory agencies. Environmental Health and Safety (EHS) performs all regulatory notifications and verifies that the spill clean-up meets regulatory requirements and standards.

6. Waste Disposal

6.1. Acid wastes should be kept separate from other waste materials and used with secondary containers.

6.2. Check waste solutions periodically for gas evolution and avoid over-pressurized containers, which may violently erupt.

6.3. Dispose of waste through your organization’s chemical waste management system.

6.4. If the waste solution does not contain any hazardous metals, elementary neutralization may be considered. The acid waste may be poured into a large quantity of ice (500 g of ice per 100 mL of acid) and neutralized with an aqueous basic solution, such as 1 M or 10% sodium hydroxide (NaOH) or saturated sodium bicarbonate ($NaHCO_3$) in water until the pH is neutral. The neutralized solution may then be poured down the drain.

6.5. If the waste solution contains any hazardous metals such as gold, platinum, lead, or chromium the solution should be labeled and disposed of through the chemical waste management system.

Summary:

The use of mineral acids in laboratories entails considerable health and safety risks but with proper handling the potential hazards may be mitigated. While a basic guideline is provided here, this document does not apply to the safe handling of hydrofluoric acid and special directions approved by the principal investigator must be followed. Hazards may vary by experiments or laboratories, which should be assessed carefully to reduce chances of laboratory accidents.

References:

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~~6.~~8. The University of Maine Storage of Chemicals in Laboratories at http://chemistry.umeche.maine.edu/Safety/Storage.html