Chemical Fact Sheet: Aqua Regia

Aqua regia is a fresh mixture of concentrated hydrochloric and nitric acids, usually in a 3:1 ratio that can dissolve the noble metals, gold and platinum. It is a highly corrosive mixture that is either a fuming yellow or red solution, depending on how fresh it is. Aqua regia is used for several purposes in the lab. One is to remove noble metals such as gold, platinum, and palladium from substrates, particularly in micro-fabrications and microelectronics labs. It is also used in etching, in specific analytic procedures, and to clean glassware by removing organic compounds and metal particles. It is highly corrosive and a powerful oxidizing agent. The gases produced when mixing the two acids are highly toxic. The initial mixture forms nitrosyl chloride and chlorine gas.

\[
\text{HNO}_3 (aq) + 3\text{HCl} (aq) \rightarrow \text{NOCl} (g) + 2\text{H}_2\text{O} (l) + \text{Cl}_2 (g)
\]

Over time, the nitrosyl chloride further decomposes to produce more chlorine gas and nitric oxide, which auto-oxidizes to produce nitrogen dioxide (NO2).

\[
2\text{NOCl} (g) \rightarrow 2\text{NO} (g) + \text{Cl}_2 (g)
\]

\[
2\text{NO} (g) + \text{O}_2 (g) \rightarrow 2\text{NO}_2 (g)
\]

Many accidents (container ruptures) have occurred because bottles were capped while the solution was still evolving gases at a high rate before the solution had fully cooled. In addition, when stored over time, the reaction continues and could result in pressure build up in containers. The mixture could remain more reactive than either hydrochloric or nitric acid alone for up to 2 weeks. There are other factors that may lead to gas build up in capped containers such as whether the solution is heated, the materials cleaned, the amount of acid and the dimension of the container. For these reasons, and the fact that there is a loss of effectiveness as the solution reacts, it is recommended this solution not be stored, but be used immediately, mixing only what you need for use.

Aqua regia should only be used when absolutely necessary. There may be somewhat safer options such as hydrogen peroxide for some of the typical uses of this chemical solution, e.g. glassware cleaning when the main concern is organics.

**Note:** This guidance is for the occasional or small-scale use of aqua regia typically less than 4 liters. If you plan a large scale ongoing process, such as an aqua regia acid bath, or if you plan on frequent mixtures of small batches you must contact the EHS Office to assure appropriate engineering controls are designed for your application. Fume hoods and duct systems have been severely corroded by routine use of this material. In some cases, and especially in applications that involve the boiling of aqua-regia, specially coated fume hoods and ductwork may be required.

**Exposure Controls:**

**Engineering Controls:** All work involving aqua regia must be done inside a fume hood. During use of aqua regia, label the fume hood with a sign such as “Extremely Hazardous. Aqua regia solution in fume hood. Highly corrosive and reactive. Toxic gas production.” Keep the fume hood sash between you and the solution. Remove any organic or other incompatible chemicals from the fume hood when working with aqua regia. It is recommended that work be done in a secondary container such as a tray to facilitate containment and cleaning.

**Personal Protective Equipment:** Wear proper personal protective equipment for work with acids, including lab coat, long pants, closed-toe shoes, and tight fitting safety glasses or goggles. Use heavy-duty neoprene gloves or other acid resistant gloves rated to protect against hydrochloric AND nitric acid. For
large scale use greater than 4 liters or where there is a chance for splash or splatter neoprene gauntlets and apron, safety goggles, and a face shield should be worn. Do not use standard disposable nitrile laboratory gloves.

Handling Procedures:

- Consult with your PI, laboratory supervisor and/or EHS Coordinator prior to initial use to discuss special hazards and precautions.
- Develop a written Lab Specific Standard Operating Procedure (SOP) for your application of aqua regia that includes safety precautions for each step of your lab activities. Work must be done in a designated area. For development of a Lab Specific SOP, refer to the template on the MIT EHS website at: https://ehs.mit.edu/site/chemical-safety/chemical-hygiene-program/plan-template
- Do not work alone with aqua regia solutions. Work within sight or hearing of at least one other person who is familiar with the hazards and procedures. Make sure you have unimpeded access to eyewash and safety shower.
- Do all work preparing and using aqua regia in a properly functioning fume hood. Put on personal protective equipment specified above.
- Use Pyrex containers or Teflon containers for aqua regia.
- Prepare only the amount you need for immediate use.
- Carefully mix, adding nitric acid slowly to the hydrochloric acid, in that order. Never add hydrochloric to nitric acid. Never put a cap on the containers immediately after mixing.
- Aqua regia is an energetic, potentially explosive solution. The reaction between nitric acid and hydrochloric is exothermic and fresh mixtures will heat up potentially greater than 100C. Handle with care. Mixing it with organic compounds may cause an explosion.
- Perform the function for which the acid solution is being used. After use, allow solution to cool and process as noted under waste storage and disposal below.
- Mix/prepare small batches of fresh solutions for each application. Do not store solutions for reuse. Do not mix this solution with other chemicals.

Storage:

- DO NOT STORE AQUA REGLA. It is not effective after storage, slowly decomposing to form gases that will pressurize the container. It is best to mix a small amount of fresh solution for each application, and dispose after use.

Waste Storage and Disposal:

Preferred method for waste management.

1. After use, the aqua regia solution should be allowed to cool down in an open container inside the labeled fume hood for several hours overnight, depending on the mixture. This can take several days depending on the solution.
2. Once cooled, collect the waste in a compatible waste container; such as a coated glass bottle, or a rinsed and dried reused nitric acid bottle. Note: metal containers should never be used, and some plastics may be degraded by this solution, so glass or coated glass is preferred.
3. The MIT EHS Office provides vented caps for 4L waste bottle at no charge for solutions where pressure buildup is a concern. Go to the Chemical Waste Collection Form on the EHS web site at: https://mit.quickbase.com/db/bms438qt8?a=nwr. Under “Do You Need Any Supplies”, specify Vented Caps. You can also send a message to environment@mit.edu.
4. Label the container with a red tag stating “Aqua Regia waste”, listing the specific constituents and approximate percentages, if that information is known.
5. Keep the waste in a well ventilated SAA; such as a fume hood or vented cabinet, separated from organic and other incompatible materials until the reaction has come to completion.

6. Do not fill the waste bottle more than ¾ full. Once the bottle is cooled to the touch and there is no visible bubbling, date the red tag, replace vent cap with an acid resistant cap, and either arrange for collection of the waste at the lab or bring the bottle to the lab’s Main Accumulation Area (MAA). If the lab chooses to leave the vent cap on the bottle as an extra precaution, that is allowed by MIT EHS for safety purposes, even when being transferred to the MAA.

7. If large quantities of aqua regia waste are generated, i.e. greater than 4 liters, you must contact EHS Office as alternative waste handling procedures may be needed. This practice is not encouraged.

Emergency Procedures:

- Ensure that detailed emergency procedures are included in your SOP. Always keep acid neutralization materials, such as sodium bicarbonate, at all locations where aqua regia is made or used. Keep absorbent pads for oxidizing acids as well.
- Eye/Skin Contact. Flush contamination from eyes/skin using the nearest emergency eyewash shower for a minimum of 15 minutes. Remove any contaminated clothing.
- If medical attention is required, call 100 from a campus phone or 617-253-1212 from a cell phone.
- When seeking medical attention, bring along a copy of this fact sheet, Safety Data Sheets (SDS) for nitric and hydrochloric acids, and your SOP.
- Spills. Notify personnel in the area and your supervisor. Restrict access and eliminate all sources of ignition if safe to do so.
  - Spills (<50 ml) may be absorbed with a pink spill pad. **Note:** Do not use paper towels for clean-up of spills, as a fire may result.
  - Large spills: Immediately evacuate lab and call 100 to report an aqua regia solution spill that is health threatening. Standby to provide information to emergency responders.
  - Any spill outside of a chemical fume hood: Toxic gases may be generated by spilled material, so immediately evacuate lab and call 100. Standby to provide information to emergency responders.

For questions or additional information, contact the MIT EHs Office at 617-452-3477 or environment@mit.edu.