Flinn Suggested **Disposal Methods**

FLINN METHOD

#1a Organic Acid Halides and Acid Anhydrides

Products in this class readily react with water, amines and alcohols. They are also generally corrosive and their vapors are lachrymators. Acid halides and acid anhydrides may be RCRA listed and/or characteristic wastes due to their reactivity or flammability. Leftover organic acid derivatives remaining in an experiment may be hydrolyzed to water-soluble products of low toxicity that can be flushed down the drain. The reactions are exothermic; immerse the reaction vessel in ice water to control the heat.

Examples

Adipoyl chloride and acetic anhydride
Saturated solution of sodium carbonate (200 g Na_2CO_3/L)

Materials Required

Hydrochloric acid, HCl, 3 M
Ice-water bath (optional)
Large glass or polyethylene container
pH paper
Stirring rod

Overview

Acid halides and acid anhydrides are reacitve derivatives of carboxylic acids. These substances react with water to form the original organic acid or its conjugate base in basic solution. Excess acid halide or acid anhydride remaining in a reaciton mixture may be decomposed with saturated sodium carbonate solution. The acid anhydride or acid halide reacts with water, and the products of that reaction, which are acidic, immediately react with sodium carbonate to form a salt of the acid. Most carboxylic acid salts are innocuous and may be flushed down the drain. Gaseous carbon dioxide is also produced, also forms, which will produce a fizzing as the reaction proceeds. The reaction of acetic anhydride proceeds as follows:

$$(CH_3CO)_2O + H_2O \rightarrow 2CH_3COOH$$
$$2CH_3COOH + Na_2CO_3 \rightarrow 2NaCH_3COO + CO_2 + H_2O$$

Note that one mole of sodium carbonate is required to fully neutralize one mole of the original acid halide or acid anhydride. To push the reaction to completion, a twofold molar excess of sodium carbonate is recommended. At 25 °C, a saturated sodium carbonate solution contains about 2 moles of sodium carbonate per liter of solution. Sodium hydroxide solution (2 M) may be substituted for saturated sodium carbonate in this procedure.

Both adipoyl chloride and sebacoyl chloride contain two chlorine atoms per molecule. Use a fourfold molar excess of sodium carbonate solution to hydrolyze these compounds.

Procedure

❶ Perform this procedure in a fume hood. Wear chemical splash goggles, chemicals-resistant gloves and a lab coat or chemical-resistant apron.

❷ Place a saturated solution of sodium carbonate in a large glass or plastic container.

❸ Slowly add a few milliliters or grams of the acid halide or anhydride to the container while constantly stirring. You can tell the decomposition reaction is occurring when the material begins to dissolve. The evolution of gaseous carbon dioxide should also be evident.

❹ If a noticeable temperature rise is observed, place the container in an ice-water bath.

❺ Continue slow addition of the acid derivative while stirring until all the compound has been consumed.

❻ When a clear solution has been obtained, cool it to room temperature and neutralize to pH 7 with 3 M hydrochloric acid.

❼ Flush the neutral mixture down the drain with a 20-fold excess of water.

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FLINN METHOD

#1b Water-Reactive Metal Halides

Products in this class may react vigorously with water. The reactions generate heat and the reaction products are strongly acidic. Water-reactive metal halides may be decomposed to products suitable for flushing down the drain by reacting them with a large excess of cold water and neutralizing the resulting acidic solution.

Examples

Aluminum chloride (anhydrous) and tin(IV) chloride

Materials Required

Sodium hydroxide solution, NaOH, 3 M or saturated sodium carbonate solution, Na_2CO_3
Ice water
Large glass or polyethylene container
pH paper
Stirring rod

Overview

As described, these substances react with water, and the products are acidic. For example:

$$SnCl_4 + 2H_2O \longrightarrow 4HCl + SnO_2$$

The HCl formed will dissolve in the excess water. It is neutralized with either sodium hydroxide (to form sodium chloride and water) or with sodium carbonate (to form sodium chloride, gaseous carbon dioxide and water).

Procedure

①

Perform this procedure in a fume hood. Wear chemical splash goggles, chemicals-resistant gloves and a lab coat or chemical-resistant apron.

②

Prepare an ice/water slush in a large glass or polyethylene container. Slowly add the water-reactive metal halide directly to the ice/water slush with constant stirring. Aluminum chloride reacts vigorously with water. Be cautious to avoid localized overheating.

③

When all the compound has been added to the water, allow the mixture to come to room temperature and neutralize to pH 7 with sodium hydroxide or sodium carbonate solution. If you use sodium carbonate solution, expect some evolution of carbon dioxide gas during neutralization. A thick white precipitate of aluminum or tin(IV) oxide will form. Let the mixture settle overnight.

④

Check local sewer discharge limits for any metal cation remaining in solution. Decant the liquid to the drain with a 20-fold excess of water if allowed. The solid residue may be suitable for landfill disposal if no RCRA toxic metals are present.

FLINN METHOD

#2 Aldehydes

Products in this class may be solids, liquids, gases or aqueous solutions. Low-molecular aldhydes may be water-soluble, but they are also fammable and likely Resource Conservation and Recovery Act (RCRA) characteristic wastes. Excess of leftover aldehyde in an experiment my be oxidized to render it nonhazardous.

Examples

Acetaldehyde and benzaldehyde

Materials Required

Potassium permanganate solution, $KMnO_4$, 0.3 M
Sodium sulfite solution, Na_2SO_3, 0.1 M
Sulfuric acid solution, H_2SO_4, 3 M
Beaker, 1-L
Magnetic stirrer/hot plate and stir bar
pH paper
Thermometer

Overview

The carbonyl group in an aldehyde is easily oxidized to a carboxylic acid, which is usually less toxic, less volatile and more water-soluble than the starting aldehyde.

Oxidation can be achieved using aqueous potassium permanganate, and the reaction can be followed by monitoring the color change. As the oxidation occurs, the purple permanganation (MnO_4^-) is reduced to brown, insoluble manganate dioxide. The oxidation of benzaldehyde, for example, leads to benzoic acid and its salt:

$$3C_6H_5CHO + 2KMnO_4 \longrightarrow 2C_6H_5CO_2K + C_6H_5CO_2H + 2MnO_2 + H_2O$$

The reaction may need to be heated, and any excess permanganate should be reduced by sodium sulfite before disposal. The mole ratio is two moles of permanganate ion per mole of carbonyl group.

Procedure

①

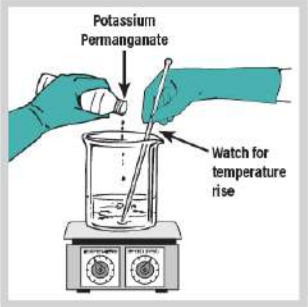
Perform this procedure in a fume hood. Wear chemical splash goggles, chemicals-resistant gloves and a lab coat or chemical-resistant apron.

②

Dilute any leftover aldehyde with 100 mL.

③

Add about 30 mL of 0.3 M potassium permanganate solution over a period of 10 minutes. If this addition is not accompanied by a rise in temperature and loss of purple permanganate color, then heat the mixture using a hot plate until the color changes.



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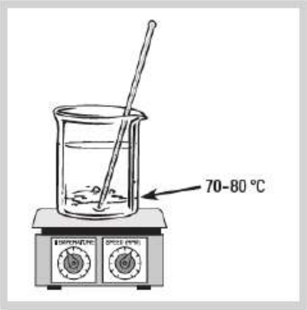
Flinn Method #2, continued

4

Slowly add additional potassium permanganate solution at 70–80 °C until the purple color does not dissipate. Stir for one hour.



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Allow the mixture to cool to room temperature and acidify to pH 7 with 3 M sulfuric acid. If any purple color remains, add 0.1 M sodium sulfite until the mixture is brown.

6

Filter the mixture, if needed, to remove insoluble MnO_2, which may be placed in the trash. The remaining solution may be flushed down the drain with a 20-fold excess of water.

FLINN METHOD

#3 Alkali Metals and Alkaline Earth Metals

Materials in this class react with air and water as well as with alcohols and halogenated hydrocarbons. These metals should not be allowed to come into contact with wastes containing these liquids. Alkali metals are stored in a dry mineral oil to keep them from air. The alkaline earth metals are usually covered with a thin coat of metal oxide, which protects them from further oxidation. The alkali and alkaline earth metals are characteristic RCRA hazardous wastes due to their reactivity. Small pieces or shavings of alkali or alkaline earth metals remaining in an experiment may be rendered nonhazardous by careful reaction with an alcohol or water, respectively.

Examples

Alkali metals include lithium, sodium and potassium. Alkaline earth metals include magnesium and calcium.

Materials Required

tert-Butyl alcohol (for potassium)
Ethyl alcohol, anhydrous (for sodium and lithium)
Hydrochloric acid, HCl, 1 M
Sodium hydroxide solution, 3 M
Class D fire extinguisher or a large bucket of clean, dry sand
Knife to cut large pieces of metal (optional)
Large glass beaker
Magnetic stirrer and stir bar or stir rod
pH paper

Overview

Alkali metals are very reactive with water to produce a base (e.g., NaOH), hydrogen gas and heat. They also react with alcohols in a more controlled manner to give similar products. The reaction is slower in alcohol due to the lower acid dissociation constant of alcohol relative to water.

$$Na + CH_3CH_2OH \longrightarrow CH_3CH_2O\,Na + \tfrac{1}{2}H_2$$

This procedure produces hydrogen gas, which is an explosion and fire hazard. The procedure also requires ethyl alcohol, another explosion and fire risk. Perform this procedure in a fume hood, behind a shield and with proper safeguards.

Anhydrous alcohols contain very little water and are preferred in this procedure. Use anhydrous ethyl alcohol for sodium or lithium and tert-butyl alcohol for potassium.

Leftover potassium is extremely dangerous due to its reactivity and tendency to form explosive peroxides. Appearance of a crumbly yellow coating indicates the formation of potassium superoxide (KO_2). Cutting or handling old potassium may result in a violent explosion. Do not attempt to destroy yellow-coated potassium. Contact a licensed hazardous waste disposal company.

Care must be taken in decomposing leftover alkali metals with alcohol. All the metals must be reacted with alcohol before water is added. Many laboratory accidents and fires have occurred by rushing this procedure and adding water too soon. The water will react with a small piece of metal generating substantial heat that autoignites the flammable alcohol.

Calcium and magnesium are less reactive with water. Leftover calcium is easily disposed of using a large amount of cold water, while excess magnesium requires dilute acid to catalyze the reaction.

$$Mg + 2H_2O + H^+ \longrightarrow Mg(OH)_2 + H_2$$

Procedure A: For Sodium and Lithium Metal

1a

Perform this procedure in a fume hood. Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

2a

Place small pieces of leftover or excess sodium or lithium in a 500-mL beaker and cover with mineral oil.

3a

Slowly add ethyl alcohol (at least 13 mL per g of sodium, 30 mL per g of lithium) to the metal at a rate to cause a reasonable hydrogen evolution. Do not add the ethyl alcohol too fast (causing excessive heat generation). Stir the mixture until all the pieces of metal have dissolved.

FLINN METHOD #3 continued on next page.

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Flinn Method #3, continued

4a

Only after all pieces of metal are gone, slowly add an equal volume of water to the mixture. Neutralize with 1 M hydrochloric acid.

5a

Flush the neutralized mixture down the drain with a 20-fold excess of water.

Procedure B: Potassium Metal

1b

Perform this procedure in a fume hood. Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

2b

Place small pieces of leftover potassium metal in a 500-mL beaker and cover with mineral oil.

3b

Slowly add tert-butyl alcohol (at least 21 mL per g of potassium) to the metal at a rate to cause a reasonable hydrogen evolution. Stir the reaction mixture until all the pieces of metal have dissolved.

4b

Only after all pieces of potassium are gone, slowly add an equal volume of water to the reaction mixture. Neutralize with 1 M hydrochloric acid.

5b

Flush the neutralized mixture down the drain with a 20-fold excess of water.

Procedure C: Calcium and Magnesium Metal

1c

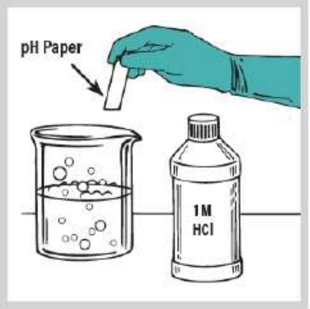
Perform this procedure in a fume hood. Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

2c

Add small increments of leftover metal (1–2 g) to 1 L of cold water (for calcium) or dilute (1 M) hydrochloric acid (for magnesium). Stir the mixture until all the metal has dissolved.

3c

Using pH paper, neutralize to pH 7 with 1 M hydrochloric acid.



4c

Flush the solution down the drain with a 20-fold excess of water.

FLINN METHOD

#4a Picric Acid

Picric acid is explosive when dry. Do not touch or handle. Picric acid cannot be disposed of by untrained personnel. You must contact a commercial waste disposal service, the local bomb squad or fire department. Bouin's solution contains picric acid; treat it just as carefully as pure picric acid.

Examples

Picric acid, Bouin's solution

Overview

Picric acid is normally sold containing 10–15% water, and in this state it is relatively safe to handle. However, dry picric acid is very explosive. The explosion can be initiated by friction, shock or sudden heating. Picric acid also reacts with metals to form explosive metal picrates, which are highly sensitive to detonation. **Do not attempt to dispose of picric acid by chemical means. This procedure merely provides a means to wet the picric acid to decrease its hazards.**

Procedure

1

Wear a full face shield, chemical-resistant gloves and a lab coat or chemical-resistant apron.

FLINN METHOD #4a continued on next page.

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Flinn Method #4a, continued

❷

Without touching the container of picric acid, determine if it has a metal cap. If it does, *do not touch the container at all.*

❸

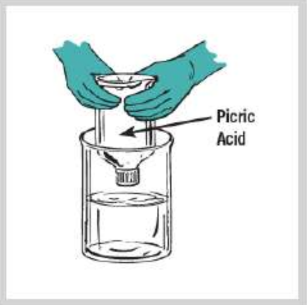
A metal-capped container of picric acid should be handled only by a trained expert, such as a member of a bomb squad. Call such an expert to remove the material from the premises as soon as possible. (Picric acid can form salts with the metal in the cap, and these salts are more explosive than picric acid itself. The friction caused in attempting to remove the metal cap from a container of picric acid has been reported to cause detonation of minute amounts of metal picrate trapped in the threads of the cap.)

❹

If—and only if—the container of picric acid has a plastic cap **and** contains visible water, you may proceed.

❺

Move the bottle to a fume hood and immerse the plastic-capped container upside-down in a beaker of water. Contact a licensed hazardous waste disposal company for further instructions and to remove the material.



FLINN METHOD

#4b Halogenated Hydrocarbons

Halogenated hydrocarbons require licensed hazardous waste disposal due to their characteristic toxicity or flammability. Halogenated organic waste should be segregated from other flammable organic solvents. The best route for disposal of nonvolatile halogenated hydrocarbons is through incineration. Use a licensed hazardous waste disposal company as described in Flinn Disposal Method #26c or #27j.

FLINN METHOD

#4c Organic Acids, Substituted

Substituted organic acids include amino acids and halogenated carboxylic acid (e.g., chloroacetic acid). Amino acids are nonhazardous, water-soluble and suitable for landfill or drain disposal using Flinn Disposal Method #26a or #26b. Water-soluble substituted carboxylic acids and their sodium, potassium, calcium or magnesium salts can be rinsed down the drain if local sewer discharge limits permit. See Flinn Disposal Method #26b.

FLINN METHOD

#5 Amines, Aromatic

Aromatic amines are relatively toxic and flammable materials. Common aromatic amines, such as, pyridine, aniline and diphenylamine, require licensed hazardous waste disposal according to Flinn Disposal Method #26c.

Many common dyes and pigments contain aromatic amine groups and do not present any unusual problems for incineration or burial in a landfill. Please consult your local regulations and Flinn Disposal Method #26a.

FLINN METHOD

#6 Substances Precipitated by Calcium Ion

Substances in this class include (a) soluble metal salts containing the fluoride ion and (b) soluble salts containing the oxyanion of a toxic heavy metal (e.g., Mo, W) for which the calcium salt is quite insoluble. Fluoride ion is highly poisonous.

Do not use procedure for hydrofluoric acid. Hydrofluoric acid is a poison and extremely dangerous in contact with human flesh. It requires licensed hazardous waste disposal.

Examples

Sodium fluoride, sodium molybdate, sodium tungstate

Materials Required

Calcium chloride solution, $CaCl_2$, 1 M, in threefold molar excess for disposal of fluoride or other salts
Hydrochloric acid, HCl, 3 M, or sodium hydroxide, NaOH, 3 M, as necessary to adjust pH
Funnel, filter paper and flask
Large plastic beaker or similar container (don't use glass for HF)
pH paper
Wood stirring stick

Procedure

❶

Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

❷

Dissolve the soluble compound (metal salt) in the smallest amount of water possible.

❸

Adjust the pH to 7 using pH indicator paper by adding 3 M sodium hydroxide or hydrochloric acid as necessary.

❹

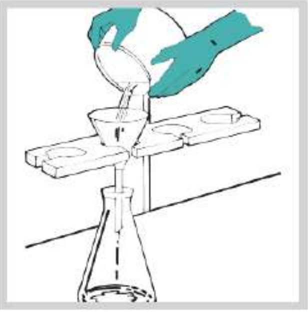
While stirring, add 1 M calcium chloride solution in a threefold molar excess to the neutral solution. Allow the resulting precipitate to stand about 15 minutes.

FLINN METHOD #6 continued on next page.

Flinn Method #6, continued

⑤

Filter or decant off the supernatant liquid. Flush the liquid down the drain with excess water.



⑥

Allow the solid to dry, place it in a plastic container, and send it to a landfill.

FLINN METHOD

#8 Azides and Azo-Compounds

Metal azides require licensed hazardous waste disposal as described in Flinn Disposal Method #26c. **Azides should NOT be drain-disposed.** They react with lead and copper in drain lines, solder joints and brass fittings to form unstable and explosive products. Drain systems have been destroyed by such explosions. In addition, azides are not biodegradable and will kill the necessary bacteria present in the digestion system of wastewater treatment plants. Stocks of these materials should be kept low. Sodium azide is a P-Listed acutely hazardous waste.

FLINN METHOD

#9 Carbon Disulfide

Carbon disulfide is a P-Listed acutely toxic hazardous waste (P022). Any discarded commercial chemical product containing carbon disulfide as the sole active ingredient will require licensed hazardous waste disposal. Proper management of P-Listed wastes is extremely important because institutions that accumulate more than 1 kg on site at anytime of acutely hazardous waste will be subject to the most stringent requirements for listing, storing and reporting all their hazardous waste.

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FLINN METHOD

#10 Bases, Strong and Weak and Basic Anhydrides

Elementary neutralization of corrosive acid and base solutions is a generally allowed disposal procedure. Two simple rules should be followed. First, the neutralization process should be mild. Any strong acids or bases should first be diluted to a concentration around 1 M or 10%. Second, the final product must be near neutral (pH 5–9) before discharge to the drain. In this procedure, bases are neutralized with dilute hydrochloric acid.

Examples

Ammonium hydroxide, sodium hydroxide

Materials Required

Hydrochloric acid, HCl, 3 M
Glass stirring rod
Ice/water slush (optional)
Large glass beaker
pH paper

Overview

Bases react with acids in aqueous solution to form a salt and water.

$$NaOH + HCl \rightarrow NaCl + H_2O$$

The neutral soluble salts formed are generally innocuous and can be rinsed down the drain with water.

Procedure

①

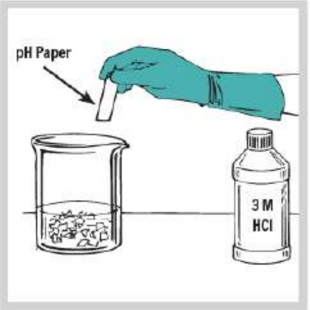
Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron. Use a fume hood if neutralizing ammonia solutions.

②

Prepare a dilute solution of (1 M or <10%) base by diluting a more concentrated solution or dissolving the solid into water. Considerable heat may be generated when dissolving a solid base. Use an ice/water slush if needed to dissolve solid sodium or potassium hydroxide.

③

When solution is complete, slowly add 3 M hydrochloric acid until the mixture is neutralized. Check with pH paper. More heat may be evolved in the neutralization process.



④

Rinse the neutral mixture down the drain with a 20-fold excess of water.

FLINN METHOD

#11 Silver Compounds

Silver and silver compounds are expensive and may be recovered or recycled but often can be reclaimed for future use. Silver compounds are characteristic hazardous wastes. Silver compounds are identified by the EPA as characteristic hazardous wastes due to their toxicity. According to the Resource Conservation and Recovery Act (RCRA), the concentration of silver ions in an extract of a solid suitable for landfill disposal cannot exceed 5 mg/L, based on the Toxicity Characteristic Leaching Procedure (TCLP). Federal guidelines also impose a concentration limit of 5 mg/L on industrial sewer disposal of silver ions in solution. Check with your local sewer authority for the allowable discharge limit in your area. In most cases, dilution with water is not an acceptable means of achieving the concentration limit.

Examples

Silver nitrate, silver chloride, silver oxide

Materials Required

Nitric acid, HNO_3, 8 M
Sodium chloride, NaCl, 1 M
Sodium hydroxide, NaOH, 2 M
Sodium hydroxide, NaOH, 6 M
Sucrose
Filtration apparatus
Glass stirring rod
Large glass beaker
Magnetic stirrer/hot plate with stir bar

Silver Recovery

Silver may be recovered and recycled for future use by dissolving the metal or metal compound in nitric acid, precipitating silver chloride and reducing the latter to silver metal. Recovery of silver metal from AgCl may be achieved by reduction with sucrose in basic solution or zinc metal in acid solution. The first step must be done in a fume hood due to the possible production of NO_2, a toxic brown gas. Note that $PbCl_2$ will co-precipitate with AgCl in the second step if the original silver is contaminated with lead. The third step may be omitted, and the silver reclaimed in the form of the precipitated silver chloride, if the original silver was relatively pure (see Procedure A).

The chemical reactions are as follows. Oxidation of silver metal may occur by one of two possible mechanisms:

$$2Ag(s) + 2HNO_3 \longrightarrow 2AgNO_3(aq) + H_2(g)$$

or

$$Ag(s) + 2HNO_3(aq) \longrightarrow AgNO_3(aq) + NO_2(g) + H_2O$$

$$Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$$

$$AgCl + NaOH(aq) + \text{Sucrose} \longrightarrow Ag(s)^*$$

*Sucrose is hydrolyzed to the reducing sugars glucose and fructose in basic solution. These sugars are oxidized to gluconic acids in the process of reducing Ag^+ ions to silver metal. The silver metal will be obtained in the form of a brown powder.

Silver(I) compounds, such as AgCl, are photosensitive and must be stored in dark bottles to prevent light-catalyzed reduction to silver.

Silver or silver ions may also be precipitated in the form of silver chloride to reduce the volume of hazardous waste requiring disposal (see Procedure B).

$$Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$$

Procedure A: Silver Recovery Process

1a

Perform this procedure in a fume hood. Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

2a

Dissolve the silver metal or silver salts in 8 M nitric acid solution. For about 10 g of silver, use 20–30 mL of 8 M nitric acid.

3a

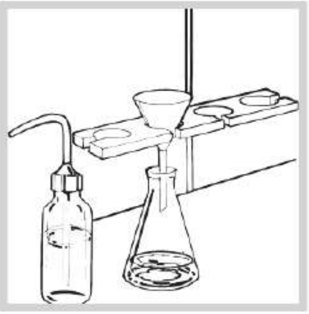
Add sodium chloride (about 60 g per 100 g of Ag) to precipitate silver chloride. Filter and wash the precipitate. (This step is necessary to rid the silver of any copper contaminant.)

4a

Suspend the AgCl in 6 M NaOH (for 100 g of Ag, use about 500 mL of NaOH) and boil it for about 30 minutes, during which time add sucrose (about 250 g or 1 cup per 100 g of Ag) in small amounts at frequent intervals. Stirring is not necessary, only occasional swirling. At first there is considerable frothing, and then the solution becomes dark brown. Finally a heavy, gray precipitate forms.

5a

Filter, wash and dry this precipitate. Store in a dark bottle.



FLINN METHOD #11 continued on next page.

Flinn Method #11, continued

Procedure B: Disposal of Silver Salts

1b

Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

2b

Dissolve the silver salt in water in a beaker.

3b

Add a 50% molar excess of sodium chloride solution and stir to ensure complete mixing.

4b

Decant or filter the resulting precipitate of silver chloride.

5b

Allow the precipitate to dry and dispose of it via licensed hazardous waste disposal.

6b

Check the supernatant liquid for residual silver, and rinse it down the drain with a 20-fold excess of water.

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FLINN METHOD

#12a Oxidizing Agents

Strong oxidizing agents, such as chlorates, permanganates and chromates, are hazardous when in contact with combustible materials. They should *never* be discarded with general refuse as they may cause fires or form explosive mixtures. Oxidizers are classified as characteristic hazardous wastes by the EPA due to their ignitability, (i.e., their ability to add oxygen to and sustain or intensify a fire involving a combustible material). Examples include nitrates, inorganic peroxides and permanganates.

Solid oxidizers will require licensed hazardous waste disposal. Leftover solutions of oxidizers remaining at the end of an experiment may be reduced as part of the experimental procedure to render them nonhazardous and suitable for drain disposal. Sodium thiosulfate is the recommended and most commonly used reducing agent for this purpose. Note that in the case of chromates, however, the reduced product will still require licensed hazardous waste disposal due to the chromium content. See Flinn Disposal Method #27f.

Examples

Bromine, iodine, sodium chlorate, potassium permanganate, sodium chromate

Materials Required

Sodium hydroxide solution, NaOH, 1 M
Sodium thiosulfate solution, $Na_2S_2O_3$, 4%
Sulfuric acid, H_2SO_4, 1 M
Glass stirring rod
Large glass beaker
pH paper

Overview

Oxidizing agents by definition oxidize other substances (i.e., they readily react with substances in low oxidation states to raise them to higher oxidation states). The oxidizing agent itself is reduced in this process.

The complementary processes of oxidation and reduction are often accompanied by the evolution of considerable heat. Leftover solutions of oxidizing agents may be reduced as part of an experimental procedure to render them nonhazardous.

Leftover oxidizing agents in solution may be safely reduced with sodium thiosulfate. The reactions proceed best in mildly basic, neutral, weakly acidic solutions. (Too much acid will react with the sodium thiosulfate directly, precipitating elemental sulfur from the mixture.) In the following example, thiosulfate ions react with the bromate ions to produce nonhazardous sulfate and bromide ions. Excess acid must be neutralized with base prior to drain disposal, if allowed.

$$3H_2O + 3S_2O_3^{-2} + 4BrO_3^- \rightarrow 6SO_4^{-2} + 4Br^- + 6H^+$$

Procedure

1

Perform this procedure in a fume hood. Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

2

This method is for small quantities of laboratory oxidizing agents only. Add the oxidizing agent to a twofold molar excess of a 4% aqueous solution of sodium thiosulfate (hypo) with continuous stirring.

FLINN METHOD #12a continued on next page.

Flinn Method #12a, continued

3

Allow the mixture to stand for about one hour for the redox reaction to proceed to completion. There may be a temperature rise during the reaction.

4

Check the pH of the mixture using pH paper. Neutralize the solution with dilute sodium hydroxide solution or sulfuric acid solution, as needed.

5

The residues from this procedure must undergo further treatment if they contain chromium. The products from the reduction of chromates and dichromates are insoluble chromium hydroxide. These materials can be removed by filtration and require Flinn Disposal Method #27f. Solutions containing chromium ions may not be drain disposed.

6

Flush other solutions down the drain with large quantities of water.

FLINN METHOD

#12b Reducing Agents

Strong reducing agents will react vigorously with oxidizing agents to produce heat and possibly fire. Some reducing agents may cause a fire when in contact with moist combustible materials. A simple oxidation reaction will render most reducing agents safe for disposal.

Examples

Potassium nitrite, sodium sulfite, sodium thiosulfate

Materials Required

Ammonium hydroxide, NH_4OH (proc. B)
Hydrochloric acid, HCl, 1 M
Hydrochloric acid, HCl, 3 M (proc. B)
Sodium carbonate, Na_2CO_3
Sodium hydroxide, NaOH, 1 M
Sodium hypochlorite solution (bleach)
Glass stirring rod
Large glass beaker
pH paper

Overview

Reducing agents by definition reduce other substances (i.e., they readily change the oxidation state of a substance from a high value to a lower value). They are the opposite of oxidizing agents. In the example involving carbon reacting with oxygen, the oxygen was the oxidizing agent because it oxidized the carbon. On the other hand, in this same reaction, carbon is the reducing agent because it changed the oxidation state of oxygen from zero to negative 2 (-2). In the process, considerable heat is produced.

Many reducing agents may be safely reacted with an oxidizing agent that will destroy their reducing power prior to disposal. Sulfides are commonly oxidized using bleach or sodium hypochlorite. This works best in a weakly basic solution. **Never mix bleach with acid!** Dissolve the reducing agent in water, then make it basic with sodium carbonate and finally react it with the hypochlorite ion. After the material is oxidized, the pH is adjusted to neutral and the resulting mixture containing innocuous ions may be flushed down the drain. The reaction of sulfite ion with hypochlorite ion produces sulfate and chloride ions as shown. (see Procedure A).

$$SO_3^{-2} + ClO^- \longrightarrow SO_4^{-2} + Cl^-$$

Nitrites are a unique class of compounds in that the nitrogen is in an intermediate oxidation state (+3). It can be either oxidized to the +5 state (NO_3^-) or reduced to a lower state (NO or N_2). Nitrites are easily destroyed by adding 50% excess ammonia and acidifying to pH 1. The resulting product is nitrogen gas. (see Procedure B).

$$HNO_2 + NH_4^+ \longrightarrow N_2 + 2H_2O + H^+$$

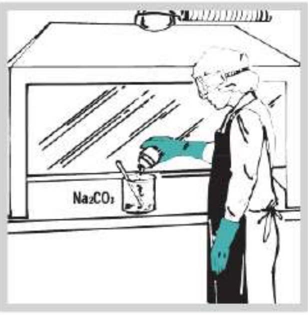
Procedure A: Sulfites

1a

Perform this procedure in a fume hood. Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

2a

In a large beaker, dissolve an equal amount of sodium carbonate and reducing agent in distilled water.



3a

Slowly add a 25% molar excess of bleach to the mixture with continuous stirring. Use caution as the reaction may be vigorous and produce heat. Allow the completed mixture to stand for several hours.

4a

Check the pH of the mixture using pH paper and neutralize as necessary. Use sodium hydroxide solution if acidic or hydrochloric acid solution if basic.

5a

Flush the neutral solution down the drain with a 20-fold excess of water.

FLINN METHOD #12b continued on next page.

Flinn Method #12b, continued

Procedure B: Nitrites

1b

Perform this reaction in a fume hood. Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

2b

Dissolve the inorganic nitrite salt in distilled water.

3b

Add a 50% molar excess of ammonium hydroxide solution.

4b

Using pH paper to monitor the process, acidify the solution to pH 1 with 3 M hydrochloric acid. Stir for two hours.

5b

Check the pH of the solution and neutralize to pH 5–10. Rinse the solution down the drain with excess water.

FLINN METHOD

#13 Organic Sulfides, Mercaptans and Thioamides

Organic sulfides and mercaptans are toxic and should not be drain disposed. Because of their toxicity, they should only be disposed of by a licensed hazardous waste disposal company as described in Flinn Disposal Method #26c.

FLINN METHOD

#14 Cyanides and Solid Metal Cyanide Complexes

All cyanides must be removed by licensed hazardous waste disposal. Cyanides are severe and rapid-acting poisons, being quickly absorbed into the body via the respiratory system, skin, eyes and mouth. Cyanides are identified as acutely hazardous, P-listed wastes by the EPA. They are also classified by the Resource Conservation and Recovery Act (RCRA) as characteristic hazardous wastes due to their reactivity with water to produce toxic hydrogen cyanide gas.

Compounds containing metal cyanide complex ions, such as potassium ferrocyanide or potassium ferricyanide, are generally considered nontoxic and are much less reactive than simple cyanide salts. Complex iron cyanides may generate hydrogen cyanide in contact with concentrated hydrochloric acid or when heated. Nevertheless, both potassium ferrocyanide and potassium ferricyanide are classified as P-listed wastes.

The following detoxification procedure using bleach only may be applied to leftover solutions containing ferri- or ferrocyanide ions as part of an experimental procedure. The detoxification procedure may NOT be used to treat any cyanide-containing hazardous waste.

Examples

Potassium ferrocyanide, potassium ferricyanide

Materials Required

Calcium hypochlorite solution, $Ca(OCl)_2$, 30%
Sodium hydroxide solution, NaOH, 3 M (twofold molar excess)
Sodium hypochlorite solution (bleach)
Glass stirring rod
Ice bath (optional)
Large glass beaker
pH paper

Overview

Ferro- and ferricyanides are much less toxic than cyanide salts and are oxidized to cyanates by hypochlorite. A 50% molar excess of bleach is required to assure complete destruction.

$$CN^- + OCl^- \rightarrow OCN^- + Cl^-$$

Commercial bleach (5.25% sodium hypochlorite) or a 30% calcium hypochlorite solution can be used for this procedure.

Procedure

1

Perform this procedure in a fume hood. Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

2

Fill a large beaker ½ full of water and, using pH paper, make it basic (at least pH 12) by adding 3 M sodium hydroxide solution, as needed.

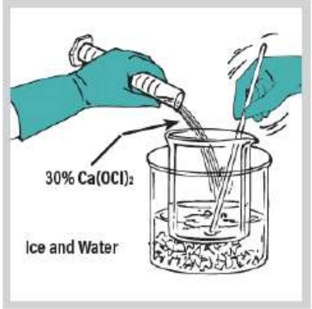
FLINN METHOD #14 continued on next page.

Flinn Method #14, continued

3

Dissolve the iron cyano-complex in the water.

4



While stirring, slowly add the sodium hypochlorite solution (about 100 mL per g of CN) or 30% calcium hypochlorite solution (20 mL per g of CN). Heat may be evolved; maintain the temperature below 50 °C by using an ice and water bath, if necessary. Once the addition of hypochlorite is completed (use a twofold molar excess), allow the mixture to stand for several hours.

5

Rinse the mixture down the drain with a 20-fold excess of water.

FLINN METHOD

#15 Ethers

Bottles of ethers that have been opened and are more than a year old may contain hazardous quantities of explosive peroxides. These bottles will require licensed hazardous waste disposal. Some companies will require that the peroxide level be verified before accepting ethers for disposal.

FLINN METHOD

#16 Hydrazines and Their Salts

Hydrazines contain a nitrogen-nitrogen single bond and are very reactive. Many hydrazines are also toxic and/or carcinogenic. Hydrazines should be disposed of by a licensed hazardous waste disposal company according to Flinn Disposal Method #26c.

FLINN METHOD

#18a Water-Soluble Alcohols, Ketones and Esters

Low-molecular weight, oxygen-containing organic compounds are volatile, soluble in water and biodegradable. Aqueous solutions and extracts containing less than 24% of volatile alcohols, ketones and esters—see the following examples—may be disposed in small quantities down the drain (sanitary sewer only) with excess water. Please check all federal, state and local regulations that may apply before proceeding. See Flinn Suggested Disposal Method #26b for more information on drain disposal.

Examples

Acetone, isopropyl alcohol, ethyl acetate

Please... Read the Narratives

Important narratives precede these specific chemical disposal methods! Please read each narrative carefully! Do not use these procedures if you are not comfortable with the chemistry. Do not use these procedures without *first consulting with your local government regulatory officials.* These procedures may not be used in some jurisdictions. All procedures involve some hazards and risks. Once again... read the narratives that precede these specific chemical disposal methods.

FLINN METHOD

#18b Hydrocarbons and Flammable Ketones, Esters, Alcohols

Nonvolatile organic compounds do not readily evaporate and are not easily converted into less toxic materials. The only disposal procedures available are disposal by a licensed hazardous waste company.

FLINN METHOD

#20 Organic Amides

Check the Safety Data Sheet (SDS) to determine whether the organic amide will be a characteristic ignitable waste (flash point <60 °C) or if it is a listed waste. Organic amides that are not hazardous wastes may be packaged for landfill disposal according to Flinn Suggested Disposal Method #26a. Characteristic and listed hazardous wastes require licensed hazardous waste disposal (see Flinn Suggested Disposal Method #26c.)

FLINN METHOD

#22a Peroxides, Inorganic

Inorganic peroxides are strong oxidizing agents and are classified by the EPA as ignitable characteristic wastes. Leftover inorganic peroxides may be reduced as part of an experimental procedure. When in contact or mixed with organic or combustible materials, fires or explosions are possible. Do not discard these materials in the trash!

Examples

Hydrogen peroxide, sodium peroxide

Materials Required

Hydrochloric acid, HCl, 3 M
Sodium metabisulfite, $Na_2S_2O_5$, 1 M
Large beaker, ¾ full of water
pH paper
Plastic spoon (optional)
Plastic stirring rod

Overview

Hydrogen peroxide may be reduced with sodium metabisulfite to render it suitable for drain disposal.

Sodium peroxide reacts violently with water to form oxygen gas and sodium hydroxide. Because of this reaction, sodium peroxide is stored in sealed containers to avoid reaction with moisture in the air. With fresh sodium peroxide the reaction with water is quite exothermic, but if used from a previously opened container, it may be less vigorous. Old sodium peroxide may have already slowly converted itself to sodium hydroxide. Test the materials for reactivity by adding a small amount (0.1 g) to water. Evolution of oxygen indicates an active peroxide. Leftover or excess sodium peroxide may be reduced.

$$Na_2O_2 + H_2O \rightarrow 2NaOH + \tfrac{1}{2}O_2$$
$$Na_2O_2 + Na_2S_2O_5 + H_2O \rightarrow 2NaOH + NaHSO_4$$

FLINN METHOD #22a continued on next page.

Flinn Method #22a, continued

Procedure A: Water Dilution

1a

Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

2a

Hydrogen peroxide of any concentration may be disposed of by pouring it into a large beaker containing at least a tenfold excess of water. Stir constantly.

3a

When the mixture is uniform, flush it down the drain with large amounts of extra water.

4a

If you are dealing with sodium peroxide, carefully add a small amount of water and break up any lumps with a plastic stirring rod.

5a

Pour the material slowly with continuous stirring into a large beaker of water. Oxygen gas will evolve, and the solution will become strongly basic. The final amount of sodium peroxide in the water should be no more than 5%. (If you have more sodium peroxide than will fit into this concentration in your beaker, do the procedure again until all the material is disposed of.)

6a

Using pH paper as a monitor, neutralize the solution with 3 M hydrochloric acid.

7a

Flush the neutral solution down the drain with excess water.

Procedure B: Reduction

1b

Perform this procedure in a fume hood. Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

2b

If you are dealing with solid sodium peroxide, carefully add a small amount of water and break up any lumps with a plastic stirring rod. Do **not** grind dry solid.

3b

Slowly add the sodium peroxide into a large beaker containing 1 M sodium metabisulfite (100 mL per g of Na_2O_2), and stir continuously.

4b

Using pH paper as a monitor, neutralize the solution with 3 M hydrochloric acid.

5b

Flush the neutral solution down the drain with excess water.

Please… Read the Narratives

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FLINN METHOD

#22b Peroxides, Organic

Organic peroxides are particularly dangerous materials that are highly flammable and explosive. Peroxides are sensitive to heat, shock, friction or contact with combustible materials. These materials are classified by the EPA as characteristic (reactive) hazardous wastes. Leftover organic peroxides may be hydrolyzed as part of an experimental procedure.

Examples

Benzoyl peroxide and lauroyl peroxide

Materials Required

Hydrochloric acid solution, HCl, 6 M
Sodium hydroxide solution, NaOH, 3 M—tenfold volume excess of the material to be destroyed, in a large glass beaker
Glass stirring rod
pH paper
Plastic spoon (optional)

Overview

When reacted with base, benzoyl peroxide and lauroyl peroxide (the only substances we catalog for which this procedure is suggested) will cleave between the two joined oxygen atoms and form sodium benzoate or sodium laurate, which are soluble in water and innocuous. Use care not to go past the neutral point when adding acid to the aqueous solution. If the solution is acidic, some benzoic acid may precipitate out.

$$(C_6H_5CO_2)_2 + 2NaOH \longrightarrow 2C_6H_5CO_2^-Na^+ + O_2$$

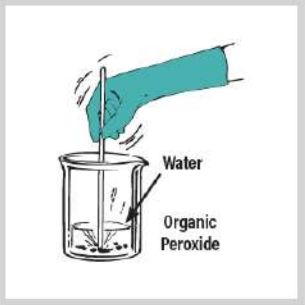
Procedure

①

Perform this procedure in a fume hood. Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron. Exercise caution working with dry organic peroxides—they are friction- and shock-sensitive.

②

Carefully add a small amount of water and break up any lumps in the organic peroxide with a plastic stirring rod. Do **not** grind the dry solid.



③

Pour the material into 3 M sodium hydroxide solution. Allow to stand at least 24 hours, stirring frequently. Benzoyl peroxide has low water solubility, so frequent agitation is important to bring the decomposition reaction to completion.

④

Using pH paper as a monitor, neutralize the solution with 6 M hydrochloric acid.

⑤

Flush the neutral solution down the drain with excess water.

FLINN METHOD

#23 Sulfides, Inorganic

Inorganic sulfides release highly toxic hydrogen sulfide gas on treatment with acid. These materials are classified by the EPA as characteristic (reactive) hazardous wastes and may not be disposed of in the trash or drain. Leftover soluble inorganic sulfides may be oxidized as part of an experimental procedure.

Examples

Sodium sulfide, ammonium sulfide

Materials Required

Sodium hydroxide solution, NaOH, 0.5 M
Sodium hypochlorite solution, NaOCl
Glass stirring rod
Large glass beaker

Overview

Inorganic sulfides are easily oxidized to sulfate ions using sodium hypochlorite as an oxidizing agent.

$$Na_2S + 4OCl^- \longrightarrow Na_2SO_4 + 4Cl^-$$

A small amount of base is added to keep the solution basic. A basic solution is needed because inorganic sulfides react with acid to produce highly toxic hydrogen sulfide gas and the hypochlorite ion is more stable at a higher pH.

The products from the reaction are sulfate salts, which are nonvolatile, odorless and have low toxicity. These materials can be rinsed down the drain.

Procedure

①

Perform this procedure in a fume hood. Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

②

Dissolve the inorganic sulfide in 0.5 M NaOH solution. For ammonium sulfide, use 100 mL of NaOH solution for every 10 mL of sulfide solution.

③

Slowly add sodium hypochlorite solution (bleach) to the inorganic sulfide. Add 200 mL bleach for each 10 mL of ammonium sulfide or 5 g of sodium sulfide.

FLINN METHOD #23 continued on next page.

Flinn Method #23, continued

❹

Allow the solution to sit overnight in the fume hood. Flush the entire solution down the drain with a 20-fold excess of water.

Note: This procedure is **not** intended for use with hydrogen sulfide gas. Gas cylinders must be used completely, vented into a ferric chloride solution through a trap, in an operating fume hood, if needed (due to a leaking valve, for example) and then disposed of in the trash. Small lecture bottles cannot be reused.

FLINN METHOD

#24a Acids, Organic

Organic carboxylic acids can be disposed of by neutralization, solid waste disposal or incineration. Water-soluble organic acids are best disposed of by neutralization with a base to form water soluble sodium salts. Solid, long chain carboxylic acids (e.g., lauric, decanoic) and their salts are insoluble in water, but small quantities pose little risk to the environment. These can be disposed of using Flinn Disposal Method #26a. All other organic acids are best disposed of using a licensed hazardous waste disposal company. Note that all liquids having a pH ≤2 are classified as corrosive wastes and must be neutralized prior to drain disposal.

Use Neutralization Method for These Acids

Acetic acid
Aceto-orcein solution
Barfoed's reagent (Copper carbonate may be formed. Filter and landfill.)
Formic acid
Fumaric acid
Lactic acid
Malonic acid
Oxalic acid
Propionic acid
Succinic acid
Tartaric acid
Trichloroacetic acid

Materials Required

Sodium carbonate, Na_2CO_3, or sodium hydroxide solution, NaOH, 3 M
Glass stirring rod
Large glass beaker
pH paper

Overview

Organic acids that are water soluble readily react with bases to form soluble sodium salts. Some organic acids that have limited solubility in water may produce soluble sodium salts (e.g., benzoic acid) and are also disposed of by this method. Sodium hydroxide solutions or sodium bicarbonate are suitable bases. If sodium bicarbonate is used, carbon dioxide is also formed.

$$CH_3CO_2H + NaHCO_3 \rightarrow CH_3CO_2Na + H_2O + CO_2$$

Please... Read the Narratives

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Procedure

❶

Perform this procedure in a fume hood. Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

❷

The organic acid may be diluted by adding it slowly to a 20-fold excess of water while stirring.

❸

Neutralize the resulting solution with sodium carbonate or sodium hydroxide solution and check the pH of the final solution with pH paper. Stir the solution until all solid organic acids have dissolved.

❹

Adjust the pH of the mixture to 5–9, if needed, and rinse the solution down the drain with an excess of water.

FLINN METHOD

#24b Acids, Inorganic

Neutralization of acid and base solutions (corrosive wastes) is a generally allowed disposal procedure and should present minimal problems. Two simple rules should be followed. First, the process should be mild. Any strong acids or bases should first be diluted to a concentration around 1 M or 10%. Remember, always add acid to water. Second, the final product must be near neutral (pH 5–9) before discharge to the drain. In this procedure, acids are neutralized with sodium carbonate.

Examples

Hydrochloric acid, sulfuric acid, nitric acid

Materials Required

Sodium carbonate solution, Na_2CO_3, 1 M
Glass stirring rod
Large borosilicate glass beaker less than ½ full of water
pH paper

Overview

This procedure is a standard neutralization of an acid with a carbonate. Neutralization may be highly exothermic. Immerse the reaction vessel in an ice bath to control the temperature, if needed.

$$2H_3PO_4 + 3Na_2CO_3 \rightarrow 3CO_2 + 2Na_3PO_4 + 3H_2O$$

FLINN METHOD #24b continued on next page.

Flinn Method #24b, continued

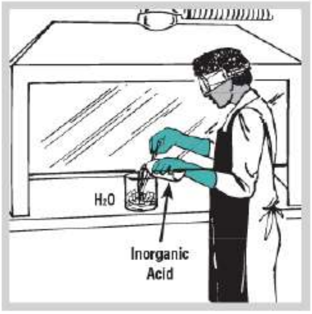
Procedure

❶

Perform this procedure in a fume hood. Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

❷

Dilute the acid by pouring it into a large beaker containing water. The final concentration of the acid should be 1 M or less.



❸

Slowly add 1 M sodium carbonate solution to the diluted acid while stirring. Carbon dioxide gas will be evolved. As the acid is neutralized by the sodium carbonate, the rate of gas evolution will decrease. When further additions of sodium carbonate solution yield no gas evolution, the neutralization is complete.

❹

Rinse the neutral mixture down the drain with a 20-fold excess of water.

Flinn Suggested Laboratory Chemical Disposal Methods

Flinn Scientific has been publishing suggested laboratory chemical disposal methods for more than 40 years. Each chemical in the *Flinn Scientific Catalog/Reference Manual* has a disposal number under its name. The disposal number refers to one of the suggested disposal procedures listed in this section. As federal, state and local regulations have changed, some of the disposal procedures have been updated or deleted. Before attempting any disposal procedures, it is essential that you check local regulations to determine if it is still allowed in your locale.

If you have any questions concerning laboratory waste disposal methods, please call (800-452-1261) or email (flinn@flinnsci.com).

FLINN METHOD

#25 Carbides

Calcium carbide reacts with water to generate acetylene, a highly flammable gas. Leftover calcium carbide in an experimental procedure may be decomposed with water.

Example

Calcium carbide

Materials Required

Hydrochloric acid, HCl, 3 M
Dry chemical (ABC) fire extinguisher
Glass stirring rod
Large glass beaker ¾ full of water
pH paper

Overview

Calcium carbide reacts with water to form acetylene gas and calcium hydroxide, which is not very soluble in water. The addition of hydrochloric acid to the suspension of calcium hydroxide will dissolve it, forming water and calcium chloride. The resulting mixture should be neutralized if needed prior to drain disposal.

$$CaC_2 + 2H_2O \longrightarrow C_2H_2 + Ca(OH)_2$$
$$Ca(OH)_2 + 2HCl \longrightarrow CaCl_2 + 2H_2O$$

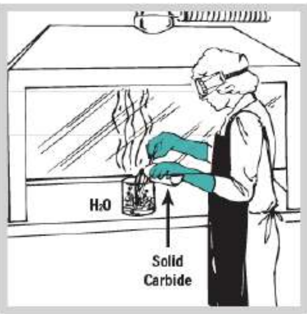
Procedure

❶

Perform this procedure in a fume hood. Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

❷

This procedure is intended for small amounts (<10 g) only! Carbides react with water, so keep these materials dry until ready for use or disposal. Slowly put the carbide granules into a large beaker of water with stirring. Flammable acetylene gas will be given off. Allow the acetylene to dissipate in the air, but avoid sources of possible ignition in the area. Allow the mixture to stand for several hours. The resulting solution will be strongly basic.



❸

Using pH paper to monitor pH, neutralize the solution with 3 M hydrochloric acid.

❹

Decant the neutral solution and rinse it down the drain with a 20-fold excess of water.

❺

Dry any remaining solid and package it for disposal in a landfill suitable for chemical wastes.

FLINN METHOD

#26a Solid Waste Disposal in Landfill

The majority of inorganic solid wastes are salts consisting of a cation and an anion. In planning the disposal of these inorganic salts, the hazards associated with the cation and anion must be determined separately. If either part presents a potential hazard, the substance should not be disposed of in a municipal landfill.

Cations that have a relatively low level of toxicity are Al, Bi, Ca, Cu, Fe, Li, Mg, Mo(VI), K, Sc, Na, Sr, Ti, Zn and Zr. Anions that have relatively low hazards are:

Bisulfite (HSO_3^-)
Borate (BO_3^{3-})
Bromide (Br^-)
Carbonates (CO_3^{2-})
Chloride (Cl^-)
Cyanate (OCN^-)
Hydroxide (OH^-)
Iodide (I^-)
Oxide (O_2^-)
Phosphate (PO_4^{3-})
Sulfate (SO_4^{2-})
Sulfite (SO_3^{2-})
Thiocyanate (SCN^-)

This list of less hazardous cations and anions is presented only as a guideline. Your chemical judgment, vlume of waste and local regulations must also be considered. For example, sodium hydroxide contains an acceptable cation (Na) and anion (OH), but is in fact a toxic and corrosive material that should be treated before disposal.

Materials Required

Cardboard boxes
Crumpled newspaper
Heavy tape to seal boxes

Procedure

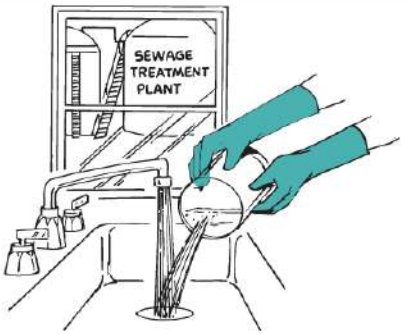
Bury solids in a landfill site approved for the disposal of chemical waste. Do not mix different materials by removing them from their separate containers because unpredictable chemical reactions may occur. Pack separate containers into sturdy cardboard boxes, separating containers from each other with crumpled newspapers to avoid inadvertent breakage. Seal the cardboard boxes with heavy tape.

This procedure is recommended for a wide array of materials, from aspirin to zinc. We use the term "landfill site approved for the disposal of chemical waste" with the full realization that many of these substances can go into the school trash. However, regulations about landfill use change with great frequency. Local regulations should be consulted about exactly what you can and cannot place in the landfill in your area. You must determine what is permitted in your area. Do not assume that it is acceptable to dump materials into the school trash. Take the time to investigate. Some instructors have made this "investigation" a student project and have learned a great deal in the process.

If you have made aqueous solutions of the water-soluble or alcohol-soluble materials classified for disposal under this procedure, we recommend that you dispose of these solutions according to Flinn Disposal Method #26b.

FLINN METHOD

#26b Waste for Drain Disposal Without Pretreatment



Aqueous solutions containing nonhazardous wastes (as defined by the EPA) may be suitable for drain disposal if—and only if—the school drains are connected to a sanitary sewer system with a water treatment plant operating on the effluent from your drains. These guidelines must be followed:

- Do not use this procedure if your drains empty into groundwater through a septic system—or into a storm sewer.*
- These materials may generally be disposed of in quantities not to exceed 100 grams each day for each substance by rinsing them down the drain with a large excess of water.
- Do not put combinations of materials down the drain at one time.

Local regulations may be more strict on drain disposal than the practices we recommend. You must determine what is permitted in your area. Sewer disposal in your community is regulated by an ordinance of your local water treatment facility. The regulations will spell out in considerable detail the allowable limits for various waste components. Because each water treatment facility is unique, you must contact the facility and get a copy of the ordinance. We also recommend meeting with representatives of the local treatment facility if a major laboratory clean-up and disposal is planned. A good working relationship with the treatment facility will make everyone more comfortable with the appropriate use of the sewer as a disposal method. For example, in some areas, compounds of aluminum, copper and zinc are not permitted in sanitary sewers. In most cases, we recommend that you substitute Flinn Disposal Method #26a for this one. All the materials recommended for this procedure are water-soluble to the extent of at least 3% and represent a very low toxicity hazard. In addition, the organic materials are readily biodegradable.

**Note:* If your drain system does not empty into a wastewater treatment facility, do not put these substances down the drain. Rather, landfill the nonflammable substances and aqueous solutions according to Flinn Disposal Method #26a, and dispose of all others using a licensed hazardous waste disposal company according to Flinn Disposal Method #26c.

Please... Read the Narratives

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FLINN METHOD

#27c Licensed Hazardous Waste Disposal

Many hazardous laboratory wastes require licensed hazardous waste disposal. It is important to choose a licensed and reputable firm. Please read the introduction on page 1288 for more information on choosing an acceptable disposal firm. Remember that the school has cradle-to-grave responsibility for its chemicals—documented proof that the chemicals have been properly disposed is required.

- ▶ Ask for and check references to make sure the firm is reputable and reliable.
- ▶ Do not automatically choose the low bid!
- ▶ Request a certificate of disposal for the chemicals.

Prior to licensed disposal, segregate and store hazardous waste in chemically resistant containers that are free of leaks or residues. Keep containers tightly closed at all times except when adding or removing waste. Label each container "Hazardous Waste" and add the name (identity) and amounts of all chemicals added to the container, along with the accumulation start date (the date you begin collecting waste in the container). Do not mix different types of characteristic hazardous wastes as unpredictable reactions may occur, generating heat and pressure inside the container. Check the chemical computability of all chemicals added to a waste container.

FLINN METHOD

#27a Scrap Metals

Some metals may have commercial value as scrap. If you do not wish to retain them, try to sell them. Otherwise dispose of them according to Flinn Disposal Method #26a.

FLINN METHOD

#27b Mercury Metal

Procedure

Mercury metal must not be disposed of by any means except to return it to a supplier for recycling. Mercury Waste Solutions, Inc. (1-800-741-3343) is a major mercury recycler and may be a disposal option. Under no circumstances should any other method of disposal be attempted. Metallic mercury is never buried, burned, placed down a drain or otherwise put into the environment. Mercury compounds also require licensed hazardous waste disposal according to Flinn Disposal Method #27f.

FLINN METHOD

#27c Phosphorus, Red and White (Yellow)

Phosphorus is a highly reactive and very flammable material. White phosphorus is pyrophoric, a poison and ignites spontaneously in air. Red phosphorus is not pyrophoric, but it is very flammable and can react explosively with strong oxidizing agents. Both chemicals must be handled with extreme caution and disposed of by a licensed hazardous waste disposal company.

FLINN METHOD

#27d Antimony, Vanadium and Their Compounds

Antimony and its compounds are toxic and may be harmful to the environment. The vanadium compounds vanadium pentoxide and ammonium meta-vanadate are classified as P-Listed acutely hazardous toxic wastes and require licensed hazardous waste disposal. Proper management of P-Listed wastes is extremely important. Institutions that generate more than 1 kg per month (in any month) of acutely hazardous waste will be subject to the most stringent generator requirements for all their hazardous wastes. They should be disposed of properly by a licensed hazardous waste disposal company according to Flinn Disposal Method #26c.

FLINN METHOD

#27f Heavy Metals and Their Salts and Compounds

Heavy metals require licensed hazardous waste disposal. The heavy metals listed here are classified by the EPA as toxicity characteristic hazardous wastes based on the Resource Conservation and Recovery Act (RCRA). Landfill disposal of heavy metals and all of their compounds is generally prohibited and subject to strict regulatory limits for the amount or concentration of the metal or metal ion that may be disposed. The regulatory limits are defined based on a test (laboratory procedure) called the Toxicity Characteristic Leaching Procedure (TCLP). TCLP limits for the various heavy metals in this category are included in the following list. Aqueous solutions of heavy metal ions are also restricted from sewer (drain) disposal by most publicly owned treatment works (POTW). Check with your local POTW for sewer discharge limits that apply in your area. General guidelines for hazardous waste disposal are described in Flinn Disposal Method #26c.

Metal	TCLP regulatory level
Barium (Flinn Method #27h)	100 mg/L
Cadmium	1 mg/L
Chromium	5 mg/L
Lead	5 mg/L
Mercury (Flinn Method #27b)	0.2 mg/L
Silver (Flinn Method #11)	5 mg/L

FLINN METHOD

#27h Barium Compounds

Soluble barium salts are extremely toxic and are classified by the EPA as characteristic (toxic) hazardous wastes. Aqueous solutions of barium salts may be precipitated in the form of barium sulfate to reduce the volume of hazardous waste requiring disposal.

Examples

All barium salts (i.e., barium nitrate, barium hydroxide, barium chloride)

Materials Required

Sodium carbonate, Na_2CO_3
Sulfuric acid, H_2SO_4, 3 M
Filtration apparatus (optional)
Glass stirring rod
Large beaker
pH paper
Wide-mouth plastic container with screw top

Overview

Barium sulfate is highly insoluble. This procedure produces barium sulfate in an acidic solution. Note that the only acid that will work in this procedure is sulfuric acid. The acid serves a double purpose in the case of barium hydroxide and barium peroxide in that it neutralizes the hydroxide ion in addition to its primary purpose of furnishing sulfate ion to react with the barium ion. Once the precipitation reaction is complete, the solid is separated from the supernatant liquid and any excess acid is neutralized with sodium carbonate. Solid barium sulfate requires licensed hazardous waste disposal. See the general guideline in Flinn Disposal Method #26c. The neutralized supernatant should be tested for residual barium and may be rinsed down the drain with excess water.

$$Ba^{+2} + SO_4^{-2} \rightarrow BaSO_4\text{ (solid)}$$
$$2H^+ + CO_3^{-2} \rightarrow CO_2\text{ (gas)} + H_2O$$

Procedure

❶

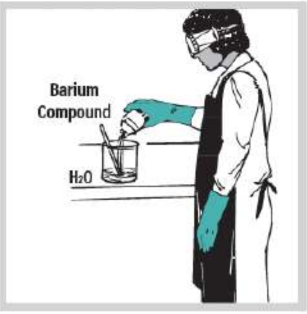
Wear chemical splash goggles, chemical-resistant gloves and a lab coat or chemical-resistant apron.

FLINN METHOD #27h continued on next page.

Flinn Method #27h, continued

②

Dissolve any leftover barium salt in a minimum amount of water. (Barium carbonate and barium peroxide are not soluble in water, so just suspend them in a tenfold excess of their weight in water.)

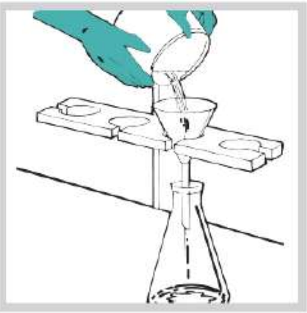


③

Add 3 M sulfuric acid to the solution while stirring until the precipitation of barium sulfate appears to be complete. Add at least a twofold molar excess of sulfuric acid.

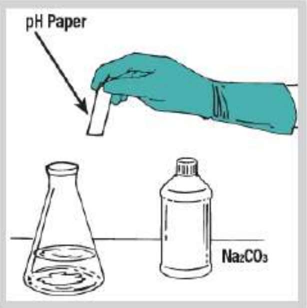
④

Allow the precipitate to settle, and decant off the supernatant liquid or filter off the precipitate.



⑤

The liquid will be acidic. Using pH indicator paper, neutralize it with sodium carbonate. Check that the neutral solution does not contain residual barium, and rinse it down the drain with excess water.



⑥

Allow the precipitate to dry and package it for licensed hazardous waste disposal.

FLINN METHOD

#27j Halogenated Solvents

Halogenated solvents are toxic compounds. They are immiscible with water and require licensed hazardous waste disposal (see Flinn Disposal Method #26c). Most halogenated solvents are characteristic (toxic) or U-Listed hazardous wastes.

REFERENCES

The disposal procedures listed in this section are obtained from the following reliable and highly regarded sources:

ACS Task Force in Laboratory Waste Management. *Laboratory Waste Management: A Guidebook*. Washington, D.C.: American Chemical Society, 2012.

Armour, Margaret-Ann. *Hazardous Laboratory Chemicals Disposal Guide*, 3rd Edition. Boca Raton, FL: CRC Press, Lewis Publishers, 2003.

"Little Known But Allowable Ways to Deal with Hazardous Waste." EPA Publication 233-B-00-002. May 2000, accessed August 2015. http://nepis.epa.gov.

Lunn, George and Eric B. Sansone. *Destruction of Hazardous Chemicals in the Laboratory*, 3rd Edition. New York: John Wiley and Sons, 2012.

National Research Council. *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards*. Washington, D.C.: National Academies Press, 2011.

Please... Read the Narratives

Important narratives precede these specific chemical disposal methods! Please read each narrative carefully! Do not use these procedures if you are not comfortable with the chemistry. Do not use these procedures without *first consulting with your local government regulatory officials.* These procedures may not be used in some jurisdictions. All procedures involve some hazards and risks. Once again... read the narratives that precede these specific chemical disposal methods.