LABORATORY CHEMICAL SAFETY SUMMARIES

This appendix presents laboratory chemical safety summaries (LCSSs) for 91 substances commonly encountered in laboratories. These summaries have been prepared in accord with the general and comprehensive approach to experiment planning and risk assessment that is outlined in this volume, and they should be used only by individuals familiar with the content of those chapters. The scope of coverage and degree of detail provided in these summaries should be appropriate for prudent experiment planning in most commonly encountered laboratory situations. Each summary includes chemical and toxicological information derived from the various secondary sources discussed in Chapter 4, as well as from material safety data sheets (MSDSs). The committee encourages the dissemination of these summaries as a means of promoting the prudent use of hazardous chemicals in laboratory work. It anticipates that these summaries will also serve as models for the preparation of additional LCSSs for chemicals not included in this appendix. In fact, *the committee recommends that laboratory workers routinely prepare new LCSSs for unfamiliar substances as part of the risk assessment they should carry out for each experiment as described in Chapter 6.*

The preparation and use of LCSSs as described here are consistent with the chemical hygiene plans required for every laboratory under the Occupational Safety and Health Administration (OSHA) Laboratory Standard. Thus, the identification of substances that meet the OSHA criteria for “particularly hazardous substances” or “select carcinogens” should be facilitated by the use of these summaries.

Limitations of LCSSs

All users of LCSSs should understand their limitations. In each summary, the content of the section on toxicity is dependent on the quality of the information available. For some chemicals the description of toxicity hazards is based on extensive experience with human exposure, whereas in other cases this discussion is based on limited data from animal tests. If a substance meets the OSHA definition of a “select carcinogen” (based on current information), then that fact is noted here. The discussion of toxic effects has been written so as to be comprehensible to the average laboratory worker, with full knowledge that the use of plain language may lead to a lack of precision in the description of toxic effects. The section on reactivity and incompatibility summarizes only those items that are likely to be encountered in normal laboratory use and should not be considered comprehensive. If more extensive information is required for any of the categories of information given in these summaries, the sources listed in Chapter 4 should be consulted. In addition, OSHA regulations (Standards—29 CFR) are now available online at http://www.osha.gov, as are further links to safety and health information.

These summaries should be used only by laboratory workers with general training in the safe handling of chemicals. LCSSs are intended to be used in conjunction with Chapters 4 through 9 of this volume, and these summaries make frequent reference to the contents of those chapters. The information in these summaries has been selected for its relevance to the *laboratory use* of chemicals. In particular, the listing of chemicals and toxicological hazards is not intended to be a comprehensive review of the literature for a given substance. These summaries do not contain information on

- Household or nonlaboratory use of a chemical;
- Commercial, manufacturing, or other large-scale use of chemicals;
- Consequences of abuse of a chemical by deliberate ingestion, inhalation, or injection;
- Environmental effects of release, disposal, or incineration of a chemical; or
- Shipment or transportation of a chemical in accordance with applicable laws and regulations.

The information contained in these summaries is believed to be accurate at the time of publication of this volume. A recent MSDS should be consulted for updated information, especially on exposure limits.

Preparation of New LCSSs

All of the information required for the preparation of new LCSSs should be available in the sources discussed in Chapter 4. The following directions should be helpful in preparing specific sections of new LCSSs:

- **Odor.** Information on odor and odor thresholds can be found in the NIOSH Pocket Guide to Chemical Hazards (DHHS/CDC/NIOSH, 2007), on International Chemical Safety Cards (ICPS, 2009), and in the American Industrial Hygiene Association publication “OdorThresholds for Chemicals with Established Occupational Health Standards.” (AIHA, 1989)
- **Toxicity data.** LD_{50} and LC_{50} values can be found in MSDSs and other sources listed in Chapters 4 and 6. Exposure limits are included in MSDSs and are listed in the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value booklet (ACGIH, 2008b), which is updated annually.
- **Major hazards.** This section should provide key words indicating only the most important potential hazards associated with the title substance.
- **Toxicity.** The first paragraph of this section should discuss acute toxicity hazards using plain language. Symptoms of exposure by inhalation, skin contact, eye contact, and ingestion should be separately described, and the degree of hazard of the substance should be identified as “high,” “moderate,” or “low,” as discussed in Chapter 6. The paragraph should indicate whether there are adequate warning properties for the substance. The second paragraph should address chronic toxicity. For potential carcinogens, whether the substance is classified as an OSHA "select carcinogen” should be indicated.
- **Flammability and explosivity.** This section should indicate the National Fire Protection Association (NFPA) rating for the substance, explosion limits, toxic substances that may be produced in a fire, and the type of fire extinguisher appropriate for fighting fires.
- **Storage and handling.** This section should make reference to the appropriate sections of Chapters 5 and 6 and should also highlight any special procedures of particular importance in work with the title substance.

The list of LCSSs is not intended to be an exhaustive compilation of known chemicals and may not fully disclose all information key to determining the hazards and properties associated with the substances contained herein. The LCSSs compliment information presented within the text and can be used as a template for the development of chemical safety summaries. A brief description of the information supplied in each LCSS is given in Table 1 *NA means information not available.*

TABLE 1 Information to Be Supplied in Laboratory Chemical Safety Summaries

Identifying Information	Name, synonyms, CAS#, and formula	
Physical properties	Odor, appearance, water solubility, vapor density, vapor pressure, flash point, autoignition temperature, boiling point (bp) and melting point (mp)	
Toxicity data	Toxicity data is based on exposure in humans, rats, and rabbits through oral, inhaled, and skin exposure.	
	LD$_{50}$	Dose of the compound that will cause death in 50% of exposed animals.
	LC$_{50}$	Concentration of the compound that will cause death in 50% of exposed animals (typical for exposure by inhalation).
	LC$_{LO}$	Lowest concentration of a compound reported to cause death in humans or animals.
Exposure limits	REL	NIOSH-recommended exposure limit.
	STEL/ceiling	Short-term exposure limit, maximum concentration an individual can be exposed to for a period of 15 minutes.
	PEL	OSHA permissible exposure limits, maximum concentration of a chemical in air based on an 8-hour weighted average.
	TLV-TWA	ACGIH threshold limit value-time weighted average.
Health and symptoms	The “General” statement summarizes the broad implication of exposure and includes a statement on the potential for odor to act as an indicator for the presence of the molecule (or warning for overexposure). Additional health risks and symptoms are categorized by routes of exposure (skin, eye, ingestion, and inhalation).	
First aid	Categorized by routes of exposure (skin, eye, ingestion, and inhalation).	
Flammability and explosivity	Describes the potential for the substance to be ignited or explode:	
	NFPA ratings for flammability	0 Material will not burn. 1 Material must be preheated before ignition can occur. 2 Material must be moderately heated or exposed to relatively high ambient temperature before ignition can occur. 3 Liquids or solids can be ignited under almost all ambient temperature conditions. 4 Materials will rapidly or completely vaporize at atmospheric pressure and normal ambient temperature, or are readily dispersed in air and will

		burn readily.
	LEL	Lower explosive limit: lowest concentration of a gas or a vapor in air that will burn in presence of an ignition source.
	UEL	Upper explosive limit: highest concentration of a gas or a vapor in air that will burn in presence of an ignition source.
Reactivity and incompatibility	Describe which chemicals will produce an undesirable chemical reaction or degradation when mixed with the title compound.	
Storage and handling	General guidelines for the storage and handling of chemicals along with recommendations for the use of personal protective equipment and clothing have been outlined in Chapter 6. For guidance on the selection and use of ventilators, consult OSHA regulation 29 CFR § 1910.134.	
	Gloves	Latex gloves are typically suitable for use with most chemicals when using prudent practices. Gloves suggested herein are those deemed to be least permeable by the named chemical during incidental chemical contact. Gloves should be selected that are best for the application. See a *glove selection guide* for additional criteria to consider when selecting a glove.
Cleanup and disposal	Additional information on the cleanup and disposal of hazardous waste is given in Chapter 8.	
Additional considerations	A few notations have been made to identify chemicals that can act as suitable replacements for substances with harsh environmental impacts. Additional information on alternative chemicals and synthetic approaches may be found on the EPA Web site. Chemicals that are not appropriate for use with students K-12 or first-year science students at the undergraduate level have been identified based on recommendations compiled by the American Chemical Society's Joint Board–Council Committee on Chemical Safety. Chemicals not appropriate for use with students may be highly explosive or flammable or have extremely unfavorable health implications or posses a significant risk larger than the intended academic benefit.	

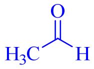
Laboratory Chemical Safety Summaries

LCSSs have been prepared for the following chemicals:

Acetaldehyde
Acetic acid
Acetone
Acetonitrile
Acetylene
Acrolein
Acrylamide
Acrylonitrile
Aluminum trichloride
Ammonia (anhydrous)
Ammonium chloride
Ammonium hydroxide
Ammonium nitrate
Aniline
Arsine
Azide
Benzene
Boron trifluoride
Bromine
tert-Butyl hydroperoxide (and related organic peroxides)
Butyllithiums (and related alkyl lithium reagents)
Carbon disulfide
Carbon monoxide
Carbon tetrachloride
Chlorine
Chloroform
Chloromethyl methyl ether
Chromium trioxide and other chromium(VI) salts
Cyanogen bromide
Diazomethane
Diborane
Dichloromethane
Diethyl ether
Diethylnitrosamine (and related nitrosamines)
Dimethyl sulfate
Dimethyl sulfoxide
Dimethylformamide
Dioxane
Ethanol
Ethidium bromide
Ethyl acetate
Ethylene dibromide
Ethylene oxide
Fluorides (inorganic)
Fluorine
Formaldehyde
Hexamethylphosphoramide
Hexane (and related aliphatic hydrocarbons)
Hydrazine
Hydrobromic acid and hydrogen bromide
Hydrochloric acid and hydrogen chloride
Hydrogen
Hydrogen cyanide
Hydrogen fluoride and hydrofluoric acid
Hydrogen peroxide
Hydrogen sulfide
Iodine
Lead and its inorganic compounds
Lithium aluminum hydride
Mercury
Methanol
Methyl ethyl ketone
Methyl iodide
Nickel carbonyl
Nitric acid
Nitrogen dioxide
Osmium tetroxide
Oxygen
Ozone
Palladium on carbon
Peracetic acid (and related percarboxylic acids)
Perchloric acid (and inorganic perchlorates)
Phenol
Phosgene
Phosphorus
Potassium
Potassium hydride and sodium hydride

Pyridine
Silver and its compounds
Sodium
Sodium azide
Sodium cyanide and potassium cyanide
Sodium hydroxide and potassium hydroxide
Sulfur dioxide
Sulfuric acid
Tetrahydrofuran
Toluene
Toluene diisocyanate
Trifluoroacetic acid
Trimethylaluminum (and related organoaluminum compounds)
Trimethyltin chloride (and other organotin compounds)

ACETALDEHYDE

SYNONYMS	CAS#	Formula
Ethanal, acetic aldehyde, ethyl aldehyde	75-07-0	

PHYSICAL PROPERTIES			
Odor:	Pungent, fruity odor detectable at 0.0068 to 1,000 ppm (mean = 0.067 ppm)	**Appearance:**	Clear, colorless
Water Solubility:	Miscible with water	**Vapor Density:**	1.52 (air = 1.0)
Flash Point:	−27 °C	**Vapor Pressure:**	740 mmHg at 20 °C
Autoignition:	140 °C	**bp/mp:**	21 °C/−124 °C

TOXICITY		EXPOSURE LIMITS	
$\mathbf{LD_{50}}$ oral (rat):	661 mg/kg	**TLV-TWA (ACGIH):**	100 ppm (180 mg/m^3)
$\mathbf{LC_{50}}$ inhal. (rat):	20,550 ppm (37,000 mg/m^3; 30 min)	**STEL (ACGIH):**	150 ppm (270 mg/m^3)
$\mathbf{LC_{50}}$ skin (rabbit):	3,540 mg/kg	**PEL (OSHA) :**	200 ppm (360 mg/m^3)

HEALTH AND SYMPTOMS	
General	Acetaldehyde has caused nasal tumors in rats exposed by inhalation and is listed by IARC in Group 2B (“possible human carcinogen”). It is not classified as a “select carcinogen” according to the criteria of the OSHA Laboratory Standard. Acetaldehyde is mutagenic and has been shown to be a reproductive toxin in animals. Acetaldehyde is a narcotic and a metabolite of ethanol. Chronic exposure to acetaldehyde can produce symptoms similar to alcoholism.
Skin	Causes irritation and burning upon skin contact
Eyes	Severe eye irritant
Ingestion	May cause severe irritation of the digestive tract leading to nausea, vomiting, headache, and liver damage.
Inhalation	Irritating to the respiratory tract and mucous membranes; this substance is a narcotic and can cause central nervous system depression.

FIRST AID	
Skin	Flush with water and remove contaminated clothing.
Eyes	Flush with water for 15 minutes and obtain medical attention immediately.
Ingestion	Obtain medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the individual to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Extremely flammable liquid and vapor

NFPA rating (flammability) = 4; LEL = 4%; UEL 60%

Use carbon dioxide or dry chemical extinguishers. Explosive vapors in air can be ignited by hot surfaces such as hot plates or lightbulbs, or by static electricity discharges. The vapor is heavier than air and may travel a considerable distance to an ignition source and flash back.

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REACTIVITY & INCOMPATIBILITY

Acetaldehyde may undergo oxidation to form explosive peroxides in the presence of air. Polymerizes violently in contact with strong acids or trace metals such as iron. Violently reactive with acid chlorides, anhydrides, amines, hydrogen cyanide, and hydrogen sulfide.

STORAGE & HANDLING

Gloves: Neoprene or butyl rubber

Use only in areas free of ignition sources. Quantities greater than 1L should be stored in tightly sealed metal containers in areas separate from oxidizers. Always store under an inert atmosphere of nitrogen or argon to prevent autoxidation.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources; soak up the acetaldehyde with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Alternatively, acetaldehyde spills may be neutralized with sodium bisulfate solution before cleanup. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess acetaldehyde and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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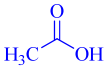
ACETIC ACID, glacial

SYNONYMS	CAS#	Formula
Ethanoic acid, Glacial acetic acid, methanecarboxylic acid	64-19-7	

PHYSICAL PROPERTIES

Odor:	Strong, pungent or sour, vinegar-like odor detectable at 0.2 to 1.0 ppm	**Appearance:**	Colorless, clear
Water Solubility:	100 g/100 mL	**Vapor Density:**	2.1 (air = 1.0)
Flash Point:	39 °C	**Vapor Pressure:**	11 mmHg at 20 °C
Autoignition:	426 °C	**bp/mp:**	118 °C/17 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	3,310 mg/kg	**TLV-TWA (ACGIH):**	10 ppm (25 mg/m^3)
LC_{50} inhal. (mice):	5,620 ppm (1 h)	**STEL (ACGIH):**	15 ppm (37 mg/m^3)
LD_{50} skin (rabbit):	1,060 mg/kg	**PEL (OSHA) :**	10 ppm (25 mg/m^3)

HEALTH AND SYMPTOMS

General	Acetic acid can cause severe burns to the eyes, skin, and digestive and respiratory tracts. The acute toxicity of acetic acid is low. The immediate toxic effects of acetic acid are due to its corrosive action and dehydration of tissues with which it comes in contact. Acetic acid is slightly toxic by inhalation; exposure to 50 ppm is extremely irritating to the eyes, nose, and throat. Acetic acid has not been found to be carcinogenic or to show reproductive or developmental toxicity in humans.
Skin	A 10% aqueous solution of acetic acid produced mild or no irritation on guinea pig skin. At 25 to 50%, generally severe irritation results. Corrosion, blackening, and hyperkeratosis of the skin occur at concentrations ≥80%.
Eyes	Causes immediate pain with 4−10% solution. Causes corrosion and irritation at concentrations ≥80%; may cause irreversible eye damage.
Ingestion	Causes internal irritation, pain, nausea, vomiting, diarrhea, and shock (may also cause a diminished ability to produce urine). Causes severe injury to digestive tract and dental erosion.
Inhalation	Causes corrosion and irritation in mucous membranes and respiratory tract. May cause chronic inflammation of the respiratory tract.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Obtain medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the individual to fresh air and seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

Flammable liquid and vapor

NFPA rating (flammability) = 2; LEL = 4%; UEL = 19.9% @ 93 °C

Use carbon dioxide or dry chemical extinguishers. Heating can release vapors that can be ignited. Vapors or gases may travel considerable distances to ignition source and “flash back.” Acetic acid vapor forms explosive mixtures with air at concentrations of 4 to 16% (by volume).

REACTIVITY & INCOMPATIBILITY

Can decompose to form carbon monoxide, carbon dioxide. Contact with strong oxidizers may cause fire. Reactive with metals, bases, halopolyfluorides, strong acids (nitric acid, oleum), aldehydes, alkyl amines, alkenyl amines, phosphorus trichloride, phosphorus isocyanate.

STORAGE & HANDLING

Gloves: Latex/rubber, neoprene, butyl rubber, Viton, or nitrile.

Use only in areas free of ignition sources. Quantities greater than 1 L should be stored in tightly sealed metal containers in areas separate from oxidizers.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, soak up the acetic acid with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Cleaned-up material is a RCRA hazardous waste. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess acetic acid and waste material containing this substance should be placed in a covered metal container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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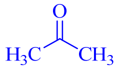
ACETONE

SYNONYMS	CAS#	Formula
2-Propanone, dimethyl ketone, ketone propane	67-64-1	

PHYSICAL PROPERTIES

Odor:	Characteristic mint-like pungent odor detectable at 33 to 700 ppm (mean = 130 ppm)	**Appearance:**	Colorless liquid
Water Solubility:	Miscible with water	**Vapor Density:**	2.0 (air = 1.0)
Flash Point:	−20 °C	**Vapor Pressure:**	180 mmHg at 20 °C
Autoignition:	465 °C	**bp/mp:**	bp 56 °C, mp −96 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	5,340 mg/kg	**TLV-TWA (ACGIH):**	750 ppm
LC_{50} inhal. (rat):	50,100 mg/m^3	**STEL (ACGIH):**	1,000 ppm (2,400 mg/m^3)
LD_{50} skin (rabbit):	20,000 mg/kg	**PEL (OSHA) :**	1,000 ppm (2,400 mg/m^3)

HEALTH AND SYMPTOMS

General	The acute toxicity of acetone is low. Acetone is primarily a central nervous system depressant at high concentrations (greater than 12,000 ppm). Nonacclimated volunteers exposed to 500 ppm acetone experienced eye and nasal irritation, but it has been reported that 1,000 ppm for an 8-hour day produced no effects other than slight transient irritation to eyes, nose, and throat. Therefore, there are good warning properties for those unaccustomed to working with acetone; however, frequent use of acetone seems to cause accommodation to its slight irritating properties. Acetone is practically nontoxic by ingestion. A case of a man swallowing 200 mL of acetone resulted in his becoming stuporous after 1 hour and then comatose; he regained consciousness 12 hours later. Acetone has not been found to be carcinogenic in animal tests or to have effects on reproduction or fertility.
Skin	Slightly irritating to the skin; prolonged contact may cause dermatitis.
Eyes	Liquid acetone produces moderate transient eye irritation.
Ingestion	Practically nontoxic by ingestion.
Inhalation	Large concentration will affect the central nervous system causing nausea, headache, dizziness, unconsciousness, and coma.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing.
Eyes	Immediately flush with copious amounts of water for 15 minutes.
Ingestion	Obtain medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the individual to fresh air and seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating (flammability) = 3; LEL = 2.5%; UEL 12.8%

Use carbon dioxide or dry chemical extinguishers. Heating can release vapors that can be ignited. Vapors or gases may travel considerable distances to ignition source and flash back.

REACTIVITY & INCOMPATIBILITY

Incompatible with strong oxidizing agents (e.g., chromium trioxide) and very strong bases (e.g., potassium *tert*-butoxide).

STORAGE & HANDLING

Gloves: Latex/rubber or butyl rubber

Use only in areas free of ignition sources. Quantities greater than 1 L should be stored in tightly sealed metal containers in areas separate from oxidizers.

CLEANUP & DISPOSAL

In case of accidental spill, remove all ignition sources, soak up the acetone with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess acetone and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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ACETONITRILE

SYNONYMS	CAS#	Formula
Methyl cyanide, cyanomethane, ethyl nitrile	75-05-8	$H_3C-\!\equiv N$

PHYSICAL PROPERTIES

Odor:	Aromatic ether-like odor detectable at 40 ppm	**Appearance:**	Colorless liquid
Water Solubility:	Miscible with water (>100 g/100 mL)	**Vapor Density:**	1.42 (air = 1.0)
Flash Point:	2 °C	**Vapor Pressure:**	73 mmHg at 20 °C
Autoignition:	524 °C	**bp/mp:**	bp 82 °C, mp −45 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	2,730 mg/kg	**TLV-TWA (ACGIH):**	40 ppm (70 mg/m^3)
LC_{50} inhal. (rat):	7,551 ppm (8 h)	**STEL (ACGIH):**	60 ppm (105 mg/m^3)
LD_{50} skin (rabbit):	1,250 mg/kg	**PEL (OSHA) :**	40 ppm (70 mg/m^3)

HEALTH AND SYMPTOMS

General	Acetonitrile is slightly toxic by acute exposure through oral intake, skin contact, and inhalation. However, acetonitrile can be converted by the body to cyanide. Symptoms of exposure include weakness, flushing, headache, difficult and/or rapid breathing, nausea, vomiting, diarrhea, blue-gray discoloration of the skin and lips (due to a lack of oxygen), stupor, and loss of consciousness. Prolonged contact with acetonitrile can lead to absorption through the skin and more intense irritation. Acetonitrile is regarded as having adequate warning properties. Acetonitrile is not mutagenic in bacterial and animal cells and has not been found to be a carcinogen in humans. Single high-dose exposure in animals during pregnancy produced birth defects possibly due to the liberation of cyanide. Multiple oral doses during pregnancy did not produce birth defects. Repeated exposure in animals produced adverse lung effects.
Skin	Slightly irritating to the skin.
Eyes	Severely irritating to the eyes.
Ingestion	Slightly toxic by acute exposure through oral intake.
Inhalation	Slightly toxic by acute exposure through inhalation.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing.
Eyes	Immediately flush with copious amounts of water for 15 minutes.
Ingestion	Obtain medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the individual to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor
NFPA rating (flammability) = 3; LEL = 3%; UEL = 16%
Hazardous gases produced in a fire include hydrogen cyanide, carbon monoxide, carbon dioxide, and oxides of nitrogen. Vapors or gases may travel considerable distances to ignition source and “flash back.” Use carbon dioxide or dry chemical extinguishers.

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REACTIVITY & INCOMPATIBILITY

Contact with strong oxidizers can result in violent reactions. Acetonitrile hydrolyzes on exposure to strong acids and bases. Incompatible with reducing agents and alkali metals and may attack plastics, rubber, and some coatings.

STORAGE & HANDLING

Gloves: Nitrile, butyl rubber, or polyvinyl

Use only in areas free of ignition sources. Quantities greater than 1 L should be stored in tightly sealed metal containers in areas separate from oxidizers.

CLEANUP & DISPOSAL

In case of accidental spill, remove all ignition sources, soak up the acetonitrile with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Evacuation and cleanup using respiratory and skin protection may be necessary in the event of a large spill or release in a confined area. Excess acetonitrile and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Acetonitrile is not suitable for use with students.

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ACETYLENE

SYNONYMS	CAS#	Formula
Ethyne; welding gas, ethine	74-86-2	

PHYSICAL PROPERTIES

Odor:	Odorless, although garliclike or "gassy" odor often detectable because of trace impurities.	**Appearance:**	Colorless gas
Water Solubility:	Slightly soluble in water (0.106g/100 mL, 2%)	**Vapor Density:**	0.91 (air = 1.0)
Flash Point:	−18 °C	**Vapor Pressure:**	3.04 × 104 mmHg (~40 atm) at 16.8 °C
Autoignition:	305 °C	**bp/mp:**	bp −84 °C (sublimes), mp −81 °C

TOXICITY		EXPOSURE LIMITS	
LC_{50} inhal., (rat):	Simple asphyxiant (>500,000 ppm)	**TLV-TWA (ACGIH)**	simple asphyxiant
		NIOSH REL	2,500 ppm (2,662 mg/m^3)

HEALTH AND SYMPTOMS

General	Acetylene is relatively nontoxic and has been used as an anesthetic.
Skin	Frostbite
Eyes	Frostbite
Ingestion	NA
Inhalation	Inhalation of acetylene can be hazardous because of its action as a simple asphyxiant. Concentrations of about 10% in air cause slight intoxication, and levels of 20% in air may produce headaches and labored breathing. At higher concentrations (33% and above), acetylene acts as a narcotic, causing unconsciousness in 7 minutes or less, with rapid and full recovery normally seen on removal from exposure of less than several hours. Concentrations of acetylene above 50% in air can cause death by asphyxiation within 5 minutes. Commercially available acetylene may contain highly toxic impurities, including phosphine, arsine, and hydrogen sulfide; the presence of these impurities must be considered in setting acceptable exposure levels to acetylene. For example, the concentration of acetylene containing 95 ppm of phosphine impurity (which has a TLV of 0.3 ppm) should not exceed 3,160 ppm to stay within the TLV for phosphine. There is no evidence that acetylene is a human carcinogen or reproductive toxin.

FIRST AID

Skin	Wash skin and remove clothing if wet. Seek medical attention immediately.
Eyes	Flush eyes immediately with large amounts of water, lifting lower and upper lids occasionally. Seek medical attention immediately.
Ingestion	NA
Inhalation	Move to fresh air.

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FLAMMABILITY & EXPLOSIVITY

Extremely flammable gas

NFPA rating (flammability) = 4; LEL = 2.5%; UEL 100%

Use carbon dioxide or dry chemical extinguishers. Firefighting is greatly facilitated by shutting off the gas supply. The dry acetylides are sensitive, powerful explosives.

REACTIVITY & INCOMPATIBILITY

Forms highly unstable acetylides with many metals, including copper, brass, mercury, potassium, silver, and gold. Acetylene may react violently with oxygen and halogens (fluorine, chlorine, bromine, iodine). Forms explosive compounds on contact with nitric acid.

STORAGE & HANDLING

Gloves: See manufacturer recommendation and select a glove suitable for the application.

Use only in well-ventilated areas free of ignition sources. Never bring in contact with brass or copper tubing, valves, or fittings. Pass through concentrated H_2SO_4 and NaOH (do not use activated carbon) to purify.

CLEANUP & DISPOSAL

In case of leak, shut down and remove all ignition sources and ventilate the area at once to prevent flammable mixtures from forming. Carefully remove cylinders with slow leaks to remote outdoor locations. Limit access to an affected area. Respiratory protection may be necessary in the event of a large release or a leak in a confined area. Excess acetylene should be returned to the vendor for disposal; disposal should not be attempted in the laboratory. Excess acetylene should be vented from reaction flasks, tubing, etc., rather than scrubbed with strong base to avoid the formation of acetylides.

ADDITIONAL CONSIDERATIONS

None

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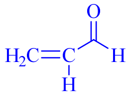
ACROLEIN

SYNONYMS	CAS#	Formula
Acrylaldehyde, acrylic aldehyde, 2-propenal, propenal, allyl aldehyde, acraldehyde	107-02-8	

PHYSICAL PROPERTIES

Odor:	Pungent, lacrimatory, intensely irritating odor detectable at 0.02 to 0.4 ppm	**Appearance:**	Colorless to yellow liquid
Water Solubility:	Highly soluble in water (21 g/100 mL)	**Vapor Density:**	1.9 (air = 1.0)
Flash Point:	−26 °C	**Vapor Pressure:**	210 mmHg at 20 °C
Autoignition:	234 °C	**bp/mp:**	bp 53 °C, mp −87 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	42 to 46 mg/kg	**TLV-TWA (ACGIH):**	0.1 ppm (0.23 mg/m^3)
LC_{50} inhal. (rat):	300 mg/m^3(30 min)	**STEL (ACGIH):**	0.3 ppm (0.69 mg/m^3)
LD_{50} skin (rabbit):	562 mg/kg	**PEL (OSHA) :**	0.1 ppm (0.25 mg/m^3)

HEALTH AND SYMPTOMS

General	Acrolein is a highly toxic and corrosive substance. This substance is regarded as having adequate warning properties. Acrolein is mutagenic in bacteria but did not cause increased tumor incidence in animals exposed chronically by injection or inhalation. Administration to pregnant rats caused malformations and lethality to embryos. Chronic exposure to as little as 0.21 ppm acrolein caused inflammatory changes in lungs, liver, kidneys, and brains of experimental animals.
Skin	Skin contact can cause severe redness, swelling, burns with blistering, and corrosion. Acrolein can be absorbed through the skin, leading to systemic effects including delayed pulmonary edema. Acrolein has been reported to be a weak skin sensitizer in some individuals.
Eyes	This substance is a powerful lacrimator, and eye contact with acrolein liquid or vapor can cause severe burns.
Ingestion	Ingestion of acrolein can cause gastrointestinal distress, pulmonary congestion, and edema.
Inhalation	Inhalation of acrolein can cause moderate to severe eye, nose, and respiratory system irritation after a few minutes of exposure to concentrations as low as 0.25 ppm. Higher concentrations can cause immediate and/or delayed lung injury including pulmonary edema and respiratory insufficiency; fatal reactions have occurred upon exposure to as little as 10 ppm.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing.
Eyes	Immediately flush with copious amounts of water for 15 minutes. Get medical attention immediately.
Ingestion	Obtain medical attention immediately.

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Inhalation Move the person to fresh air and seek medical attention at once, because immediate or delayed respiratory injury may result.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating (flammability) = 3; LEL = 2.8%; UEL 31%

Carbon dioxide or dry chemical extinguishers should be used to fight fires. Vapors or gases may travel considerable distances to ignition source and flash back.

REACTIVITY & INCOMPATIBILITY

Can polymerize violently upon exposure to heat (temperatures above 50 ° C), light, or various chemical initiators such as amines, bases, and acids. Commercial acrolein contains an inhibitor such as hydroquinone; samples from which the inhibitor has been removed (e.g., by distillation) are extremely hazardous. Incompatible with amines, oxidizers, acids, and bases.

STORAGE & HANDLING

Gloves: Butyl rubber

Must be used only in the hood. Use only in areas free of ignition sources. Containers of acrolein should be stored in secondary containers in areas separate from amines, oxidizers, acids, and bases.

CLEANUP & DISPOSAL

Excess acrolein and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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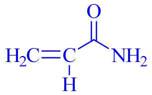
ACRYLAMIDE

SYNONYMS	CAS#	Formula
acrylamide monomer, acrylic amide, propenamide, 2-propenamide	79-06-1	 $H_2C=CH-C(=O)NH_2$

PHYSICAL PROPERTIES

Odor:	Odorless solid	**Appearance:**	Colorless crystals
Water Solubility:	Soluble in water (216 g/100 mL)	**Vapor Density:**	2.45 (air = 1.0)
Flash Point:	280 °C	**Vapor Pressure:**	0.007 mmHg
Autoignition:	240 °C	**bp/mp:**	125 °C (25 mmHg)/85 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	124 mg/kg	**TLV-TWA (ACGIH):**	0.03 mg/m^3—skin
LD_{50} skin (rat):	400 mg/kg	**PEL (OSHA):**	0.3 mg/m^3—skin

HEALTH AND SYMPTOMS

General	The acute toxicity of acrylamide is moderate by ingestion or skin contact. The chronic toxicity of acrylamide is high. Repeated exposure to ~2 mg/kg per day may result in neurotoxic effects, including unsteadiness, muscle weakness, and numbness in the feet (leading to paralysis of the legs), numbness in the hands, slurred speech, vertigo, and fatigue. Exposure to slightly higher repeated doses in animal studies has induced multisite cancers and reproductive effects, including abortion, reduced fertility, and mutagenicity. Acrylamide is listed in IARC Group 2B (“possible human carcinogen”) and is classified as a “select carcinogen” under the criteria of the OSHA Laboratory Standard.
Skin	Redness and peeling of the skin of the palms
Eyes	Aqueous acrylamide solutions cause eye irritation; exposure to a 50% solution of acrylamide caused slight corneal injury and slight conjunctival irritation, which healed in 8 days.
Ingestion	Acute toxicity is moderate. May produce fatigue, memory difficulties, and dizziness.
Inhalation	May produce fatigue, memory difficulties, and dizziness.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing.
Eyes	Immediately flush with copious amounts of water for 15 minutes.
Ingestion	Obtain medical attention immediately.
Inhalation	If the individual is overcome by fumes, move him or her to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 1; LEL = NA; UEL = NA

Does not pose a significant flammability hazard. Carbon dioxide or dry chemical extinguishers should be used to fight fires.

REACTIVITY & INCOMPATIBILITY

May polymerize violently on strong heating or exposure to strong base. Acrylamide may react violently with strong oxidizers.

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STORAGE & HANDLING

Gloves: Butyl rubber or Viton

This substance should be handled only when wearing appropriate impermeable gloves to prevent skin contact. All operations that have the potential of producing acrylamide dusts or aerosols of solutions should be conducted in a fume hood to prevent exposure by inhalation.

CLEANUP & DISPOSAL

In case of accidental spill, mix acrylamide with an absorbent material (avoid raising dust), place in an appropriate container, and dispose of properly. Evacuation and cleanup using respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess acrylamide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Because of its neurotoxic effects, acrylamide is not suitable for use by students.

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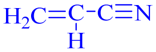
ACRYLONITRILE

SYNONYMS	CAS#	Formula
Vinyl cyanide, 2-propenenitrile, cyanoethylene, ACN	107-13-1	 $H_2C{=}\underset{H}{C}{-}C{\equiv}N$

PHYSICAL PROPERTIES

Odor:	Mild pyridine-like odor at 2 to 22 ppm	**Appearance:**	Colorless liquid
Water Solubility:	Moderately soluble in water (7.3 g/100 mL)	**Vapor Density:**	1.83 (air = 1.0)
Flash Point:	−5 °C	**Vapor Pressure:**	86.25 mmHg at 20 °C
Autoignition:	481 °C	**bp/mp:**	77 °C/−82 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	78 mg/kg	**TLV-TWA (ACGIH)**	2 ppm—skin
LC_{50} inhal. (rat):	333 ppm (4 h)	**STEL (ACGIH)**	NA
LC_{50} skin (rabbit):	63 mg/kg	**PEL (OSHA)**	2 ppm

HEALTH AND SYMPTOMS

General	Acrylonitrile is classified as moderately toxic by acute exposure through oral intake, skin contact, and inhalation. Symptoms of exposure include weakness, lightheadedness, diarrhea, nausea, and vomiting. Acrylonitrile is mutagenic in bacterial and mammalian cell cultures and embryotoxic/teratogenic in rats at levels that produce maternal toxicity. Acrylonitrile is carcinogenic in rats and is regulated by OSHA as a carcinogen (29 CFR § 1910.1045). Acrylonitrile is listed in IARC Group 2A (“probable human carcinogen”) and is classified as a “select carcinogen” under the criteria of the OSHA Laboratory Standard.
Skin	Causes irritation and may produce allergic reaction. Prolonged contact with the skin can lead to burns.
Eyes	Causes severe irritation, redness, and pain. Lachrymator. Can cause corneal injury.
Ingestion	May be fatal if swallowed. Abdominal pain, vomiting.
Inhalation	May be fatal if inhaled. Irritant to the respiratory tract. Can cause nausea, headache, dizziness, unconsciousness and coma.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Obtain medical attention immediately.
Inhalation	If the individual is overcome by fumes, move him or her to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating (flammability) = 3; LEL = 3%; UEL 17%

Vapor forms explosive mixtures with air at concentrations of 3 to 17% (by volume). Hazardous

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gases produced in fire include hydrogen cyanide, carbon monoxide, and oxides of nitrogen. Carbon dioxide or dry chemical extinguishers should be used to fight fires.

REACTIVITY & INCOMPATIBILITY

Violent reaction may occur on exposure to strong acids and bases, amines, strong oxidants, copper, and halogens. Violent polymerization can be initiated by heat, light, strong bases, peroxides, and azo compounds. Decomposes to form hydrogen cyanide, nitrogen oxides, carbon monoxide, carbon dioxide.

STORAGE & HANDLING

Gloves: Viton or PVA (480-minute limit of use)

Wash hands thoroughly after use. Work with acrylonitrile should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Acrylonitrile should be used only in areas free of ignition sources. Containers of acrylonitrile should be stored in secondary containers in the dark in areas separate from oxidizers and bases.

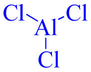
CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, soak up the acrylonitrile with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Evacuation and cleanup using respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess acrylonitrile and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Because this molecule has been identified as a carcinogen, it is not suitable for use by students.

ALUMINUM TRICHLORIDE

SYNONYMS	CAS#	Formula
Aluminum chloride, trichloroaluminium	7446-70-0	

PHYSICAL PROPERTIES

Odor:	Hydrogen chloride odor detectable when exposed to moist air	**Appearance:**	White crystalline solid
Water Solubility:	70 g/100 mL at 15 °C; reacts violently with water	**Vapor Pressure:**	1 mmHg at 100 °C
Flash Point:	NA	**bp/mp:**	Sublimes at 181 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	3,730 mg/kg	**TLV-TWA (ACGIH):**	2 mg(Al)/m^3
LC_{50} skin (rabbit):	>2 g/kg	**STEL (ACGIH):**	2 mg/m^3

HEALTH AND SYMPTOMS

General	Aluminum chloride is strongly irritating and highly corrosive to the skin, eyes, and mucous membranes owing to its reaction with water to form hydrochloric acid. In some animal tests, aluminum chloride has shown developmental and reproductive toxicity. Aluminum chloride has not been found to be carcinogenic in humans.
Skin	Can cause severe burns. May cause allergic skin reactions.
Eyes	Can cause severe burns.
Ingestion	Slightly toxic, can cause severe burns to the mouth and digestive tract until hydrolyzed in the stomach.
Inhalation	May be fatal if inhaled. Inhalation of aluminum trichloride dust, vapor, or its hydrolysis products can result in severe damage to the tissues of the respiratory tract and can lead to shortness of breath, wheezing, coughing, and headache. Large amounts and long-term exposure may lead to respiratory tract spasms, lung damage, and pulmonary edema and can be fatal.

FIRST AID

Skin	Immediately flush with water. Remove contaminated clothing and wash before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Wash the mouth with water and seek immediate medical attention.
Inhalation	If the individual is overcome by fumes, move him or her to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Carbon dioxide or dry chemical extinguishers should be used to fight fires. Toxic fumes (HCl and reaction products) can be released during fires.

REACTIVITY & INCOMPATIBILITY

Reacts violently with water (90 g/100 mL) to produce hydrochloric acid and with nitrobenzene upon heating. Reacts violently or explosively with ethylene oxide, organic azides, organic perchlorates, and sodium borohydride. Highly corrosive to most metals.

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STORAGE & HANDLING

Gloves: PVC

Work with this substance should be conducted in a fume hood, and impermeable gloves should be worn at all times when handling. Store in a sealed container under an inert atmosphere in a cool, dry place. Care should be taken in opening containers of this compound because of the possibility of the buildup of HCl vapor from hydrolysis with traces of moisture.

CLEANUP & DISPOSAL

Vacuum or sweep up (avoid raising dust) and collect in a bag. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Small spills and excess amounts may be collected and carefully hydrolyzed with a large excess of cold water, neutralized with base, and filtered. The insoluble solids should be placed in an appropriate container. The neutral aqueous solution should be flushed down a drain with plenty of water.

ADDITIONAL CONSIDERATIONS

Aluminum trichloride reacts violent with water and is not suitable for use by students.

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AMMONIA (ANHYDROUS)

SYNONYMS		**CAS#**	**Formula**
Anhydrous ammonia, aqua ammonia, aqueous ammonia		7664-41-7	NH_3
PHYSICAL PROPERTIES			
Odor:	Intense pungent (detectable at 17 ppm)	**Appearance:**	Colorless gas
Water Solubility:	Highly soluble (89.9 g/100 mL at 0 °C)	**Vapor Density:**	0.59 (air = 1.0)
Flash Point:	NA	**Vapor Pressure:**	8.5 atm
Autoignition:	690 °C	**bp/mp:**	−33 °C/−78 °C
TOXICITY		**EXPOSURE LIMITS**	
LD_{50} oral (rat):	350 mg/kg	**TLV-TWA (ACGIH):**	25 ppm (17 mg/m^3)
LC_{50} inhal. (rat):	2,000 ppm (4 h)	**STEL (ACGIH):**	35 ppm (27 mg/m^3)
LC_{50} skin (rat):	112,000 mg/m^3 (15 M)	**OSHA PEL:**	50 ppm (35 mg/m^3)

HEALTH AND SYMPTOMS	
General	Ammonia gas is extremely corrosive and irritating to the skin, eyes, nose, and respiratory tract. Ammonia gas is regarded as having adequate warning properties. Ammonia has not been found to be carcinogenic or to show reproductive or developmental toxicity in humans. Chronic exposure to ammonia can cause respiratory irritation and damage.
Skin	Ammonia vapor, mists, and liquid can cause severe irritation and burns; contact with the liquid results in cryogenic burns as well.
Eyes	Eye contact with ammonia vapor is severely irritating, and exposure of the eyes to liquid ammonia or mists can result in serious damage, which may result in permanent eye injury and blindness. Lacrimation and irritation begin at 130 to 200 ppm, and exposure at 3,000 ppm is intolerable. Can cause permanent eye injury and blindness.
Ingestion	May be fatal if swallowed. Can cause tissue burns resulting in severe abdominal pain, nausea, vomiting, and collapse.
Inhalation	May be fatal if inhaled. Causes irritation of the nose, throat, and mucous membranes. Exposure to high concentrations (above approximately 2,500 ppm) is life threatening, causing severe damage to the respiratory tract, resulting in bronchitis, chemical pneumonitis, and pulmonary edema, which can be fatal.
FIRST AID	
Skin	Immediately flush with water and remove contaminated clothing. Wash clothing prior to reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Obtain medical attention immediately.
Inhalation	If the individual is overcome by fumes, move them to fresh air and seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 1; LEL = 15%; UEL 28%

Forms explosive mixtures with air in the range 16 to 25%.

REACTIVITY & INCOMPATIBILITY

Can react with compounds of silver, gold, and mercury to produce unstable and highly explosive products.

Do not use a mercury manometer for measuring ammonia gas pressure. Highly explosive nitrogen halides can form in reactions of ammonia with halogens, hypohalites, and similar compounds. Violent reactions can occur with oxidizing agents such as chromium trioxide, hydrogen peroxide, nitric acid, sodium and potassium nitrate, chlorite, chlorate, and bromated salts. Dissolution of ammonia in water is accompanied by heat evolution.

STORAGE & HANDLING

Gloves: Butyl rubber or nitrile

All work should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Cylinders of ammonia should be stored in locations appropriate for compressed gas storage and separated from incompatible compounds such as acids, halogens, and oxidizers. Only steel valves and fittings should be used on ammonia containers; copper, silver, and zinc should not be permitted to come into contact with ammonia.

CLEANUP & DISPOSAL

Respiratory protection may be necessary in the event of a large release. In the event of a gaseous ammonia leak, shut down all ignition sources and ventilate the area at once to prevent flammable mixtures from forming. Limit access to an affected area. Cylinders with slow leaks can be placed in a fume hood or remote outdoor location. Cylinders containing excess ammonia should be returned to the manufacturer. In a fume hood, ammonia gas may be dissolved in water and neutralized with a nonoxidizing strong acid such as HCl. When ammonia gas is directed into water, precautions should be taken to prevent the suckback of water into the ammonia-containing vessel or cylinder. In some localities, the neutralized aqueous ammonia may be disposed of down the drain. If drain disposal or neutralization is not permitted, the aqueous ammonia should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Because of its corrosive properties, ammonia is not suitable for use by students.

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AMMONIUM HYDROXIDE

SYNONYMS	CAS#	Formula
Aqua ammonia, ammonia	1336-21-6	NH_3 in H_2O

PHYSICAL PROPERTIES

Odor:	Strong pungent ammonia odor detectable at 17 ppm	**Appearance:**	Colorless liquid
Water Solubility:	Concentrated ammonium hydroxide is a 29% solution of NH_3 in H_2O.	**Vapor Density:**	0.59 for anhydrous NH_3 (air = 1.0)
Flash Point:	NA	**Vapor Pressure:**	115 mmHg at 20 °C for 29% solution
Autoignition:	651 °C (for ammonia)	**bp/mp:**	unstable above 27.8 °C/−69 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	350 mg/kg	**NIOSH REL:**	NA
		TLV-TWA (ACGIH)	25 ppm (17 mg/m^3)
		STEL (ACGIH)	35 ppm (27 mg/m^3)
		OSHA PEL:	35 ppm (27 mg/m^3)

HEALTH AND SYMPTOMS

General	Ammonia solutions are extremely corrosive and irritating to the skin, eyes, and mucous membranes. Ammonium hydroxide has not been found to be carcinogenic or to show reproductive or developmental toxicity in humans. Chronic exposure to ammonia can cause respiratory irritation and damage.
Skin	Can result in severe irritation, and contact with the liquid results in cryogenic burns as well.
Eyes	Severely irritating. May result in serious and/or permanent eye injury and blindness.
Ingestion	Can cause burns of the mouth, throat, and gastrointestinal tract and can lead to severe abdominal pain, nausea, vomiting, and collapse.
Inhalation	May be fatal if inhaled. Can cause irritation of the nose, throat, and mucous membranes. High concentration (above 2,500 ppm) can cause severe damage to the respiratory tract and result in bronchitis, chemical pneumonitis, and pulmonary edema.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Clothing should be washed prior to reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Obtain medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 1; LEL = NA; UEL NA

Ammonia forms explosive mixtures with air in the range 16 to 25%. Water, carbon dioxide, or dry chemical extinguishers should be used for fires.

REACTIVITY & INCOMPATIBILITY

Highly explosive nitrogen halides will form in reactions with halogens, hypohalites, and similar compounds. Reaction with certain gold, mercury, and silver compounds may form explosive products. Violent reactions can occur with oxidizing agents such as chromium trioxide, hydrogen peroxide, nitric acid, chlorite, chlorate, and bromated salts. Exothermic and violent reactions may occur if concentrated ammonium hydroxide solution is mixed with strong acids, acidic metal and nonmetal halides, and oxyhalides.

STORAGE & HANDLING

Gloves: Butyl rubber, neoprene, latex/rubber, nitrile

All work with this substance should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Containers should be tightly sealed to prevent escape of vapor and should be stored in a cool area separate from halogens, acids, and oxidizers. Containers stored in warm locations may build up dangerous internal pressures of ammonia gas.

CLEANUP & DISPOSAL

In the event of a spill, soak up ammonium hydroxide with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Alternatively, flood the spill with water to dilute the ammonia before cleanup. Boric, citric, and similar powdered acids are good granular neutralizing spill cleanup materials. Respiratory protection may be necessary in the event of a large spill or release in a confined area. In some localities, ammonium hydroxide may be disposed of down the drain after appropriate neutralization and dilution (see disposal for ammonia).

ADDITIONAL CONSIDERATIONS

None

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AMMONIUM CHLORIDE

SYNONYMS	CAS#	Formula
Ammonium chloratum, ammonium chloridum, ammonium muriate, sal ammoniac, salmiac	12125-02-9	NH_4Cl

PHYSICAL PROPERTIES

Odor:	Odorless	**Appearance:**	Colorless or white powder
Water Solubility:	37 g/mL	**Vapor Density:**	NA
Flash Point:	NA	**Vapor Pressure:**	1 mmHg (161 °C)
Autoignition:	NA	**bp/mp:**	520 °C (sublimes)/338 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	1,650 mg/kg	**NIOSH REL:**	10 mg/m^3 TWA
		STEL (ACGIH)	20 mg/m^3 (fume)

HEALTH AND SYMPTOMS

General	Irritating to eyes, skin, and respiratory system. Can cause cough, dyspnea (breathing difficulty), and pulmonary sensitization.
Skin	Can cause irritation. May cause redness.
Eyes	Can cause irritation. May cause redness and pain.
Ingestion	Can cause irritation to the digestive tract. May cause systemic toxicity with acidosis.
Inhalation	Can cause irritation to respiratory tract and asthma-like allergy.

FIRST AID

Skin	Immediately flush with water for at least 15 minutes and remove contaminated clothing. Wash clothing prior to reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Obtain medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Water, carbon dioxide, or dry chemical extinguishers should be used for fires.

REACTIVITY & INCOMPATIBILITY

Incompatible with alkalis (and their carbonates), lead salts, silver salts, strong oxidizers, ammonium nitrate, potassium chlorate, bromine trifluoride. Corrodes most metals at high temperatures.

STORAGE & HANDLING

Gloves: Butyl rubber, neoprene, latex/rubber, nitrile

All work with this substance should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Containers should be tightly sealed to prevent escape of vapor and should be stored in a cool area separate from incompatible material.

CLEANUP & DISPOSAL

Vacuum or sweep up material and place into a suitable disposal container. Avoid generating dusty conditions. Provide ventilation.

ADDITIONAL CONSIDERATIONS

None

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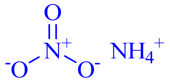
AMMONIUM NITRATE

SYNONYMS	CAS#	Formula
Ammonium saltpeter; nitric acid, ammonium salt	6484-52-2	

PHYSICAL PROPERTIES

Odor:	odorless	**Appearance:**	White, gray, or brown solid
Water Solubility:	190 g/100 mL at 20 °C	**Vapor Density:**	negligible
Flash Point:	>93.3 °C	**Vapor Pressure:**	NA
Autoignition:	300 °C	**bp/mp:**	NA/169 °C

TOXICITY		EXPOSURE LIMITS
LD_{50} oral (rat):	2,217 mg/kg	

HEALTH AND SYMPTOMS

General	Aniline is a moderate skin irritant, a moderate to severe eye irritant, and a skin sensitizer in animals. Aniline is moderately toxic via inhalation and ingestion. Symptoms of exposure (which may be delayed up to 4 hours) include headache, weakness, dizziness, nausea, difficulty breathing, and unconsciousness. Exposure to aniline results in the formation of methemoglobin and can thus interfere with the ability of the blood to transport oxygen. Effects from exposure at levels near the lethal dose include hypoactivity, tremors, convulsions, liver and kidney effects, and cyanosis. Aniline has not been found to be a carcinogen or reproductive toxin in humans. Some tests in rats demonstrate carcinogenic activity. However, other tests in which mice, guinea pigs, and rabbits were treated by various routes of administration gave negative results. Aniline produced developmental toxicity only at maternally toxic dose levels but did not have a selective toxicity for the fetus. It produces genetic damage in animals and in mammalian cell cultures but not in bacterial cell cultures.
Skin	See General.
Eyes	See General.
Ingestion	Can cause irritation to the gastrointestinal tract. Can cause methemoglobinemia characterized by dizziness, drowsiness, headache, shortness of breath, cyanosis, increase in heart rate, and browning of the blood.
Inhalation	May cause death if inhaled. Can cause irritation to the respiratory tract. Can cause methemoglobinemia, convulsions, tachycardia, dyspnea (labored breathing), and systemic acidosis.

FIRST AID

Skin	Immediately flush with water for at least 15 minutes and remove contaminated clothing. Wash clothing prior to reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Obtain medical attention immediately. If conscious, the individual can be given 2–4 cups of milk or water.
Inhalation	Move the person to fresh air and seek medical attention at once. If breathing becomes difficult or stops, oxygen or artificial breathing device should be used.

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FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Water, carbon dioxide, or dry chemical extinguishers should be used for fires.

REACTIVITY & INCOMPATIBILITY

Strong oxidizer and hydroscopic. Incompatible with strong reducing agents, strong acids, finely powdered metals, organic matter, chlorides, combustible materials, phosphorus, and urea. Should be considered explosive if contaminated with oil, charcoal, or other organic materials. There is a risk of explosion if heated under confinement. Decomposes to form oxides of nitrogen.

STORAGE & HANDLING

Gloves: Butyl rubber, neoprene, latex/rubber, nitrile, Viton and PVC

Wash hands thoroughly after use. Stable at room temperature in closed containers under normal storage and handling conditions. Keep away from heat, sources of ignition, and combustible material. Avoid generating dust and contamination with incompatible material. Do not heat in a confined space. Store in a tightly sealed container in a cool, dry, well-ventilated explosion-proof area separate from incompatible material.

CLEANUP & DISPOSAL

Collect the spill immediately by vacuuming or sweeping up material and placing into a suitable disposal container. Keep material damp and avoid generating dusty conditions. Provide ventilation and keep combustibles away from spilled material.

ADDITIONAL CONSIDERATIONS

Ammonium nitrate is explosive and not suitable for use by students. Chloride salts can be used in place of this substance.

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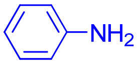
ANILINE

SYNONYMS	CAS#	Formula
Phenylamine, aminobenzene, benzenamine	62-53-3	

PHYSICAL PROPERTIES

Odor:	Sweet, amine-like odor detectable at 0.6 to 10 ppm	**Appearance:**	Colorless, oily liquid; darkens to brown on exposure to air and light
Water Solubility:	3.5 g/100 mL at 20 °C	**Vapor Density:**	3.2 (air = 1.0)
Flash Point:	70 °C	**Vapor Pressure:**	0.7 mmHg at 20 °C
Autoignition:	615 °C	**bp/mp:**	184 °C/−6 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	250 mg/kg	**TLV-TWA (ACGIH)**	2 ppm (7.6 mg/m^3)—skin
LC_{50} inhal. (rat):	478 ppm	**OSHA PEL:**	5 ppm (19 mg/m^3)—skin
LC_{50} skin (rabbit):	820 mg/kg		

HEALTH AND SYMPTOMS

General Aniline is a moderate skin irritant, a moderate to severe eye irritant, and a skin sensitizer in animals. Aniline is moderately toxic via inhalation and ingestion. Symptoms of exposure (which may be delayed up to 4 hours) include headache, weakness, dizziness, nausea, difficulty breathing, and unconsciousness. Exposure to aniline results in the formation of methemoglobin and can thus interfere with the ability of the blood to transport oxygen. Effects from exposure at levels near the lethal dose include hypoactivity, tremors, convulsions, liver and kidney effects, and cyanosis. Aniline has not been found to be a carcinogen or reproductive toxin in humans. Some tests in rats demonstrate carcinogenic activity. However, other tests in which mice, guinea pigs, and rabbits were treated by various routes of administration gave negative results. Aniline produced developmental toxicity only at maternally toxic dose levels but did not have a selective toxicity for the fetus. It produces genetic damage in animals and in mammalian cell cultures but not in bacterial cell cultures.

Skin Readily absorbs through the skin. Causes moderate irritation and could produce allegic reactions.

Eyes Lachrymator. Causes severe irritation, blurred vision, and photophobia. May cause chemical conjunctivitis and corneal damage.

Ingestion Can be fatal if ingested. Moderately toxic.

Inhalation Moderately toxic.

FIRST AID

Skin Immediately flush with water and remove contaminated clothing. Wash clothing prior to reuse.

Eyes Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.

Ingestion Obtain medical attention immediately.

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Inhalation Move the person to fresh air and seek medical attention at once. If breathing becomes difficult or stops, oxygen or artificial breathing device should be used.

FLAMMABILITY & EXPLOSIVITY

Combustible liquid

NFPA rating (flammability) = 2; LEL = 1.3%; UEL = 11%

Carbon dioxide or dry chemical extinguishers should be used to fight aniline fires.

REACTIVITY & INCOMPATIBILITY

Smoke from a fire involving aniline may contain toxic nitrogen oxides and aniline vapor. Aniline vapors given off at high temperatures form explosive mixtures in air. Reacts violently with strong oxidizing agents, including nitric acid, peroxides, and ozone. Incompatible with acids, aluminum, dibenzoyl peroxide, oxidizers, and plastics.

STORAGE & HANDLING

Gloves: Neoprene and butyl rubber

Only use in areas free of ignition sources. Quantities greater than 1 L should be stored in tightly sealed metal containers in areas separate from oxidizers.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, soak up the aniline with a spill pillow or absorbent material, place in a covered metal container, label clearly, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess aniline and waste material containing this substance should be placed in a covered metal container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Aniline is poisonous and not suitable for use by students.

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ARSINE

SYNONYMS	CAS#	Formula
Arsenic hydride, arsenic trihydride, hydrogen arsenide, aresenous hydride	7784-42-1	AsH_3

PHYSICAL PROPERTIES

Odor:	Garliclike odor detectable at 0.5 to 1 ppm	**Appearance:**	Colorless gas
Water Solubility:	0.07 g/100 mL at 20 °C	**Vapor Density:**	2.7 (air = 1.0)
Flash Point:	<−62 °C	**Vapor Pressure:**	>760 mmHg at 20 °C
Autoignition:	Not established	**bp/mp:**	−62 °C/−117 °C

TOXICITY		EXPOSURE LIMITS	
LC_{50} inhal. (rat)	50 ppm (4 H)	**TLV-TWA (ACGIH)**	0.05 ppm (0.16 mg/m^3)
		OSHA PEL:	0.05 ppm (0.2 mg/m^3)

HEALTH AND SYMPTOMS

General The acute toxicity of arsine by inhalation is extremely high and this substance does not have suitable warning properties to avoid overexposure. Symptoms may be delayed for several hours, particularly if very low concentrations have been inhaled. Symptoms of exposure to arsine may include headache, malaise, weakness, dizziness, breathing difficulty, abdominal pain, nausea, vomiting, jaundice, dark red (bloody) urine followed by absence of urination, pulmonary edema, and coma. In cases where the amount of inhaled arsine is insufficient to produce acute effects, or where small quantities are inhaled over prolonged periods, destruction of red blood cells will occur. The only symptoms noted may be general tiredness, pallor, breathlessness on exertion, and palpitations as would be expected with severe secondary anemia. The carcinogenicity of arsine in humans has not been established; however, arsenic and certain inorganic arsenic compounds are recognized human carcinogens.

Skin Liquefied gas can cause frostbite.

Eyes Liquefied gas can cause frostbite.

Ingestion Ingestion is unlikely.

Inhalation Inhalation can cause death. Acute toxicity is extremely high and can cause the breakdown of red blood cells and hemoglobin, impairment of kidney function, damage to the liver and heart, electroencephalogram abnormality, hemolytic anemia, and death due to kidney or heart failure. *Note that the established exposure limit is 0.05 ppm, but the amount necessary to detect the molecule by odor is 0.5 ppm.*

FIRST AID

Skin Immediately move to an uncontaminated area and flush with water and remove contaminated clothing. Dispose of clothing as waste.

Eyes Immediately move to an uncontaminated area and wash eyes with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.

Ingestion Do not induce vomiting.

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Inhalation Move the person to fresh air and immediately seek emergency medical attention. If breathing becomes difficult or stops, oxygen or artificial breathing device should be used. Keep victim warm, quiet, and calm.

FLAMMABILITY & EXPLOSIVITY

Extremely flammable liquid and vapor

NFPA rating (flammability) = 4; LEL = 4.5%; UEL = 78%

Combustion products (arsenic trioxide and water) are less toxic than arsine itself. In the event of an arsine fire, stop the flow of gas if possible without risk of harmful exposure and let the fire burn itself out.

REACTIVITY & INCOMPATIBILITY

Arsine is a strong reducing agent and reacts violently with oxidizing agents such as fluorine, chlorine, nitric acid, and nitrogen trichloride.

STORAGE & HANDLING

Gloves: Viton and nylon

Cylinders of arsine should be stored and used in a continuously ventilated gas cabinet or fume hood. Local fire codes should be reviewed for limitations on quantity and storage requirements. Carbon steel, stainless steel, Monel, and Hastelloy C are preferred materials for handling arsine; brass and aluminum should be avoided. Kel-F and Teflon are preferred gasket materials; Viton and nylon are acceptable.

CLEANUP & DISPOSAL

Emergency response and rescue procedures should be in place before beginning work with arsine. Local rescue assistance may be needed and should be prearranged. In the event of a release of arsine, the area should be evacuated immediately. If responding to the release, use appropriate protective equipment and clothing. Positive pressure air-supplied respiratory protection is required. Close cylinder valve and ventilate area. Remove cylinder to a fume hood or remote area if it cannot be shut off.

ADDITIONAL CONSIDERATIONS

Arsine is poisonous and not suitable for use by students.

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AZIDE

SYNONYMS	CAS#	Formula
Sodium azide, azium, sodium salt of hydrazoic acid	26628-22-8	$Na^+ \; {}^-N=N^+=N^-$

PHYSICAL PROPERTIES

Odor:	Odorless	**Appearance:**	Colorless or white solid
Water Solubility:	42 g/100 mL (17.2 °C)	**Vapor Density:**	2.2
Flash Point:	NA	**Vapor Pressure:**	NA
Autoignition:	NA	**bp/mp:**	decomposes/275 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	27 mg/kg	**TLV-TWA (ACGIH)**	0.29 mg/m^3
LC_{50} inhal. (rat)	37 mg/m^3		
LD_{50} skin (rat):	50 mg/kg		

HEALTH AND SYMPTOMS

General	May be fatal by all routs of exposure.
Skin	May be fatal if absorbed through the skin.
Eyes	Can cause irritation. May cause systemic toxicity.
Ingestion	May be fatal if ingested. May cause irritation of the digestive tract, low blood pressure, rapid heartbeat, skin discoloration, and possible coma.
Inhalation	May be fatal if inhaled. May cause severe irritation of the respiratory tract with sore throat, coughing, shortness of breath, and delayed lung edema.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing prior to reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Only allow medical professionals to induce vomiting.
Inhalation	Do not use mouth-to-mouth resuscitation. Move the person to fresh air and seek medical attention at once. If breathing becomes difficult or stops, oxygen or artificial breathing device should be used.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Combustible solid if heated above 300 °C

REACTIVITY & INCOMPATIBILITY

Incompatible with acids, metals, and water. Sodium azide reacts slowly with copper, lead, brass, or solder in plumbing systems to form an accumulation of the highly explosive compounds of lead azide and copper azide. The vapor of hydrazoic acid may be present where sodium azide is handled.

STORAGE & HANDLING

All work should be conducted in a fume hood. Avoid producing dust. Store in a tightly sealed container in a cool, dry, well-ventilated explosion-proof area separate from incompatible material.

CLEANUP & DISPOSAL

Vacuum or sweep up (being careful not to create dust) and place in the appropriate container. Excess and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

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ADDITIONAL CONSIDERATIONS

Azide is explosive and not suitable for use by students.

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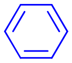
BENZENE

SYNONYMS	CAS#	Formula
Benzol, phenyl hydride	71-43-2	

PHYSICAL PROPERTIES

Odor:	“Paint-thinner-like” odor detectable at 12 ppm	**Appearance:**	Colorless liquid
Water Solubility:	0.18 g/100 mL	**Vapor Density:**	2.7 (air = 1.0)
Flash Point:	−11.1 °C	**Vapor Pressure:**	75 mmHg at 20 °C
Autoignition:	498 °C	**bp/mp:**	80.1 °C/ 5.5 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	930 mg/kg	**TLV-TWA (ACGIH)**	10 ppm (32 mg/m^3)
LC_{50} inhal. (rat)	10,000 ppm (7 h)	**STEL (ACGIH)**	5 ppm (16 mg/m^3)
		OSHA PEL:	1 ppm (3.2 mg/m^3)

HEALTH AND SYMPTOMS

General	May cause death if inhaled, ingested, or absorbed through the skin or mucous membranes**.** Chronic exposure to benzene affects the blood and blood-forming organs such as the bone marrow, causing irreversible injury; blood disorders including anemia and leukemia may result. In addition, chronic exposure may cause fatigue, nervousness, irritability, blurred vision, and labored breathing. Benzene is regulated by OSHA as a carcinogen (Standard 29 CFR § 1910.1028) and is listed in IARC Group 1 (“carcinogenic to humans”). The acute toxicity of benzene is low.
Skin	Causes moderate irritation. Readily penetrates the skin with effects similar to that produced by inhalation and ingestion.
Eyes	Causes severe irritation.
Ingestion	Moderate effects resemble that of inhalation exposure. Severe exposure may lead to collapse, unconsciousness, coma, respiratory failure, and chemical pneumonitis.
Inhalation	Can cause dizziness, euphoria, giddiness, headache, nausea, drowsiness, and weakness.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air and seek medical attention at once. If breathing becomes difficult or stops, oxygen or artificial breathing device should be used.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor
NFPA rating (flammability) = 3; LEL = 1.2%; UEL = 7.1%

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Vapors may travel a considerable distance to a source of ignition and flash back. Vapor–air mixtures are explosive above the flash point. Carbon dioxide and dry chemical extinguishers should be used to fight benzene fires.

REACTIVITY & INCOMPATIBILITY

Fire and explosion hazard with strong oxidizers such as oxygen and halogens (in the presence of catalysts such as iron) and with strong acids.

STORAGE & HANDLING

Gloves: Butyl rubber, latex/rubber, Viton

Work with benzene should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Store in a tightly sealed container in a cool, dry, well-ventilated explosion-proof area separate from incompatible material.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources; soak up the benzene with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection should be employed during spill cleanup. Excess benzene and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Benzene is a known carcinogen and not suitable for use by students. Toluene can be used in place of benzene.

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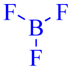
BORON TRIFLUORIDE

SYNONYMS	CAS#	Formula
Boron fluoride, trifluoroborane	7637-07-2	

PHYSICAL PROPERTIES

Odor:	Pungent odor detectable at 1.5 ppm	**Appearance:**	Colorless gas, fumes in moist air
Water Solubility:	106 g/100 mL in cold water	**Vapor Density:**	2.4 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	>1 mmHg at 20 °C
Autoignition:	Not established	**bp/mp:**	−100 °C/−127 °C

TOXICITY		EXPOSURE LIMITS	
LC_{50} inhal. (rat):	387 ppm (1,070 mg/m^3; 1 h)	**TLV-TWA (ACGIH):**	1 ppm (3 mg/m^3; ceiling)
		STEL (ACGIH):	1 ppm (3 mg/m^3; ceiling)
		OSHA PEL:	1 ppm (3 mg/m^3; ceiling)

HEALTH AND SYMPTOMS

General	Boron trifluoride (and organic complexes such as BF_3-etherate) are extremely corrosive substances that are destructive to all tissues of the body. Upon contact with moisture in the skin and other tissues, these compounds react to form hydrofluoric acid and fluoroboric acid, which cause severe burns. This compound is not considered to have adequate warning properties. Boron trifluoride has not been found to be carcinogenic or to show reproductive or developmental toxicity in humans. Chronic exposure to boron trifluoride gas can cause respiratory irritation and damage.
Skin	Extremely irritating.
Eyes	Causes extreme irritation, severe burns, and blindness.
Ingestion	Ingestion of gas is unlikely.
Inhalation	May cause death if inhaled. Causes severe irritation and burning of the respiratory tract, difficulty breathing, and possibly respiratory failure.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Ingestion of gas is unlikely. Get medical attention if needed.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA Rating (flammability) = 0; LEL = NA; UEL = NA

Water should not be used to extinguish any fire in which boron trifluoride is present. Dry chemical powder should be used for fires involving organic complexes of boron trifluoride.

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REACTIVITY & INCOMPATIBILITY

Incompatible with alkali and alkaline metals and calcium oxide. It may react exothermically with alkyl nitrates, ethylene oxide, and butadiene. Reacts violently with water to form highly toxic hydrogen fluoride, boric acid, and fluoboric acid.

STORAGE & HANDLING

Gloves: PVC

All work should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn to prevent eye and skin contact. Cylinders of boron trifluoride should be stored in locations appropriate for compressed gas storage and separated from alkali metals, alkaline earth metals, and other incompatible substances. Solutions of boron trifluoride should be stored in tightly sealed containers under an inert atmosphere in secondary containers.

CLEANUP & DISPOSAL

In the event of accidental release, evacuate the area. Leaking cylinder should be removed to a fume hood or open area if possible to do so safely. Positive-pressure air-supplied respiratory protection and protective clothing may be necessary to deal with a leaking cylinder, and emergency response personnel should be notified. Cylinders containing excess boron trifluoride should be returned to the manufacturer. Solutions of boron trifluoride should be labeled and disposed of according to your organization's disposal guidelines.

ADDITIONAL CONSIDERATIONS

Boron trifluoride reacts violently and is not suitable for use by students.

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BROMINE

SYNONYMS		CAS#	Formula
		7726-95-6	Br_2

PHYSICAL PROPERTIES

Odor:	Odor detected at concentrations as low as 0.05 ppm	**Appearance:**	Dark red-brown liquid
Water Solubility:	3.5 g/100 mL	**Vapor Density:**	5.5 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	175 mmHg at 20 °C
Autoignition:		**bp/mp:**	59 °C/−7 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	1,700 mg/kg	**NIOSH REL:**	TWA 0.1 ppm (0.7 mg/m^3) ST 0.3 ppm (2 mg/m^3)
LC_{50} inhal. (rat):	2,700 mg/m^3	**TLV-TWA (ACGIH):**	0.1 ppm (0.7 mg/m^3)
		STEL (ACGIH):	0.3 ppm (2 mg/m^3)
		OSHA PEL:	0.1 ppm

HEALTH AND SYMPTOMS

General	Highly corrosive to skin and eyes; moderately toxic via inhalation. Highly irritating at 50 ppm and a short exposure (minutes) to 1,000 ppm would likely be fatal for humans.
Skin	Corrosive to the skin, causing irritation and destruction with blister formation. If bromine is not removed from the skin immediately, deep-seated ulcers develop, which heal slowly.
Eyes	Exposure to concentrations below 1 ppm causes lacrimation. Severely painful and destructive eye burns may result from contact with either liquid or concentrated vapors of bromine.
Ingestion	Corrosive to the mucous membranes. It is highly unlikely that ingestion will occur.
Inhalation	Vapor exposures can cause irritation and damage to the upper and lower respiratory tract (nose, throat, and lungs) to varying degrees depending on the concentration. If exposure is sufficiently high, it will cause pulmonary edema, which could lead to death. Other reported symptoms of overexposure include coughing, tightness of chest, nosebleed, headache, and dizziness, followed after some hours by abdominal pain, diarrhea, and a measles-like rash on the trunk and extremities. Animal studies on the chronic toxicity of bromine revealed disturbances in the respiratory, nervous, and endocrine systems after exposure to 0.2 ppm for 4 months; similar exposure to 0.02 ppm did not produce any adverse effects.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Contaminated clothing should be disposed of as waste. Seek medical attention.
Eyes	Immediately flush with copious amounts of water and obtain medical attention.
Ingestion	*Do not attempt to induce vomiting.* Give the person large amounts of milk or water to dilute the bromine and obtain medical attention immediately.
Inhalation	If the individual is overcome by fumes, move him or her to fresh air and seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Accelerates the burning of combustible material.

REACTIVITY & INCOMPATIBILITY

Incompatible with acetaldehyde, alcohols, alkalis, amines, combustible materials, ethylene, fluorine, hydrogen, ketones, metals, and sulfur. Bromine reacts violently with easily oxidized substances, including many organic compounds and a number of metals. Explosions have been reported to occur, for example, on addition of bromine to methanol, acetaldehyde, and dimethylformamide. Fires and/or explosions may result from the reactions of bromine with hydrogen, acetylene, ammonia, aluminum, mercury, sodium, potassium, and phosphorus.

STORAGE & HANDLING

Gloves: Viton and PVC

Work in a fume hood to prevent exposure by inhalation. Use of a respirator may be recommended, which would require additional training. See NIOSH website for recommendations of appropriate respirator type for given concentrations. Gloves and splash goggles should be worn at all times when handling bromine. Containers of bromine should be stored at room temperature in a secondary container separately from readily oxidizable compounds and combustible substances.

CLEANUP & DISPOSAL

Treat small spills of bromine with sodium thiosulfate and inert absorbent, place in an appropriate container, and dispose of properly. Large spills may require evacuation of the area and cleanup using full protective equipment. Excess bromine and waste should be placed in the appropriate container, clearly labeled, and disposed of properly.

ADDITIONAL CONSIDERATIONS

Bromine is corrosive and not suitable for use by students.

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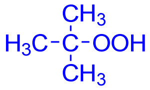
tert-BUTYL HYDROPEROXIDE (and related organic peroxides)

SYNONYMS	CAS#	Formula
TBHP, 2-hydroperoxy-2-methylpropane	75-91-2	 $H_3C{-}\overset{CH_3}{\underset{CH_3}{C}}{-}OOH$

PHYSICAL PROPERTIES

Odor:	Pungent odor	**Appearance:**	Colorless liquid
Water Solubility:	Miscible in water	**Vapor Density:**	3.1
Flash Point:	27 to 54 °C	**Vapor Pressure:**	62 mmHg at 45 °C
Autoignition:	204 °C; self-accelerating decomp. at 88 to 93 °C	**bp/mp:**	96 °C/−3 °C

TOXICITY		EXPOSURE LIMITS
LD_{50} oral (rat):	406 mg/kg	
LC_{50} inhal. (rat):	500 ppm (4 h)	
LC_{50} skin (rat):	460 mg/kg	

HEALTH AND SYMPTOMS

General	*tert*-Butyl hydroperoxide has not been found to be carcinogenic or to show reproductive or developmental toxicity in humans.
Skin	Can cause severe irritation. Symptoms include redness, pain, and blisters
Eyes	Can cause severe irritation. Symptoms include redness and pain.
Ingestion	Moderately toxic.
Inhalation	Moderately toxic

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Washing clothing prior to reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Obtain medical attention immediately.
Inhalation	Obtain medical attention immediately.

FLAMMABILITY & EXPLOSIVITY

Flammable liquid and vapor

NFPA rating (flammability) = 2; LEL = NA; UEL NA

Pure TBHP is shock sensitive and may explode on heating. Carbon dioxide or dry chemical extinguishers should be used for fires involving *tert*-butyl hydroperoxide.

REACTIVITY & INCOMPATIBILITY

Highly reactive oxidizing agent; sensitive to heat and shock. *tert*-butyl hydroperoxide and concentrated aqueous solutions of TBHP react violently with traces of acid and the salts of certain metals, including, in particular, manganese, iron, and cobalt.

Mixing anhydrous *tert*-butyl hydroperoxide with organic and readily oxidized substances can cause ignition and explosion. TBHP can initiate polymerization of certain olefins.

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STORAGE & HANDLING

Gloves: Neoprene, butyl rubber, latex/rubber, nitrile

Store in the dark at room temperature (do not refrigerate) separately from oxidizable compounds, flammable substances, and acids. Reactions involving this substance should be carried out behind a safety shield.

CLEANUP & DISPOSAL

Cleanup of anhydrous *tert*-butyl hydroperoxide and concentrated solutions requires special precautions and should be carried out by trained personnel working from behind a body shield. In the event of a spill, remove all ignition sources, soak up the *tert*-butyl hydroperoxide with a spill pillow or noncombustible absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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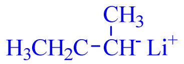
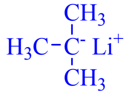
BUTYLLITHIUMS (and related alkyl lithium reagents)

SUBSTANCES	CAS#	Formula
n-Butyllithium	109-72-8	$CH_3CH_2CH_2CH_2^-\ Li^+$
sec-Butyllithium (1-methylpropyllithium)	598-30-1	 $H_3CH_2C-\overset{CH_3}{CH^-}\ Li^+$
tert-Butyllithium (1,1-dimethylethyllithium)	594-19-4	 $H_3C-\underset{CH_3}{\overset{CH_3}{C^-}}\ Li^+$

Usually supplied and handled as solutions in ether or hydrocarbon solvents

PHYSICAL PROPERTIES

Odor:	Odor of the solvent	**Appearance:**	Clear solution
Water Solubility:	NA	**Vapor Density:**	NA
Flash Point:	*sec*-Butyllithium = 20 °C *tert*-Butyllithium = −30 °C	**Vapor Pressure:**	NA
Autoignition:	*sec*-Butyllithium = 518 °C *tert*-Butyllithium = 285 °C	**bp/mp:**	NA

TOXICITY

LD$_{50}$ oral (rat):	364 mg/m^3/4H (*tert*-butyllithium)
LC$_{50}$ inhal. (rat):	>2,000 mg/kg (*tert*-butyllithium)

EXPOSURE LIMITS

HEALTH AND SYMPTOMS

General	There is little toxicity data available for the butyllithiums; for data on ether and hydrocarbon solvents, see the appropriate LCSSs. Solutions of the butyllithiums are corrosive to the skin, eyes, and mucous membranes.
Skin	See General.
Eyes	See General.
Ingestion	See General.
Inhalation	See General.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing prior to reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Obtain medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Extremely flammable and explosive; may ignite spontaneously on exposure to air.

NFPA rating (flammability) = NA; LEL = 1.4%; UEL = 8.3% for *tert*-butyllithium

The risk of fire or explosion depends on the identity of the organolithium compound, the nature of the solvent, the concentration of the solution, and the humidity. Dilute solutions (1.6 M, 15% or less) of *n*-butyllithium in hydrocarbon solvents are highly flammable, but have a low degree of pyrophoricity (do not spontaneously ignite). Under normal laboratory conditions (25 °C, relative

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humidity of 70% or less), solutions of ~20% concentration will usually not ignite spontaneously on exposure to air. More concentrated solutions of *n*-butyllithium (50 to 80%) are most dangerous and will immediately ignite on exposure to air.

REACTIVITY & INCOMPATIBILITY

Highly reactive; may ignite spontaneously on exposure to air.

Violent explosions occur on contact with water (solvent and butane will ignite). Reaction with water generates highly corrosive lithium alkoxides and lithium hydroxide. The butyllithiums ignite on contact with oxygen, carbon dioxide, and halogenated hydrocarbons. Incompatible with acids, halogenated hydrocarbons, alcohols, and many other classes of organic compounds.

STORAGE & HANDLING

Store and handle under an inert atmosphere in areas free of ignition sources. Work should be conducted in a fume hood under an inert gas such as nitrogen or argon. Safety glasses, impermeable gloves, and a fire-retardant laboratory coat are required.

CLEANUP & DISPOSAL

For spills, remove all ignition sources, and allow the butyllithium to react with atmospheric moisture. Treat the residue with water, soak up with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess can be destroyed by dilution with hydrocarbon solvent to a concentration of approximately 5 wt %, followed by gradual addition to water with vigorous stirring under an inert atmosphere. Alternatively, the butyllithium solution can be slowly poured (transfer by cannula for *sec*- or *tert*-butyllithium) into a plastic tub or other container of powdered dry ice. The residues from the above procedures and excess butyllithium should be placed in an appropriate container, clearly labeled, and disposed of accordingly

ADDITIONAL CONSIDERATIONS

None

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CARBON DISULFIDE

SYNONYMS	CAS#	Formula
	75-15-0	$S=C=S$

PHYSICAL PROPERTIES			
Odor:	Cabbagelike odor detectable at 0.016 to 0.42 ppm (mean = 0.2 ppm)	**Appearance:**	Colorless liquid
Water Solubility:	0.22 g/100 mL	**Vapor Density:**	2.6 (air = 1.0)
Flash Point:	−30 °C	**Vapor Pressure:**	297 mmHg at 20 °C
Autoignition:	90 °C	**bp/mp:**	46 °C/−111 °C

TOXICITY		EXPOSURE LIMITS	
LD$_{50}$ oral (rat):	1,200 mg/kg	**TLV-TWA (ACGIH):**	10 ppm (31 mg/m^3)—skin
LC$_{50}$ inhal. (rat):	25,000 mg/m^3 (2 h)	**STEL (ACGIH):**	12 ppm (36 mg/m^3)—skin
		OSHA PEL:	4 ppm (12 mg/m^3)

HEALTH AND SYMPTOMS	
General	Carbon disulfide is only slightly toxic to laboratory animals by inhalation or ingestion, but its toxicity is relatively greater in humans. Exposure to 5,000 ppm of carbon disulfide for 15 minutes can be fatal to humans. By all routes of exposure, carbon disulfide affects the central nervous system as indicated by headache, dizziness, fatigue, muscle weakness, numbness, nervousness, or psychological disturbances. Chronic overexposure to carbon disulfide causes increased atherosclerosis, leading to risk of cardiovascular disease. Prolonged exposure of female workers to low concentrations of carbon disulfide has been associated with birth defects in offspring; exposure limit values provide little margin of safety for risk of developmental effects. Carbon disulfide is regarded as a substance with good warning properties. Chronic exposure to relatively high concentrations of carbon disulfide may cause the central nervous system effects described above. In addition, chronic overexposure to carbon disulfide causes increased atherosclerosis, leading to risk of cardiovascular disease. Prolonged exposure of female workers to low concentrations of carbon disulfide has been associated with birth defects in offspring; exposure limit values provide little margin of safety for risk of developmental effects. Carbon disulfide has not been found to be a carcinogen in humans.
Skin	Toxic effects if absorbed through skin. Can cause rash or skin irritation.
Eyes	May cause irritation.
Ingestion	See General.
Inhalation	See General.

FIRST AID	
Skin	Immediately flush with water and remove contaminated clothing. Wash clothing prior to reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Obtain medical attention immediately.

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Inhalation Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating (flammability) = 3; LEL = 1.3%; UEL = 50%

Rust (iron oxide) may increase the likelihood of ignition by hot surfaces. Vapor is heavier than air and can travel a considerable distance to a source of ignition and flash back. The vapor forms explosive mixtures in air. Carbon disulfide fires should be extinguished with carbon dioxide or dry chemical extinguishers.

REACTIVITY & INCOMPATIBILITY

May react explosively with alkali metals. Reacts violently with metal azides.

STORAGE & HANDLING

Gloves: PVA, Viton

Use only in areas free of ignition sources (including hot plates, incandescent lightbulbs, and steam baths). Store in tightly sealed metal containers in areas separate from oxidizers.

CLEANUP & DISPOSAL

In the event of a spill, take care to remove all ignition sources, soak up the carbon disulfide with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly, taking appropriate precautions because of the extreme flammability of the liquid and vapor. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess carbon disulfide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Carbon disulfide is extremely flammable and not suitable for use by students.

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CARBON MONOXIDE

SYNONYMS	CAS#	Formula
Carbonic oxide, monoxide	630-08-0	$^{+}O\equiv C^{-}$

PHYSICAL PROPERTIES

Odor:	Odorless gas	**Appearance:**	Colorless gas
Water Solubility:	0.004 g/100 mL at 20 °C	**Vapor Density:**	0.97 (air = 1.0)
Flash Point:	<−191 °C	**Vapor Pressure:**	>760 mmHg at 20 °C
Autoignition:	609 °C	**bp/mp:**	−191.5 °C/−205 °C

TOXICITY		**EXPOSURE LIMITS**	
LC_{50} inhal. (rat):	1,807 ppm (2,065 mg/m^3; 4 h)	**TLV-TWA (ACGIH):**	25 ppm (29 mg/m^3)
LC_{LO} inhal. (man):	4,000 ppm (4,570 mg/m^3; 30 min)	**OSHA PEL:**	50 ppm (55 mg/m^3)

HEALTH AND SYMPTOMS

General	Exposure to CO may be fatal. CO can decrease the ability of the blood to carry oxygen to the tissues. Since CO is odorless, colorless, and tasteless, it has no warning properties, and overexposure can readily occur. The acute toxicity of carbon monoxide by inhalation is moderate. Carbon monoxide is a chemical asphyxiant that exerts its effects by combining preferentially with hemoglobin, the oxygen-transport pigment of the blood, thereby excluding oxygen. Symptoms of exposure to CO at 500 to 1,000 ppm include headache, palpitations, dizziness, weakness, confusion, and nausea. Loss of consciousness and death may result from exposure to concentrations of 4,000 ppm and higher; high concentrations may be rapidly fatal without producing significant warning symptoms. Exposure to this gas may aggravate heart and artery disease and may cause chest pain in individuals with preexisting heart disease. Pregnant women are more susceptible to the effects of carbon monoxide exposure. Carbon monoxide has not been found to be carcinogenic in humans. This substance has shown developmental toxicity in animal tests. Chronic exposures to carbon monoxide at levels around 50 ppm are thought by some investigators to have a negative impact on the results of behavioral tests such as time discrimination, visual vigilance, choice response tests, visual evoked responses, and visual discrimination thresholds.
Skin	If absorbed through the skin, symptoms will be similar to those of inhalation.
Eyes	May be absorbed through the eyes and other mucous membranes. Symptoms similar to that of inhalation.
Ingestion	Unlikely that ingestion of a gas will occur.
Inhalation	Moderate acute toxicity, chemical asphyxiant.

FIRST AID

Skin	Move to an area that is not contaminated. Seek immediate medical attention.
Eyes	Move to an area that is not contaminated. Seek immediate medical attention.
Ingestion	Move to an area that is not contaminated. Seek immediate medical attention.
Inhalation	Rescue of an affected individual requires appropriate respiratory protection. Remove exposed individual to an uncontaminated area and seek immediate emergency help. Keep victim warm, quiet, and at rest and provide assisted respiration if breathing has stopped.

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FLAMMABILITY & EXPLOSIVITY

Extremely flammable liquid and vapor

NFPA Rating = 4; LEL = 12.5%; UEL = 74%.

Carbon monoxide is a flammable gas that forms explosive mixtures with air.

REACTIVITY & INCOMPATIBILITY

Carbon monoxide is a reducing agent; it reacts violently with strong oxidizers. Reacts violently with many interhalogen compounds such as ClF_3, BrF_3, and BrF_5. Reacts with metals to form metal carbonyls, which may explode on heating, and reduces many metal oxides exothermically. Reacts with sodium and with potassium to form explosive products that are sensitive to shock, heat, and contact with water.

STORAGE & HANDLING

Gloves: Neoprene, butyl rubber, nitrile, PVC, Viton

Cylinders of carbon monoxide should be stored and used in a continuously ventilated gas cabinet or fume hood. Local fire codes should be reviewed for limitations on quantity and storage requirements.

CLEANUP & DISPOSAL

In the event of a release of carbon monoxide, evacuate the area immediately. To respond to a release, use appropriate protective equipment and clothing. Positive-pressure air-supplied respiratory protection is required. Close cylinder valve and ventilate area. Remove cylinder to a fume hood or remote area if it cannot be shut off. Excess carbon monoxide should be returned to the manufacturer, according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Carbon monoxide is toxic and not suitable for use by students.

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CARBON TETRACHLORIDE

SYNONYMS	CAS#	Formula
Carbon tet, Tetrachloromethane	56-23-5	

PHYSICAL PROPERTIES

Odor:	Ethereal, sweet, pungent odor detectable at 140 to 584 ppm (mean = 252 ppm)	**Appearance:**	Colorless liquid
Water Solubility:	0.05 g/100 mL	**Vapor Density:**	5.3 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	91 mmHg at 20 °C
Autoignition:	>982 °C	**bp/mp:**	77 °C/−23 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	2,350 mg/kg	**TLV-TWA (ACGIH):**	5 ppm (32.5 mg/m^3)—skin
LC_{50} inhal. (rat):	8,000 ppm (4 h)	**STEL (ACGIH):**	10 ppm (65 mg/m^3)
LD_{50} skin (rabbit):	>20 g/kg	**OSHA PEL:**	2 ppm (13 mg/m^3)

HEALTH AND SYMPTOMS

General	The acute toxicity of carbon tetrachloride is low to moderate. It is harmful to the liver, kidneys, and central nervous system. The odor of carbon tetrachloride does not provide adequate warning of the presence of harmful concentrations. Carbon tetrachloride shows carcinogenic effects in animal studies and is listed by IARC in Group 2B (“possible human carcinogen”). It is not classified as a “select carcinogen” according to the criteria of the OSHA Laboratory Standard. Prolonged or repeated exposure to this substance may result in liver and kidney damage. There is some evidence from animal studies that carbon tetrachloride may be a developmental and reproductive toxin in both males and females.
Skin	Can cause irritation, and prolonged contact may cause dryness and cracking. Can be slowly absorbed through the skin.
Eyes	Can cause irritation.
Ingestion	Swallowing 4 mL can be fatal in humans. Effects similar to that of inhalation.
Inhalation	Exposure to 1,000 to 2,000 ppm for 30 to 60 minutes can be fatal to humans. Can produce symptoms such as dizziness, headache, fatigue, nausea, vomiting, stupor, and diarrhea.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Obtain medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Carbon tetrachloride is noncombustible. Exposure to fire or high temperatures may lead to formation of phosgene, a highly toxic gas.

REACTIVITY & INCOMPATIBILITY

Carbon tetrachloride may react explosively with reactive metals such as the alkali metals, aluminum, magnesium, and zinc. Can react violently with boron and silicon hydrides, and upon heating with dimethylformamide.

STORAGE & HANDLING

All work should be handled in a fume hood to avoid the inhalation of dust, and impermeable gloves should be worn at all times to prevent skin contact.

CLEANUP & DISPOSAL

In the event of a spill, soak up carbon tetrachloride with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess carbon tetrachloride and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Carbon tetrachloride is a carcinogen and not suitable for use by students. Ethyl acetate, acetone, or ethanol are suitable replacements for halogenated solvents in most applications.

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CHLORINE

SYNONYMS	CAS#	Formula
	7782-50-5	Cl_2

PHYSICAL PROPERTIES			
Odor:	Highly pungent, bleach-like odor detectable at 0.02 to 3.4 ppm (mean = 0.08 ppm)	**Appearance:**	Greenish colored gas or amber liquid
Water Solubility:	0.7 g/100 mL	**Vapor Density:**	2.4 (air = 1.0)
Flash Point:	NA	**Vapor Pressure:**	5,170 mmHg at 20 °C
Autoignition:	NA	**bp/mp:**	−34.1 °C/−101 °C

TOXICITY		EXPOSURE LIMITS	
LC_{50} inhal. (rat):	293 ppm (879 mg/m^3; 1 h)	**TLV-TWA (ACGIH):**	0.5 ppm (1.5 mg/m^3)
		STEL (ACGIH):	1 ppm (2.9 mg/m^3)
		OSHA PEL:	1.0 ppm (3 mg/m^3)

HEALTH AND SYMPTOMS	
General	**Exposure to chlorine can be fatal.** Highly irritating and corrosive to the eyes, skin, respiratory tract, and mucous membranes; reacts violently with readily oxidized substances. Severe irritant of the eyes, skin, and mucous membranes. May cause coughing, choking, nausea, vomiting, headache, dizziness, difficulty breathing, and delayed pulmonary edema. Chlorine can be detected by its odor below the permissible limit; however, because of olfactory fatigue, odor may not always provide adequate warning of the presence of harmful concentrations of this substance. Chronic exposures in animals up to 2.5 ppm for 2 years caused effects only in the upper respiratory tract, primarily the nose. Higher concentrations or repeated exposure have caused corrosion of the teeth. There is no evidence for carcinogenicity or reproductive or developmental toxicity of chlorine in humans.
Skin	Causes severe irritation. Liquid chlorine can cause severe burns.
Eyes	Exposure to 3 to 8 ppm causes stinging and burning of the eyes, and contact with liquid chlorine or high concentrations of the vapor can cause severe burns.
Ingestion	Ingestion of a gas is unlikely.
Inhalation	Exposure to ~500 ppm for 30 minutes may be fatal, and 1,000 ppm can be lethal after a few breaths.

FIRST AID	
Skin	Immediately flush with water and remove contaminated clothing. Contaminated clothing should be disposed of as waste.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention at once.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL NA

Chlorine is noncombustible but is a strong oxidizer and will support combustion of most flammable substances.

REACTIVITY & INCOMPATIBILITY

Extremely reactive. Chlorine reacts violently or explosively with a wide range of substances, including hydrogen, acetylene, many hydrocarbons in the presence of light, ammonia, reactive metals, and metal hydrides and related compounds, including diborane, silane, and phosphine.

STORAGE & HANDLING

Gloves: Viton or butyl rubber

All work should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Cylinders of chlorine should be stored in locations appropriate for compressed gas storage and separated from incompatible compounds such as hydrogen, acetylene, ammonia, and flammable materials.

CLEANUP & DISPOSAL

In case of accidental release of chlorine gas, such as from a leaking cylinder or associated apparatus, evacuate the area and eliminate the source of the leak if this can be done safely. Full-face supplied-air respiratory protection and protective clothing may be required to deal with a chlorine release. Cylinders with slow leaks should be carefully removed to a fume hood or remote outdoor locations. Chlorine leaks may be detected by passing a rag dampened with aqueous ammonia over the suspected valve or fitting. White fumes indicate escaping chlorine gas. Excess chlorine in cylinders should be returned to the manufacturer for disposal.

ADDITIONAL CONSIDERATIONS

Chlorine gas is extremely corrosive and not suitable for use by students.

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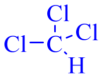
CHLOROFORM

SYNONYMS	CAS#	Formula
Trichloromethane	67-66-3	 $CHCl_3$

PHYSICAL PROPERTIES

Odor:	Ethereal, sweet odor detectable at 133 to 276 ppm (mean = 192 ppm)	**Appearance:**	Colorless liquid
Water Solubility:	0.8 g/100 mL	**Vapor Density:**	4.1 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	160 mmHg at 20 °C
Autoignition:	NA	**bp/mp:**	61 °C/−63.5 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	908 mg/kg	**TLV-TWA (ACGIH):**	10 ppm (48 mg/m^3)
LC_{50} inhal. (rat):	9,937 ppm (47,702 mg/m^3; 4 h)	**OSHA PEL:**	50 ppm (240 mg/m^3; ceiling)
LD_{50} skin (rabbit)	>20 g/kg		

HEALTH AND SYMPTOMS

General	Exposure to 25,000 ppm for 5 minutes can be fatal to humans. The acute toxicity of chloroform is low by all routes of exposure. Olfactory fatigue occurs on exposure to chloroform vapor, and it is not regarded as a substance with adequate warning properties. Chloroform shows carcinogenic effects in animal studies and is listed by IARC in Group 2B (“possible human carcinogen”). It is not classified as a “select carcinogen “according to the criteria of the OSHA Laboratory Standard. There is some evidence from animal studies that chloroform is a developmental and reproductive toxin.
Skin	Can cause irritation. May cause redness, pain, and dry skin.
Eyes	Can cause irritation. Liquid splashed in the eyes causes burning pain, reversible corneal injury.
Ingestion	Causes severe burning of the mouth and throat, chest pain, and vomiting.
Inhalation	Can cause dizziness, headache, drowsiness, and nausea, and at higher concentrations, disorientation, delirium, and unconsciousness. Inhalation of high concentrations may also cause liver and kidney damage. Olfactory fatigue can occur.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash contaminated clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Obtain medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Chloroform is noncombustible. Exposure to fire or high temperatures may lead to formation of phosgene, a highly toxic gas.

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REACTIVITY & INCOMPATIBILITY

Chloroform reacts violently with alkali metals such as sodium and potassium, with a mixture of acetone and base, and with a number of strong bases such as potassium and sodium hydroxide, potassium *tert*-butoxide, sodium methoxide, and sodium hydride. Chloroform reacts explosively with fluorine and dinitrogen tetroxide.

STORAGE & HANDLING

Gloves: Neoprene or PVA

In the presence of light, chloroform undergoes autoxidation to generate phosgene; this can be minimized by storing this substance in the dark under nitrogen. Commercial samples of chloroform frequently contain 0.5 to 1% ethanol as a stabilizer.

CLEANUP & DISPOSAL

In the event of a spill, soak up chloroform with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area.

Excess chloroform and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Chloroform is a carcinogen and not suitable for use by students. Ethyl acetate, acetone, and ethanol are suitable replacements for halogenated solvents in most applications.

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CHLOROMETHYL METHYL ETHER

SYNONYMS	CAS#	Formula
CMME	107-30-2	 $ClH_2C-O-CH_3$

PHYSICAL PROPERTIES

Odor:	Similar to HCl	**Appearance:**	Colorless liquid
Water Solubility:	Decomposes	**Vapor Density:**	2.8
Flash Point:	15 °C	**Vapor Pressure:**	260 mmHg at 20 °C
Autoignition:	Not established	**bp/mp:**	55 to 59 °C/−104 °C

TOXICITY		EXPOSURE LIMITS
LD_{50} oral (rat):	817 mg/kg	
LC_{50} inhal. (rat):	55 ppm (180 mg/m^3; 7 h)	

HEALTH AND SYMPTOMS

General	The acute toxicity of chloromethyl methyl ether is moderate to high. Chloromethyl methyl ether is regulated by OSHA as a carcinogen (29 CFR § 1910.1006) and is listed in IARC Group 1 (“carcinogenic to humans”). This substance is classified as a “select carcinogen” under the criteria of the OSHA Laboratory Standard. Note also that some commercial samples of chloromethyl methyl ether contain up to 7% of highly carcinogenic bis(chloromethyl)ether.
Skin	Contact with the liquid can cause severe irritation and severe and painful burns.
Eyes	Contact with the liquid can result in severe and painful burns.
Ingestion	Can cause severe burns of the mouth and stomach and can be fatal.
Inhalation	Inhalation of the vapor is severely irritating to the eyes, skin, nose, and respiratory tract, and causes sore throat, fever, chills, and difficulty breathing. Exposure to high concentrations can lead to delayed pulmonary edema, which can be fatal.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Obtain medical attention immediately.
Inhalation	Move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating (flammability) = 3; LEL = NA; UEL = NA

Chloromethyl methyl ether is highly flammable. Fires involving this substance should be extinguished with carbon dioxide or dry chemical extinguishers.

REACTIVITY & INCOMPATIBILITY

Chloromethyl methyl ether reacts readily with oxidizing agents. Hydrolysis of chloromethyl methyl ether produces HCl and formaldehyde, which can recombine to form bis(chloromethyl)ether.

STORAGE & HANDLING

All work with this substance should be conducted in a fume hood to prevent exposure by inhalation, and appropriate impermeable gloves and splash goggles should be worn at all times to

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prevent skin and eye contact. Chloromethyl methyl ether is also highly flammable and should be used only in areas free of ignition sources; quantities greater than 1 L should be stored in tightly sealed metal containers in areas separate from oxidizers in secondary containers.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources; soak up the chloromethyl methyl ether with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess chloromethyl methyl ether and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Chloromethyl methyl ether is a carcinogen and not suitable for use by students.

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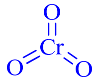
CHROMIUM TRIOXIDE AND OTHER CHROMIUM(VI) SALTS

SYNONYMS	CAS#	Formula
Chromic anhydride, chromic acid, chromium(VI) oxide, chromic trioxide, chromium oxide, chromic oxide, chromium trioxide	1333-82-0	

PHYSICAL PROPERTIES

Odor:	odorless	**Appearance:**	Dark red flakes or crystals
Water Solubility:	62 g/100 mL	**Vapor Density:**	NA
Flash Point:	Noncombustible	**Vapor Pressure:**	Very low
Autoignition:	NA	**bp/mp:**	196 °C/decomposes at 250 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	80 mg/kg	**TLV-TWA (ACGIH):**	0.05 mg (Cr)/m^3
		OSHA PEL:	0.1 mg (CrO_3)/m^3 (ceiling)

HEALTH AND SYMPTOMS

General	Several hexavalent compounds of chromium, including chromium trioxide, are listed in IARC Group 1 (“carcinogenic to humans”) and are classified as “select carcinogens” under the criteria of the OSHA Laboratory Standard. Exposure to chromium trioxide by inhalation or skin contact may lead to sensitization. Chromium trioxide has exhibited teratogenic activity in animal tests.
Skin	Can cause irritation, and prolonged contact can cause ulceration.
Eyes	Chromium trioxide and its solutions can cause severe burns and possible loss of vision.
Ingestion	Moderately toxic, 1 to 15 g may be a fatal dose in humans. Lower doses can cause stomach, liver, and kidney damage; symptoms include clammy, cyanotic skin, sore throat, gastric burning, vomiting, and diarrhea.
Inhalation	Inhalation of chromate dust or chromic acid mist can result in severe irritation of the nose, throat, bronchial tubes, and lungs and may cause coughing, labored breathing, respiratory system ulcers, and swelling of the larynx.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Give the person large amounts of water or milk and obtain medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL= NA%

Contact with easily oxidized organic or other combustible materials (including paper and oil) may result in ignition, violent combustion, or explosion. The use of dry-chemical, carbon dioxide, Halon, or water spray extinguishers is recommended for fires involving chromium(VI) compounds.

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REACTIVITY & INCOMPATIBILITY

Chromium trioxide and certain other chromium(VI) compounds are useful as strong oxidizing agents in the laboratory, but appropriate precautionary measures should be taken when conducting these reactions. Chromium trioxide has been reported to react violently with a variety of substances, including readily oxidized organic compounds such as acetone, acetaldehyde, methanol, ethanol, diethyl ether, ethyl acetate, acetic acid, and dimethylformamide, and violent reactions may also occur on reaction with alkali metals, gaseous ammonia, phosphorus, and selenium.

STORAGE & HANDLING

Gloves: Butyl rubber or Viton

All work should be handled in a fume hood to avoid the inhalation of dust, and impermeable gloves should be worn at all times to prevent skin contact. Chromate solutions should not be used to clean glassware. Store in areas separated from readily oxidized materials.

CLEANUP & DISPOSAL

In the event of a spill, remove all combustibles from the area, sweep up the chromium compounds, place in an appropriate container, and dispose of properly. In the event solutions containing chromium compounds are spilled, neutralize (if possible) with aqueous base, soak up with a spill pillow or appropriate noncombustible absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill of powder, particularly in a confined area. Excess and waste should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Chromium compounds are carcinogens and not suitable for use by students.

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CYANOGEN BROMIDE

SYNONYMS	CAS#	Formula
Bromine cyanide, bromocyanogen, cyanobromide	506-68-3	$Br-C\equiv N$

PHYSICAL PROPERTIES

Odor:	Penetrating odor	**Appearance:**	Colorless needles
Water Solubility:	Slow reaction	**Vapor Density:**	3.6
Flash Point:	NA	**Vapor Pressure:**	100 mmHg at 22.6 °C
Autoignition:	NA	**bp/mp:**	62 °C/52 °C

TOXICITY		EXPOSURE LIMITS
LC_{LO} inhal. (human):	92 ppm (398 mg/m^3; 10 min)	

HEALTH AND SYMPTOMS

General	High acute toxicity; severely irritating. Toxic effects are similar to but not as severe as those of hydrogen cyanide. Toxic symptoms may include cyanosis, nausea, dizziness, headache, lung irritation, chest pain, and pulmonary edema, which may be fatal.
Skin	See General.
Eyes	See General.
Ingestion	See General.
Inhalation	See General.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Cyanogen bromide is noncombustible. Impure material decomposes rapidly and can be explosive.

REACTIVITY & INCOMPATIBILITY

Cyanogen bromide can react violently with large quantities of acid. It may decompose when exposed to heat, moist air, or water, producing toxic fumes of hydrogen cyanide and hydrogen bromide. Cyanogen bromide can polymerize violently on prolonged storage at ambient temperature.

STORAGE & HANDLING

In particular, work with BrCN should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Containers of cyanogen bromide should be kept tightly sealed and stored under nitrogen in a secondary container in a refrigerator.

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CLEANUP & DISPOSAL

In the event of a spill, sweep up cyanogen bromide, place in an appropriate container, and dispose of properly. Respiratory and appropriate impermeable protective gloves and clothing should be worn while conducting cleanup of this highly toxic substance. Excess cyanogen bromide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Cyanogen bromide is corrosive and not suitable for use by students.

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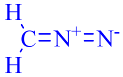
DIAZOMETHANE

SYNONYMS	CAS#	Formula
Diazirine, azimethylene	334-88-3	 $H_2C=N^+=N^-$

PHYSICAL PROPERTIES			
Odor:	Musty odor (no accepted threshold value)	**Color:**	Yellow gas
Water Solubility:	Reacts with water	**Vapor Density:**	1.4 (air = 1.0)
Flash Point:	NA	**Vapor Pressure:**	Very low
Autoignition:	150 °C; impure material explodes at lower temperature	**bp/mp:**	−23 °C/−145 °C

TOXICITY		EXPOSURE LIMITS	
LC_{LO} inhal. (cat)	175 ppm (10 min)	**TLV-TWA (ACGIH):**	0.2 ppm (0.4 mg/m^3)
		PEL (OSHA):	0.2 ppm (0.4 mg/m^3)

HEALTH AND SYMPTOMS	
General	Diazomethane vapor causes severe irritation of the skin, eyes, mucous membranes, and lungs. Symptoms include headache, chest pain, cough, fever, severe asthmatic attacks, and pulmonary edema, which can be fatal. It is considered to be a substance with poor warning properties, and the effects of exposure may be delayed in onset. Symptoms of exposure may include headache, chest pain, cough, fever, severe asthmatic attacks, and pulmonary edema, which can be fatal. Exposure of the skin and mucous membranes to diazomethane may cause serious burns. Diazomethane is a powerful allergen. Prolonged or repeated exposure to diazomethane can lead to sensitization of the skin and lungs, in which case asthmalike symptoms or fever may occur as the result of exposure to concentrations of diazomethane that previously caused no symptoms. Chronic exposure to diazomethane has been reported to cause cancer in experimental animals, but this substance has not been identified as a human carcinogen. Note that diazomethane is often prepared in situ from precursors that may themselves be highly toxic and/or carcinogenic.
Skin	Can cause irritation and serious burns. Prolonged or repeated exposure can lead to skin sensitization.
Eyes	Can cause irritation and serious burns.
Ingestion	NA
Inhalation	Can cause severe irritation to mucous membranes and the lungs. Prolonged or repeated exposure can lead to sensitization of the lungs, in which case asthmalike symptoms or fever may occur as the result of exposure to concentrations of diazomethane that previously caused no symptoms.

FIRST AID	
Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reused.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.

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Ingestion	NA
Inhalation	If the individual is overcome by fumes, move the person to fresh air, and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Extremely flammable gas

NFPA rating (flammability) = 4; LEL = NA; UEL = NA

Readily flammable and can explode easily. Explosion can be caused by contact with rough surfaces such as ground-glass joints, etched or scratched flasks, and glass tubing that has not been carefully fire-polished. Direct sunlight and strong artificial light may also cause explosions of this substance. Violent reactions may occur on exposure of diazomethane to alkali metals.

REACTIVITY & INCOMPATIBILITY

Explosions may occur on exposure of diazomethane to alkali metals and calcium sulfate (Drierite).

STORAGE & HANDLING

Diazomethane should be handled in solution using glassware specially designated for diazomethane (e.g., with Clear-Seal joints) and should be used as soon as possible after preparation. Storage of diazomethane solutions (even at low temperature) is not advisable. All work should be conducted in a fume hood behind a safety shield, and appropriate impermeable gloves, protective clothing, and safety goggles should be worn at all times.

CLEANUP & DISPOSAL

Small amounts of excess diazomethane can be destroyed by carefully adding acetic acid dropwise to a dilute solution of the diazomethane in an inert solvent such as ether at 0 ºC. Excess diazomethane solutions and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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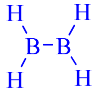
DIBORANE

SYNONYMS	CAS#	Formula
Boroethane, boron hydride, diboron hexahydride	19287-45-7	

PHYSICAL PROPERTIES

Odor:	Repulsive odor detectable at 1.8 to 3.5 ppm	**Color:**	Colorless gas
Water Solubility:	Rapidly decomposes in water to form hydrogen gas	**Vapor Density:**	0.96 (air = 1.0)
Flash Point:	−90 °C	**Vapor Pressure:**	27.8 mmHg at 25 °C
Autoignition:	38 to 52 °C	**bp/mp:**	−23 °C/−145 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):		**TLV-TWA (ACGIH):**	0.1 ppm
LC_{50} inhal. (rat):	50 ppm (4 h)	**PEL (OSHA) :**	0.1 ppm

HEALTH AND SYMPTOMS

General	**Death can result from pulmonary edema (fluid in the lungs) and/or from lack of oxygen.** Overexposure to diborane can cause damage to the central nervous system, liver, and kidneys. The odor of diborane cannot be detected below the permissible exposure limit, so this substance is considered to have poor warning properties. Overexposure to diborane can cause damage to the central nervous system, liver, and kidneys. Chronic exposure to low concentrations of diborane may cause headache, lightheadedness, fatigue, weakness in the muscles, and tremors. Repeated exposure may produce chronic respiratory distress, particularly in susceptible individuals. Diborane has not been shown to have carcinogenic or reproductive or developmental effects in humans.
Skin	May cause serious burns. An existing dermatitis may also be worsened by repeated exposure to the liquid.
Eyes	High concentrations can cause serious eye irritation, and contact with the liquid can cause burns.
Ingestion	The ingestion of gas is unlikely.
Inhalation	Can result in irritation of the respiratory tract and may result in headache, cough, nausea, difficulty in breathing, chills, fever, weakness, and severe asthmatic attacks.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing prior to reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention.
Inhalation	If this compound is inhaled, move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

Extremely flammable gas

NFPA Rating = 4; LEL = 0.8%; UEL = 88%

Diborane is a flammable gas that ignites spontaneously in moist air at room temperature and forms explosive mixtures with air. Diborane reacts with halogenated hydrocarbons. Therefore, do not use fire extinguishing agents such as Halon or carbon tetrachloride. Carbon dioxide extinguishers should be used to fight diborane fires. Fires involving diborane sometimes release toxic gases such as boron oxide smoke.

REACTIVITY & INCOMPATIBILITY

Explodes on contact with fluorine, chlorine, halogenated hydrocarbons (e.g., chloroform and carbon tetrachloride), fuming nitric acid, and nitrogen trifluoride. Diborane is a strong reducing agent that produces hydrogen upon heating or reaction with water. Contact with aluminum, lithium, and other active metals forms metal hydrides, which may ignite spontaneously. Diborane is incompatible with oxidizing agents, halogens, and halogenated compounds. Diborane will attack some forms of plastic, rubber, and coatings.

STORAGE & HANDLING

Diborane should be used only in a fume hood free of ignition sources and should be stored in a cold, dry, well-ventilated area separated from incompatible substances and isolated from sources of sparks and open flames.

CLEANUP & DISPOSAL

Excess diborane and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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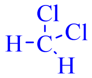
DICHLOROMETHANE

SYNONYMS	CAS#	Formula
Methylene chloride, aerothene MM	75-09-2	 $H{-}\overset{Cl}{\underset{H}{C}}{-}Cl$

PHYSICAL PROPERTIES

Odor:	Odor threshold 160 to 230 ppm	**Color:**	Colorless liquid
Water Solubility:	Slightly soluble in water (1.32 g/100 mL)	**Vapor Density:**	2.93 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	440 mmHg at 25 °C
Autoignition:	556 °C	**bp/mp:**	40 °C/−97 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	1,600 mg/kg	**TLV-TWA (ACGIH):**	50 ppm
LC_{50} inhal. (rat):	88,000 mg/m^3; 30 min	**STEL (ACGIH):**	125 ppm
		PEL (OSHA):	500 ppm (8 h)

HEALTH AND SYMPTOMS

General	Dichloromethane is classified as only slightly toxic by the oral and inhalation routes. Exposure to high concentrations of dichloromethane vapor (>500 ppm for 8 h) can lead to lightheadedness, fatigue, weakness, and nausea. Dichloromethane is not teratogenic at levels up to 4,500 ppm or embryotoxic in rats and mice at levels up to 1,250 ppm.
Skin	Mild skin irritant, and upon prolonged contact (e.g., under the cover of clothing or shoes) can cause burns after 30- to 60-minute exposure.
Eyes	Contact of the compound with the eyes causes painful irritation and can lead to conjunctivitis and corneal injury if not promptly removed by washing.
Ingestion	Slightly toxic if ingested.
Inhalation	Slightly toxic if inhaled.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA Rating (flammability) = 1; LEL = 14%; UEL = 22%

Noncombustible. Dichloromethane vapor concentrated in a confined or poorly ventilated area can be ignited with a high-energy spark, flame, or high-intensity heat source.

REACTIVITY & INCOMPATIBILITY

Reacts violently with alkali metals, aluminum, magnesium powder, potassium *tert*-butoxide, nitrogen tetroxide, and strong oxidizing agents.

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STORAGE & HANDLING

Gloves: Butyl rubber

Secure cylinder to protect from falling. Use suitable hand truck to move cylinders. Store in a tightly closed container under an inert atmosphere. Store in a cool, dry place, and well-ventilated area. Avoid heat, flames, sparks, and other sources of ignition.

CLEANUP & DISPOSAL

Excess dichloromethane and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Dichloromethane is a carcinogen and not suitable for use by students. Ethyl acetate, acetone, or ethanol is a suitable replacement for halogenated solvents in most applications.

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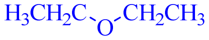
DIETHYL ETHER

SYNONYMS	CAS#	Formula
Ethyl ether, ether	60-29-7	 $H_3CH_2C\underset{O}{\diagdown\diagup}CH_2CH_3$

PHYSICAL PROPERTIES

Odor:	Pungent odor detectable at 0.33 ppm	**Color:**	Colorless liquid
Water Solubility:	Slightly soluble in water (8 g/100 mL)	**Vapor Density:**	2.6 (air = 1.0)
Flash Point:	−45 °C	**Vapor Pressure:**	442 mmHg at 20 °C
Autoignition:	160 °C	**bp/mp:**	35 °C/−116 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat)	1,215 mg/kg	**TLV-TWA (ACGIH)**	400 ppm
LC_{50} inhal. (rat)	73,000 ppm (2 h)	**STEL (ACGIH)**	500 ppm
		PEL (OSHA)	400 ppm

HEALTH AND SYMPTOMS

General	The acute toxicity of diethyl ether is low. Chronic exposure to diethyl ether vapor may lead to loss of appetite, exhaustion, drowsiness, dizziness, and other central nervous system effects. Diethyl ether is regarded as having adequate warning properties. There is no evidence for carcinogenicity of diethyl ether, and no reproductive effects have been reported.
Skin	Mild irritant. Repeated contact can cause dryness and cracking of the skin due to removal of skin oils. The liquid is not readily absorbed through the skin, in part because of its high volatility.
Eyes	Mild irritant, but does not generally cause irreversible damage.
Ingestion	Slightly toxic if ingested.
Inhalation	High concentrations can cause sedation, unconsciousness, and respiratory paralysis. These effects are usually reversible upon cessation of exposure.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Extremely flammable liquid and vapor

NFPA Rating (flammability) = 4; LEL = 1.9%; UEL = 36%.

Diethyl ether is extremely flammable and is one of the most dangerous fire hazards commonly encountered in the laboratory, owing to its volatility and extremely low ignition temperature. Ether vapor may be ignited by hot surfaces such as hot plates and static electricity discharges, and

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since the vapor is heavier than air, it may travel a considerable distance to an ignition source and flash back. Ether vapor forms explosive mixtures with air. Carbon dioxide or dry chemical extinguishers should be used for ether fires. Diethyl ether forms unstable peroxides on exposure to air in a reaction that is promoted by light; the presence of these peroxides may lead to explosive residues upon distillation.

REACTIVITY & INCOMPATIBILITY

Diethyl ether may react violently with halogens or strong oxidizing agents such as perchloric acid.

STORAGE & HANDLING

Gloves: Butyl rubber

Use only in areas free of ignition sources (including hot plates, incandescent lightbulbs, and steam baths), and this substance should be stored in tightly sealed metal containers in areas separate from oxidizers. Because of the tendency of diethyl ether to form peroxides on contact with air, containers should be dated upon receipt and at the time they are opened. Once opened, containers of diethyl ether should be tested periodically for the presence of peroxides according to the procedures described in Chapter 6. Diethyl ether is generally supplied with additives that inhibit peroxide formation; distillation removes these inhibitors and renders the liquid more prone to peroxide formation. Material found to contain peroxides should be treated to destroy the peroxides before use or disposed of properly.

CLEANUP & DISPOSAL

Excess diethyl ether and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Hexane can be utilized in place of ether.

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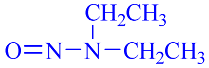
DIETHYLNITROSAMINE (and related nitrosamines)

SYNONYMS	CAS#	Formula
N-Nitrosodiethylamine; *N*-ethyl-*N*-nitrosoethananime	55-18-5	 $O{=}N{-}\overset{\overset{CH_2CH_3}{\vert}}{N}{-}CH_2CH_3$

PHYSICAL PROPERTIES

Odor:	NA	**Color:**	Yellow liquid
Water Solubility:	Soluble in water	**Vapor Density:**	NA
Flash Point:	61 °C	**Vapor Pressure:**	1.7 mmHg at 20 °C
Autoignition:	NA	**bp/mp:**	177 °C

TOXICITY	EXPOSURE LIMITS
LD_{50} oral (rat) 280 mg/kg	

HEALTH AND SYMPTOMS

General	The acute toxicity of diethylnitrosamine is classified as moderate. Other nitrosamines of higher molecular weight are somewhat less toxic. Chronic exposure to nitrosamines can cause severe liver damage. It is listed in IARC Group 2A ("probable human carcinogen") and is classified as an OSHA "select carcinogen." Nitrosamines are suspected of causing cancers of the lung, nasal sinuses, brain, esophagus, stomach, liver, bladder, and kidney. Diethylnitrosamine is mutagenic and teratogenic. This substance does not have adequate warning properties.
Skin	Not available
Eyes	Not available
Ingestion	May cause nausea, vomiting, and fever.
Inhalation	May cause nausea, vomiting, and fever.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Place contaminated items in a plastic bag. Seal the bag and dispose of it appropriately.
Eyes	In case of eye contact, promptly wash with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Combustible liquid

NFPA rating (flammability) = 2; LEL = NA; UEL = NA

Volatilization during combustion produces hazardous vapors. Combustion products contain nitrogen oxides.

REACTIVITY & INCOMPATIBILITY

Diethylnitrosamine is decomposed by strong acids, liberating nitrous acid. Nitrosamines are incompatible with strong oxidizing agents.

STORAGE & HANDLING

Gloves: Butyl rubber or SilverShield

All work should be conducted in a fume hood to prevent exposure by inhalation, and appropriate impermeable gloves and splash goggles should be worn at all times.

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CLEANUP & DISPOSAL

Excess diethylnitrosamine and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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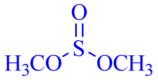
DIMETHYL SULFATE

SYNONYMS	CAS#	Formula
Methyl sulfate; DMS	77-78-1	 $H_3CO-S(=O)-OCH_3$

PHYSICAL PROPERTIES

Odor:	Almost odorless	**Color:**	Colorless, oily liquid
Water Solubility:	2.8 g/100 mL at 20 °C	**Vapor Density:**	4.3 (air = 1.0)
Flash Point:	83 °C	**Vapor Pressure:**	0.5 mmHg at 20 °C
Autoignition:	495 °C	**bp/mp:**	189 °C/−32 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	205 mg/kg	**TLV-TWA (ACGIH):**	0.1 ppm (0.52 mg/m^3)—skin
LC_{50} inhal. (rat):	9 ppm (45 mg/m^3; 4 h)	**PEL (OSHA):**	1 ppm (5 mg/m^3)—skin

HEALTH AND SYMPTOMS

General	Dimethyl sulfate is extremely hazardous because of its lack of warning properties (the odor does not provide adequate warning) and delayed toxic effects. The vapor of this compound is extremely irritating to the skin, eyes, and respiratory tract, and contact with the liquid can cause very severe burns to the eyes and skin. The effects of overexposure to dimethyl sulfate vapor may be delayed. After a latent period of 10 hours or more, headache and severe pain to the eyes upon exposure to light may occur, followed by cough, tightness of the chest, shortness of breath, difficulty in swallowing and speaking, vomiting, diarrhea, and painful urination. Fatal pulmonary edema may develop. Systemic effects of dimethyl sulfate include damage to the liver and kidneys. Dimethyl sulfate is listed by IARC in Group 2A (“probable human carcinogen”) and is classified as a “select carcinogen” under the criteria of the OSHA Laboratory Standard. Data indicate that dimethyl sulfate does not specifically harm unborn animals; dimethyl sulfate is not a developmental toxin. It is a strong alkylating agent and does produce genetic damage in animals and in bacterial and mammalian cell cultures.
Skin	Can cause extreme irritation and very severe burns.
Eyes	Can cause extreme irritation and very severe burns.
Ingestion	Can cause extreme irritation and very severe burns to the mouth, throat, and gastrointestinal tract.
Inhalation	Can cause nausea, vomiting, and fever

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

Combustible liquid

NFPA Rating (flammability) = 2; LEL = NA; UEL = NA

Dimethyl sulfate is a combustible liquid. Toxic dimethyl sulfate vapors are produced in a fire. Carbon dioxide or dry chemical extinguishers should be used to fight dimethyl sulfate fires.

REACTIVITY & INCOMPATIBILITY

Dimethyl sulfate can react violently with ammonium hydroxide, sodium azide, and strong oxidizers.

STORAGE & HANDLING

Gloves: NA

All work with dimethyl sulfate should be conducted in a fume hood to prevent exposure by inhalation, and appropriate impermeable gloves and safety goggles should be worn at all times to prevent skin and eye contact.

CLEANUP & DISPOSAL

Excess dimethyl sulfate and waste material containing this substance should be placed in a covered metal container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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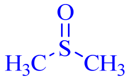
DIMETHYL SULFOXIDE

SYNONYMS	CAS#	Formula
DMSO, methyl sulfoxide	67-68-5	

PHYSICAL PROPERTIES

Odor:	Mild garlic odor	**Appearance:**	Colorless liquid
Water Solubility:	Miscible with water	**Vapor Density:**	2.7 (air = 1.0)
Flash Point:	95 °C	**Vapor Pressure:**	0.37 mmHg at 20 °C
Autoignition:	215 °C	**bp/mp:**	189 °C (decomposes)/18.5 °C

TOXICITY

LD_{50} oral (rat):	14,500 mg/kg
LC_{50} inhal. (rat):	1,600 mg/m^3 (4 h)
LD_{50} skin (rabbit):	40,000 mg/kg

EXPOSURE LIMITS

HEALTH AND SYMPTOMS

General	The acute toxicity of DMSO by all routes of exposure is very low and exposure can cause slight to moderate irritation by all routes. Dimethyl sulfoxide has not been found to be carcinogenic or to show reproductive or developmental toxicity in humans.
Skin	Relatively nontoxic by skin absorption, but can cause itching, scaling, and a transient burning sensation. Dimethyl sulfoxide can increase the tendency for other chemicals to penetrate the skin and so increase their toxic effects.
Eyes	May cause irritation with redness, pain, and blurred vision. Chronic exposure to dimethyl sulfoxide can cause damage to the cornea.
Ingestion	Slightly toxic and may cause vomiting, abdominal pain, and lethargy.
Inhalation	Can cause irritation of the respiratory tract, and at higher concentrations may cause vomiting, chills, headache, and dizziness.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Combustible liquid

NFPA rating (flammability) = 1; LEL = 2.6%; UEL = 42%

Combustible when exposed to heat or flame. Carbon dioxide or dry chemical extinguishers should be used to fight DMSO fires.

REACTIVITY & INCOMPATIBILITY

DMSO reacts violently with strong oxidizers, many acyl halides, boron hydrides, and alkali metals. DMSO can form explosive mixtures with metal salts of oxoacids (sodium perchlorate, iron(III) nitrate).

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STORAGE & HANDLING

Gloves: Nitrile, neoprene, natural rubber, PVC, butyl rubber, Viton

Store in a tightly closed container. Store in a cool, dry, ventilated area away from sources of heat or ignition.

CLEANUP & DISPOSAL

Excess dimethyl sulfoxide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Dimethyl sulfoxide is rapidly absorbed through the skin and is not suitable for use by students.

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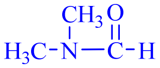
DIMETHYLFORMAMIDE

SYNONYMS	CAS#	Formula
N,*N*-Dimethylformamide, DMF	68-12-2	 $H_3C-N(CH_3)-C(=O)-H$

PHYSICAL PROPERTIES

Odor:	Faint, ammonia-like odor detectable at 100 ppm	**Appearance:**	Colorless clear liquid
Water Solubility:	Miscible with water in all proportions	**Vapor Density:**	2.5 (air = 1.0)
Flash Point:	58 °C	**Vapor Pressure:**	2.6 mmHg at 20 °C
Autoignition:	445 °C	**bp/mp:**	153 °C/−61 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	2,800 mg/kg	**TLV-TWA (ACGIH):**	10 ppm (30 mg/m^3–skin)
LC_{50} inhal. (rat):	9,400 mg/m^3; 2 h	**PEL (OSHA):**	10 ppm (30 mg/m^3–skin
LD50 skin (rabbit):	4,720 mg/kg		

HEALTH AND SYMPTOMS

General	The acute toxicity of DMF is low by inhalation, ingestion, and skin contact. Exposure to high concentrations of DMF may lead to liver damage and other systemic effects. Dimethylformamide is listed by IARC in Group 2B (“possible human carcinogen”). It is not classified as a “select carcinogen” according to criteria of the OSHA Laboratory Standard. No significant reproductive effects have been observed in animal tests. Repeated exposure to DMF may result in damage to the liver, kidneys, and cardiovascular system.
Skin	Can cause irritation and is readily absorbed through the skin. DMF is an excellent solvent for many toxic materials that are not ordinarily absorbed and can increase the hazard of these substances by skin contact.
Eyes	May cause irritation.
Ingestion	May be harmful if swallowed
Inhalation	May cause irritation

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Flammable liquid and vapor

NFPA rating (flammability) = 2; LEL = 2.2%; UEL = 15.2%.

DMF is a combustible liquid. Vapors are heavier than air and may travel to source of ignition and flash back. DMF vapor forms explosive mixtures with air. Carbon dioxide or dry chemical extinguishers should be used to fight DMF fires.

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REACTIVITY & INCOMPATIBILITY

Though stable at normal temperatures and storage conditions, DMF may react violently with halogens, acyl halides, strong oxidizers, and polyhalogenated compounds in the presence of iron. Decomposition products include toxic gases and vapors such as dimethylamine and carbon monoxide. DMF will attack some forms of plastics, rubber, and coatings.

STORAGE & HANDLING

Gloves: Butyl, nitrile, SilverShield

In particular, DMF should be used only in areas free of ignition sources, and quantities greater than 1 L should be stored in tightly sealed metal containers in areas separate from oxidizers.

CLEANUP & DISPOSAL

Excess DMF and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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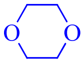
DIOXANE

SYNONYMS	CAS#	Formula
1,4-Dioxane, *p*-dioxane, diethylene ether, 1,4-diethylene dioxide	123-91-1	

PHYSICAL PROPERTIES

Odor:	Mild etherlike odor detectable at 0.8 to 172 ppm (mean = 12 ppm)	**Appearance:**	Colorless liquid
Water Solubility:	Miscible with water	**Vapor Density:**	3 (air = 1.0)
Flash Point:	12 °C	**Vapor Pressure:**	40 mmHg at 25 °C
Autoignition:	180 °C	**bp/mp:**	101 °C/12 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat)	5,700 mg/kg	**TLV-TWA (ACGIH)**	25 ppm (90 mg/m^3)—skin
LC_{50} inhal. (rat)	13,000 ppm (46,800 mg/m^3; 2 h)	**PEL (OSHA**	100 ppm (360 mg/m^3)—skin
LD_{50} skin (rabbit)	7,600 mg/kg		

HEALTH AND SYMPTOMS

General	The acute toxicity of 1,4-dioxane is low. Exposure to 200 to 300 ppm causes irritation of the eyes, nose, and throat. Symptoms of overexposure may include upper respiratory tract irritation, coughing, drowsiness, vertigo, headache, stomach pains, nausea, and vomiting. The odor of dioxane is not unpleasant, and its irritating effects may be transitory; consequently, it is not regarded as a substance with adequate warning properties. Dioxane shows carcinogenic effects in animal studies and is listed by IARC in Group 2B ("possible human carcinogen"). It is not classified as a "select carcinogen" according to the criteria of the OSHA Laboratory Standard. Prolonged or repeated exposure to this substance may result in liver and kidney injury. Dioxane has not been shown to be a reproductive or developmental toxin in humans.
Skin	Prolonged or repeated contact may produce drying and cracking of the skin.
Eyes	Can cause irritation.
Ingestion	Effects of exposure similar to that of inhalation.
Inhalation	Inhalation of higher concentrations can result in damage to the kidneys and liver.

FIRST AID

Skin	In the event of skin contact, immediately wash with soap and water and remove contaminated clothing.
Eyes	In case of eye contact, promptly wash with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	If ingested seek medical attention immediately
Inhalation	If this compound is inhaled, move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating = 3; LEL = 2%; UEL = 22%

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Dioxane is a highly flammable liquid. Its vapor is heavier than air and may travel a considerable distance to a source of ignition and flash back. Dioxane vapor forms explosive mixtures with air. Fires involving dioxane should be extinguished with carbon dioxide or dry powder extinguishers. Dioxane can form shock- and heat-sensitive peroxides that may explode on concentration by distillation or evaporation. Samples of this substance should always be tested for the presence of peroxides before distilling it or allowing it to evaporate. Dioxane should never be distilled to dryness.

REACTIVITY & INCOMPATIBILITY

Dioxane can form potentially explosive peroxides upon long exposure to air. Dioxane may react violently with Raney nickel catalyst, nitric and perchloric acids, sulfur trioxide, and strong oxidizing reagents.

STORAGE & HANDLING

Gloves: Butyl, SilverShield

Dioxane should be used only in areas free of ignition sources, and quantities greater than 1 L should be stored in tightly sealed metal containers in areas separate from oxidizers. Containers of dioxane should be dated when opened and tested periodically for the presence of peroxides.

CLEANUP & DISPOSAL

Excess dioxane and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Dioxane is not suitable for use by students.

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SYNONYMS	**CAS#**	**Formula**
Ethyl alcohol, alcohol, methylcarbinol	64-17-5	CH_3CH_2OH

PHYSICAL PROPERTIES

Odor:	Pleasant alcoholic odor detectable at 49 to 716 ppm (mean = 180 ppm)	**Appearance:**	Colorless liquid
Water Solubility:	Miscible with water	**Vapor Density:**	1.6 (air = 1.0)
Flash Point:	13 °C	**Vapor Pressure:**	43 mmHg at 20 °C
Autoignition:	363 °C	**bp/mp:**	101 °C/12 °C

TOXICITY		**EXPOSURE LIMITS**	
LD_{50} oral (rat):	7,060 mg/kg	**TLV-TWA (ACGIH):**	1,000 ppm (1,900 mg/m^3)
LC_{50} inhal. (rat):	20,000 ppm(10 h)	**PEL (OSHA):**	1,000 ppm (1,900 mg/m^3)
LD_{50} skin (rabbit):	>20 mL/kg		

HEALTH AND SYMPTOMS

General	The acute toxicity of ethanol is very low. Exposure to 200 to 300 ppm causes irritation of the eyes, nose, and throat. Symptoms of overexposure may include upper respiratory tract irritation, coughing, drowsiness, vertigo, headache, stomach pains, nausea, and vomiting. Ethanol is regarded as a substance with good warning properties. Tests in some animals indicate that ethanol may have developmental and reproductive toxicity if ingested. There is no evidence that laboratory exposure to ethanol has carcinogenic effects. To discourage deliberate ingestion, ethanol for laboratory use is often “denatured” by the addition of other chemicals; the toxicity of possible additives must also be considered when evaluating the risk of laboratory exposure to ethanol.
Skin	High concentrations of ethanol vapor can cause significant irritation.
Eyes	Can cause significant irritation.
Ingestion	Can cause temporary nervous system depression with anesthetic effects such as dizziness, headache, confusion, and loss of consciousness; large doses (250 to 500 mL) can be fatal in humans.
Inhalation	High concentrations of ethanol vapor can cause significant irritation to the respiratory tract. High concentrations (over 1,000 ppm) can cause central nervous system effects, including dizziness, headache, and giddiness followed by depression, drowsiness, and fatigue.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating = 3; LEL = 4.3%; UEL = 19%

Ethanol is a flammable liquid, and its vapor can travel a considerable distance to an ignition source and flash back. Ethanol vapor forms explosive mixtures with air. Hazardous gases produced in ethanol fires include carbon monoxide and carbon dioxide. Carbon dioxide or dry chemical extinguishers should be used for ethanol fires.

REACTIVITY & INCOMPATIBILITY

Contact of ethanol with strong oxidizers, peroxides, strong alkalis, and strong acids may cause fires and explosions.

STORAGE & HANDLING

Gloves: Latex, rubber, or nitrile

In particular, ethanol should be used only in areas free of ignition sources, and quantities greater than 1 L should be stored in tightly sealed metal containers in areas separate from oxidizers.

CLEANUP & DISPOSAL

Excess ethanol and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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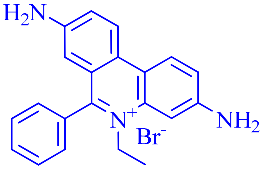
ETHIDIUM BROMIDE

SYNONYMS	CAS#	Formula
Dromilac, homidium bromide	1239-45-8	

PHYSICAL PROPERTIES

Odor:	Odorless solid	**Appearance:**	Dark red crystals
Water Solubility:	Soluble in water (5 g/100 mL)	**Vapor Density:**	NA
Flash Point:	NA	**Vapor Pressure:**	NA
Autoignition:	NA	**bp/mp:**	260 to 262 °C

TOXICITY		EXPOSURE LIMITS
LD_{50} oral (rat):	1503 mg/kg	
LC_{50} inhal. (rat):	0.0118-0.1340 ppm	

HEALTH AND SYMPTOMS

General	Acute toxic effects from exposure to ethidium bromide have not been thoroughly investigated. Although there is no evidence for the carcinogenicity or teratogenicity of this substance in humans, ethidium bromide is strongly mutagenic and therefore should be regarded as a possible carcinogen and reproductive toxin.
Skin	Can cause irritation.
Eyes	Can cause irritation.
Ingestion	May cause sore throat
Inhalation	Can cause irritation to the upper respiratory tract and mucous membranes.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Ethidium bromide does not pose a flammability hazard.

REACTIVITY & INCOMPATIBILITY

No incompatibilities are known.

STORAGE & HANDLING

Gloves: NA

Because of its mutagenicity, stock solutions of this compound should be prepared in a fume hood, and protective gloves should be worn at all times while handling this substance. Operations capable of generating ethidium bromide dust or aerosols of ethidium bromide solutions should be conducted in a fume hood to prevent exposure by inhalation.

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CLEANUP & DISPOSAL

Excess ethidium bromide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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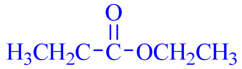
ETHYL ACETATE

SYNONYMS	CAS#	Formula
Acetic acid ethyl ester, ethyl ethanoate, acetoxyethane	141-78-6	 $H_3CH_2C-\overset{O}{\overset{\|}{C}}-OCH_2CH_3$

PHYSICAL PROPERTIES

Odor:	Pleasant fruity odor detectable at 7 to 50 ppm (mean = 18 ppm)	**Appearance:**	Colorless liquid
Water Solubility:	Moderately soluble in water (9 g/100 mL)	**Vapor Density:**	3.0 (air = 1.0)
Flash Point:	−4 °C	**Vapor Pressure:**	76 mmHg at 20 °C
Autoignition:	427 °C	**bp/mp:**	77 °C/−84 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat)	5,620 mg/kg	**TLV-TWA (ACGIH)**	400 ppm (1,440 mg/m^3)
LC_{50} inhal. (rat)	1,600 ppm (8 h)	**PEL (OSHA**	400 ppm (1,400 mg/m^3)

HEALTH AND SYMPTOMS

General	The acute toxicity of ethyl acetate is low. The vapor causes eye, skin, and respiratory tract irritation at concentrations above 400 ppm. Exposure to higher concentrations may lead to headache, nausea, blurred vision, central nervous system depression, dizziness, drowsiness, and fatigue. Ethyl acetate is regarded as a substance with good warning properties. No chronic systemic effects have been reported in humans, and ethyl acetate has not been shown to be a human carcinogen or reproductive or developmental toxin.
Skin	May cause irritation.
Eyes	Can cause irritation and lacrimation.
Ingestion	Can cause gastrointestinal irritation and, with larger amounts, central nervous system depression.
Inhalation	Causes headache, nausea, blurred vision, central nervous system depression, dizziness, drowsiness, and fatigue.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating (flammability) = 3; LEL = 2%; UEL = 11.5%

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Ethyl acetate is a flammable liquid, and its vapor can travel a considerable distance to an ignition source and flash back. Ethyl acetate vapor forms explosive mixtures with air. Hazardous gases produced in ethyl acetate fires include carbon monoxide and carbon dioxide. Carbon dioxide or dry chemical extinguishers should be used for ethyl acetate fires.

REACTIVITY & INCOMPATIBILITY

Contact with strong oxidizers, strong alkalis, and strong acids may cause fires and explosions

STORAGE & HANDLING

Gloves: Butyl rubber, neoprene, SilverShield

In particular, ethyl acetate should be used only in areas free of ignition sources, and quantities greater than 1 L should be stored in tightly sealed metal containers in areas separate from oxidizers.

CLEANUP & DISPOSAL

Excess ethyl acetate and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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ETHYLENE DIBROMIDE

SYNONYMS	CAS#	Formula
1,2-Dibromoethane, ethylene bromide, EDB	106-93-4	$BrCH_2CH_2Br$

PHYSICAL PROPERTIES

Odor:	Mild, sweet odor detectable at 10 ppm	**Appearance:**	Colorless liquid
Water Solubility:	Slightly soluble in water (0.4 g/100 mL at 20 °C)	**Vapor Density:**	6.5 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	12 mmHg at 25 °C
Autoignition:	NA	**bp/mp:**	131 °C/9 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat)	108 mg/kg	**PEL (OSHA) :**	20 ppm (150 mg/m^3)
LC_{50} inhal. (rat)	14,300 mg/m^3 (30 min)		
LD_{50} skin (rabbit)	20 ppm (150 mg/m^3)		

HEALTH AND SYMPTOMS

General	Ethylene dibromide is moderately toxic by inhalation, ingestion, and skin contact and is a severe irritant of the skin, eyes, and mucous membranes. EDB is listed in IARC Group 2A (“probable human carcinogen”) and is classified as a “select carcinogen” under the criteria of the OSHA Laboratory Standard. Chronic inhalation may cause pulmonary, renal, and hepatic damage. EDB is a suspected reproductive toxin implicated in reduction in male fertility. Ethylene dibromide is moderately toxic by inhalation, ingestion, and skin contact and is a severe irritant of the skin, eyes, and mucous membranes. Odor may not be detectable and therefore does not provide adequate warning.
Skin	Can cause severe irritation and blistering. Serious skin injury can result from contact with clothing and shoes wet with EDB. This compound can be absorbed through the skin in toxic amounts.
Eyes	Vapors are severely irritating to the eyes, and contact with the liquid can damage vision.
Ingestion	Intake of 5 to 10 mL can be fatal to humans owing to liver and kidney damage.
Inhalation	Overexposure may cause depression of the central nervous system, respiratory tract irritation, and pulmonary edema.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Ethylene dibromide is a noncombustible substance.

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REACTIVITY & INCOMPATIBILITY

Ethylene dibromide reacts vigorously with alkali metals, zinc, magnesium, aluminum, caustic alkalis, strong oxidizers, and liquid ammonia. Liquid ethylene dibromide will attack some forms of plastic, rubber, and coatings.

STORAGE & HANDLING

Gloves: NA

In particular, work with ethylene dibromide should be conducted in a fume hood to prevent exposure by inhalation, and appropriate impermeable gloves and safety goggles should be worn to prevent skin contact. Gloves and protective clothing should be changed immediately if ethylene dibromide contamination occurs. Since ethylene dibromide can penetrate neoprene and other plastics, protective apparel made of these materials does not provide adequate protection from contact with ethylene dibromide.

CLEANUP & DISPOSAL

Excess ethylene dibromide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Ethylene dibromide is not suitable for use by students because of its toxicity.

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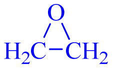
ETHYLENE OXIDE

SYNONYMS	CAS#	Formula
1,2-Epoxyethane; oxacyclopropane; dimethylene oxide	75-21-8	

PHYSICAL PROPERTIES

Odor:	Sweet odor detectable at 257 to 690 ppm (mean = 420 ppm)	**Appearance:**	Colorless liquid or gas
Water Solubility:	Miscible with water	**Vapor Density:**	1.5 at bp (air = 1.0)
Flash Point:	−20 °C	**Vapor Pressure:**	1,095 mmHg at 20 °C
Autoignition:	429 °C	**bp/mp:**	10.7 °C/−111.3 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	72 mg/kg	**TLV-TWA (ACGIH):**	1 ppm (2 mg/m^3)
LC_{50} inhal. (rat):	800 ppm (1,600 mg/m^3)	**PEL (OSHA):**	1 ppm (2 mg/m^3)

HEALTH AND SYMPTOMS

General	Ethylene oxide is a severe irritant to the eyes, skin, and respiratory tract and exhibits moderate acute toxicity by all routes of exposure. Symptoms of overexposure by inhalation may be delayed and can include nausea, vomiting, headache, drowsiness, and difficulty breathing. Ethylene oxide can cause serious burns to the skin, which may only appear after a delay of 1 to 5 hours. Ethylene oxide is listed by IARC in Group 2A (“probable human carcinogen”) and is classified as a “select carcinogen” under the criteria of the OSHA Laboratory Standard. There is some evidence from animal studies that ethylene oxide may be a developmental and reproductive toxin in both males and females. Exposure to this substance may lead to sensitization. Odor may not be detectable and therefore does not provide adequate warning.
Skin	Can cause serious burns, which may only appear after a delay of 1 to 5 hours. This substance may also be absorbed through the skin to cause the systemic effects listed above.
Eyes	Can cause severe burns.
Ingestion	Ingestion is unlikely, but toxic if ingested. Seek medical attention immediately..
Inhalation	Overexposure may be delayed and can include nausea, vomiting, headache, drowsiness, and difficulty breathing.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Extremely flammable liquid and vapor
NFPA rating (flammability) = 4; LEL = 3%; UEL = 100%

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Ethylene oxide is an extremely flammable substance. Ethylene oxide vapor may be ignited by hot surfaces such as hot plates and static electricity discharges, and since the vapor is heavier than air, it may travel a considerable distance to an ignition source and flash back. Ethylene oxide vapor forms explosive mixtures with air. Carbon dioxide or dry chemical extinguishers should be used for ethylene oxide fires. Ethylene oxide may explode when heated in a closed vessel.

REACTIVITY & INCOMPATIBILITY

Ethylene oxide can undergo violent polymerization, which can be initiated by contact with metal surfaces, strong acids or bases, alkali metals, iron oxide or chloride, and aluminum chloride.

STORAGE & HANDLING

In particular, work with ethylene oxide should be conducted in a fume hood to prevent exposure by inhalation, and appropriate impermeable gloves and splash goggles should be worn at all times to prevent skin and eye contact. Ethylene oxide should be used only in areas free of ignition sources and should be stored in the cold in tightly sealed containers placed within a secondary container.

CLEANUP & DISPOSAL

Excess ethylene oxide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Ethylene oxide is not suitable for use by students because of its explosivity.

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FLUORIDES (INORGANIC)

SYNONYMS	CAS#	Formula
Sodium fluoride	7681-49-4	NaF
Potassium fluoride		KF
Stannous fluoride		SnF

PHYSICAL PROPERTIES

Odor:	Odorless	**Appearance:**	White powder
Water Solubility:	NaF: 4.0 g/100 ml at 20°C KF: Easily soluble SnF: 30 g/100 ml at 20°C	**Vapor Density:**	NaF: NA KF: 2.0 (air = 1.0) SnF: NA
Flash Point:	NA	**Vapor Pressure:**	NA
Autoignition:	NA	**bp/mp:**	NaF: 1,700 °C/993 °C KF: 1505 °C/860 °C SnF: 830 °C /213 °C

TOXICITY		EXPOSURE LIMITS	
LD$_{50}$ oral (rat)	NaF: 52 mg/kg KF: 245 mg/kg SnF: 377 mg/kg	**TLV-TWA (ACGIH)**	NaF: 2.5 mg/m^3 KF: 2.5 mg/m^3 SnF: 2.5 mg/m^3
		PEL (OSHA)	NaF: 2.5 mg/m^3 KF: 2.5 mg/m^3 SnF: 2.5 mg/m^3

HEALTH AND SYMPTOMS

General	Moderate acute toxicity; irritating to eyes and respiratory tract. High exposures may cause irritation of the eyes and respiratory tract. In humans the approximate lethal dose of NaF by ingestion is 5 g. Fluorides have not been shown to be carcinogenic or to show reproductive or developmental toxicity in humans.
Skin	Repeated contact may cause a rash.
Eyes	High exposures may cause irritation.
Ingestion	May cause a salty or soapy taste, vomiting, abdominal pain, diarrhea, shortness of breath, difficulty in speaking, thirst, weak pulse, disturbed color vision, muscular weakness, convulsions, loss of consciousness, and death. In humans the approximate lethal dose of NaF by ingestion is 5 g.
Inhalation	Repeated inhalation of fluoride dust may cause excessive calcification of the bone and calcification of ligaments of the ribs, pelvis, and spinal column.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Fluorides are not combustible.

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REACTIVITY & INCOMPATIBILITY

Contact with strong acids may cause formation of highly toxic and corrosive hydrogen fluoride.

STORAGE & HANDLING

Gloves: NA

Fluorides should be handled in the laboratory using the "basic prudent practices."

CLEANUP & DISPOSAL

In the event of a spill, sweep up fluorides, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess fluorides and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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FLUORINE

SYNONYMS	CAS#	Formula
	7782-41-4	F_2

PHYSICAL PROPERTIES

Odor:	Strong ozonelike odor detectable at 0.1 to 0.2 ppm	**Appearance:**	Pale yellow gas
Water Solubility:	Reacts with water	**Vapor Density:**	1.3 (air = 1.0)
Flash Point:	NA	**Vapor Pressure:**	>760 mmHg at 20 °C
Autoignition:	NA	**bp/mp:**	−188 °C/−219°C

TOXICITY		EXPOSURE LIMITS	
LC_{50} inhal. (rat)	185 ppm (300 mg/m^3; 1 h)	**TLV-TWA (ACGIH)**	1 ppm (1.6 mg/m^3)
		STEL (ACGIH)	2 ppm (3.1 mg/m^3)
		PEL (OSHA)	0.1 ppm (0.2 mg/m^3)

HEALTH AND SYMPTOMS

General	The acute toxicity of fluorine is high. Even very low concentrations irritate the respiratory tract, and brief exposure to 50 ppm can be intolerable. High concentrations can cause severe damage to the respiratory system and can result in the delayed onset of pulmonary edema, which may be fatal. Chronic toxicity is unlikely to occur because of the corrosive effects of fluorine exposure. Fluorine has not been found to be carcinogenic or to show reproductive or developmental toxicity in humans. Fluorine is not considered to have adequate warning properties.
Skin	Extremely corrosive to the skin, causing damage similar to second-degree thermal bums.
Eyes	Highly irritating to the eyes, and high concentrations cause severe injury and can lead to permanent damage and blindness.
Ingestion	Ingestion of gas is unlikely.
Inhalation	High concentrations can cause severe damage to the respiratory system and can result in the delayed onset of pulmonary edema, which may be fatal.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA Rating (flammability) = 0; LEL = NA; UEL = NA

Fluorine is not flammable, but is a very strong oxidizer, reacting vigorously with most oxidizable materials at room temperature, frequently with ignition. Water should not be used to fight fires involving fluorine.

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REACTIVITY & INCOMPATIBILITY

Fluorine is an extremely powerful oxidizing agent that reacts violently with a great many materials, including water, most organic substances (including greases, many plastics, rubbers, and coatings), silicon-containing compounds, and most metals. The reaction with water produces HF and ozone. Fluorine reacts explosively or forms explosive compounds, often at very low temperatures, with chemicals as diverse as graphite, sodium acetate, stainless steel, perchloric acid, and water or ice. Fluorine ignites on contact with ammonia, ceramic materials, phosphorus, sulfur, copper wire, acetone, and many other organic and inorganic compounds. The literature on incompatibilities of fluorine should be carefully reviewed before attempting work with this substance.

STORAGE & HANDLING

Gloves: NA

Work with fluorine requires special precautions and protective equipment and should be carried out only by specially trained personnel. Fluorine will react with many materials normally recommended for handling compressed gases.

CLEANUP & DISPOSAL

In the event of a small leak, stop flow of gas if possible, or move cylinder to a fume hood or to a safe location in the open air. Accidental releases of fluorine require evacuation of the affected area and should be handled only by trained personnel equipped with proper protective clothing and respiratory protection. Excess fluorine should be returned to the manufacturer if possible, according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Fluorine gas is corrosive and not suitable for use by students.

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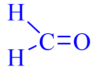
FORMALDEHYDE

SYNONYMS	CAS#	Formula
Methanal, formalin (37% aqueous solution, usually containing 10 to 15% methanol), paraformaldehyde (solid polymer)	50-00-0	

PHYSICAL PROPERTIES

Odor:	Pungent odor detectable at 1 ppm	**Appearance:**	Clear, colorless liquid
Water Solubility:	Miscible with water	**Vapor Density:**	~1 (air = 1.0)
Flash Point:	50 °C for formalin containing 15% methanol	**Vapor Pressure:**	Formaldehyde: 10 mmHg at −88 °C Formalin: 23 to 26 mmHg at 25 °C
Autoignition:	424 °C for formalin containing 15% methanol	**bp, mp:**	Formaldehyde: −19 °C/−92 °C Formalin: 96 °C/−15 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	500 mg/kg	**TLV-TWA (ACGIH):**	0.3 ppm (ceiling) (0.37 mg/m^3)
LC_{50} inhal. (rat):	203 mg/m^3 (2 h)	**STEL (ACGIH):**	2 ppm (2.5 mg/m^3)
LD_{50} skin (rabbit):	270 mg/kg	**PEL (OSHA):**	1 ppm (1.5 mg/m^3)

HEALTH AND SYMPTOMS

General	Formaldehyde is moderately toxic by skin contact and inhalation. Exposure to formaldehyde gas can cause irritation of the eyes and respiratory tract, coughing, dry throat, tightening of the chest, headache, a sensation of pressure in the head, and palpitations of the heart. Formaldehyde is regulated by OSHA as a carcinogen (Standard 29 CFR § 1910.1048) and is listed in IARC Group 2A (“probable human carcinogen”). This substance is classified as a “select carcinogen” under the criteria of the OSHA Laboratory Standard.
Skin	Prolonged or repeated exposure to formaldehyde can cause dermatitis and sensitization. Following contact, a symptom-free period may occur in sensitized individuals. Subsequent exposures can cause itching, redness, and blisters.
Eyes	Exposure to 0.1 to 5 ppm of formaldehyde causes irritation; above 10 ppm, severe lacrimation occurs. Formalin solutions can cause severe eye burns and loss of vision. Eye contact may lead to delayed effects that are not appreciably eased by eye washing.
Ingestion	Formaldehyde has low acute toxicity via the oral route. Can cause irritation of the mouth, throat, and stomach and nausea, vomiting, convulsions, and coma. An oral dose of 30 to 100 mL of 37% formalin can be fatal in humans.
Inhalation	Exposure to 0.1 to 5 ppm of formaldehyde causes irritation of the nose and throat; above 10 ppm, burning in the nose and throat is experienced and breathing becomes difficult. Acute exposure to concentrations above 25 ppm can cause serious injury, including fatal pulmonary edema. Can cause sensitization of the respiratory tract.

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FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Flammable liquid and vapor for 37% formaldehyde (15% methanol)

NFPA rating (flammability) = 2 for 37% formaldehyde (15% methanol)

NFPA rating (flammability) = 4 for 37% formaldehyde (methanol free); LEL = 7%; UEL = 73%

Formaldehyde gas is extremely flammable; formalin solution is a combustible liquid. Toxic vapors may be given off in a fire. Carbon dioxide or dry chemical extinguishers should be used to fight formaldehyde fires.

REACTIVITY & INCOMPATIBILITY

Formaldehyde may react violently with strong oxidizing agents, ammonia and strong alkalis, isocyanates, peracids, anhydrides, and inorganic acids. Formaldehyde reacts with HCl to form the potent carcinogen, bis(chloromethyl) ether.

STORAGE & HANDLING

Gloves: Nitrile, PVC, butyl rubber, Viton

In particular, work with formaldehyde should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Formaldehyde should be used only in areas free of ignition sources. Containers of formaldehyde should be stored in secondary containers in areas separate from oxidizers and bases.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources; soak up the formaldehyde with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess formaldehyde and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Formaldehyde is a carcinogen and not suitable for use by students.

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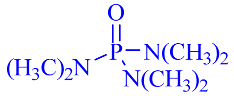
HEXAMETHYLPHOSPHORAMIDE

SYNONYMS	CAS#	Formula
Hexamethylphosphoric triamide, HMPA, HMPT	680-31-9	 $(H_3C)_2N{-}P(=O)(N(CH_3)_2)_2$

PHYSICAL PROPERTIES

Odor:	Spicy odor (no threshold data)	**Appearance:**	Colorless liquid
Water Solubility:	Completely miscible with water	**Vapor Density:**	6.2 (air = 1.0)
Flash Point:	105 °C	**Vapor Pressure:**	0.07 mmHg at 25 °C
Autoignition:		**bp/mp**	233 °C/6 °C

TOXICITY		EXPOSURE LIMITS
LD_{50} oral (rat)	2,525 mg/kg	
LD50 skin (rabbit)	2,600 mg/kg	

HEALTH AND SYMPTOMS

General	The acute toxicity of hexamethylphosphoramide is low. Hexamethylphosphoramide has been found to cause cancer in laboratory animals exposed by inhalation and meets the criteria for classification as an OSHA "select carcinogen." Chronic exposure to HMPA can cause damage to the lungs and kidneys. Reproductive effects in male animals treated with hexamethylphosphoramide have been observed. HMPA should be regarded as a substance with poor warning properties.
Skin	Can cause irritation upon contact.
Eyes	Can cause irritation upon contact.
Ingestion	Can cause irritation upon contact.
Inhalation	Can cause irritation of the respiratory tract.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 1; LEL = NA; UEL = NA

Combustible liquid. Its decomposition at high temperatures or in a fire can produce phosphine, phosphorus oxides, and oxides of nitrogen, which are extremely toxic. Carbon dioxide or dry chemical extinguishers should be used for HMPA fires.

REACTIVITY & INCOMPATIBILITY

Incompatible with strong oxidizing agents and strong acids.

STORAGE & HANDLING

In particular, this compound should be handled only in a fume hood, using appropriate impermeable gloves and splash goggles to prevent skin and eye contact. Containers of this substance should be stored in secondary containers

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CLEANUP & DISPOSAL

In the event of a spill, soak up the hexamethylphosphoramide with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess hexamethylphosphoramide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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HEXANE (and related aliphatic hydrocarbons)

SYNONYMS	CAS#	Formula
Normal hexane, skellysolve B	110-54-3	C_6H_{14}

PHYSICAL PROPERTIES

Odor:	Mild gasoline-like odor detectable at 65 to 248 ppm	**Appearance:**	Colorless liquid
Water Solubility:	0.014 g/100 mL	**Vapor Density:**	3.0 (air = 1.0)
Flash Point:	−21.7 °C	**Vapor Pressure:**	124 mmHg at 20 °C
Autoignition:	225 °C	**bp/mp**	69 °C/−95 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	28,700 mg/kg	**TLV-TWA (ACGIH):**	50 ppm
LC_{50} inhal. (rat):	48000 ppm (4h)	**STEL (ACGIH):**	1000ppm
		PEL (OSHA):	500 ppm (1,800 mg/m^3)

HEALTH AND SYMPTOMS

General	Hexane and related aliphatic hydrocarbons exhibit only slight acute toxicity by all routes of exposure. The liquid may cause irritation upon contact with skin or eyes. Chronic exposure to hexane or other aliphatic hydrocarbons may cause central nervous system toxicity. Hexane has not been found to be a carcinogen or reproductive toxin in humans. Odor is a suitable indicator for the presence of the substance.
Skin	Prolonged skin exposure may cause irritation due to the ability of these solvents to remove fats from the skin.
Eyes	The liquid may cause irritation upon contact with skin or eyes.
Ingestion	Ingestion of hexane or other hydrocarbons may lead to aspiration of the substance into the lungs, causing pneumonia.
Inhalation	Hexane vapor (and the vapor of other volatile hydrocarbons) at high concentrations (>1,000 ppm) is a narcotic, and inhalation may result in lightheadedness, giddiness, nausea, and headache.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, mover the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating (flammability) = 3; LEL = 1.1%; UEL = 7.5 %

Hexane is extremely flammable, and its vapor can travel considerable distance to an ignition source and flash back. Hexane vapor forms explosive mixtures with air. Hydrocarbons of significantly higher molecular weight have correspondingly higher vapor pressures and therefore present a reduced flammability hazard. Carbon dioxide or dry chemical extinguishers should be used for hexane fires.

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REACTIVITY & INCOMPATIBILITY

Contact with strong oxidizing agents may cause explosions or fires.

STORAGE & HANDLING

Gloves: Nitrile

In particular, hexane should be used only in areas free of ignition sources, and quantities greater than 1 L should be stored in tightly sealed metal containers in areas separate from oxidizers.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources; soak up the hexane with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess hexane and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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HYDRAZINE

SYNONYMS	CAS#	Formula
Diamide, diamine	302-01-2	NH_2NH_2

PHYSICAL PROPERTIES

Odor:	Fishy or ammonia-like odor detectable at 3 to 4 ppm (mean = 3.7 ppm)	**Appearance:**	Colorless oily liquid that fumes in air
Water Solubility:	Miscible with water	**Vapor Density:**	1.04 (air = 1.0)
Flash Point:	38 °C	**Vapor Pressure:**	14.4 mmHg at 25 °C
Autoignition:	24 °C on iron rust surface; 270 °C on glass surface	**bp/mp**	113.5 °C/1.4 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	60 mg/kg	**TLV-TWA (ACGIH):**	0.1 ppm (0.13 mg/m^3)—skin
LC_{50} inhal. (rat):	570 ppm (744 mg/m^3; 4 h)	**PEL (OSHA) :**	1 ppm (1.3 mg/m^3)—skin
LD50 skin (rabbit):	91 mg/kg		

HEALTH AND SYMPTOMS

General	Chronic exposure to subacute levels of hydrazine can cause lethargy, vomiting, tremors, itching and burning of the eyes and skin, conjunctivitis, and contact dermatitis. It is extremely destructive to the tissues of the mucous membranes and upper respiratory tract, eyes, and skin. Hydrazine is listed by IARC in Group 2B "possible human carcinogen" and is classified as a "select carcinogen" according to the criteria of the OSHA Laboratory Standard. Hydrazine has been found to exhibit reproductive and developmental toxicity in animal tests. Odor may not be detectable and therefore does not provide adequate warning.
Skin	Can result in severe burns and is readily absorbed through the skin, leading to systemic effects, which may include damage to the liver, kidney, nervous system, and red blood cells.
Eyes	Vapor is extremely irritating and can cause temporary blindness. Contact can result in severe burns and permanent damage.
Ingestion	Toxic if swallowed. Causes burns to the mouth and throat.
Inhalation	Vapor is irritating to the nose, throat, and respiratory tract, and inhalation of high concentrations may be fatal as a result of spasm, inflammation, chemical pneumonitis, and pulmonary edema. Symptoms include a burning sensation, coughing, wheezing, laryngitis, shortness of breath, headache, nausea, and vomiting.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 3; LEL = 2.9%; UEL = 98%

Hydrazine is a flammable liquid over a very broad range of vapor concentrations (4.7 to 100%). May undergo autoxidation and ignite spontaneously when brought in contact with porous substances such as rusty surfaces, earth, wood, or cloth. Fires should be extinguished with water spray, carbon dioxide, or dry chemical extinguishers.

REACTIVITY & INCOMPATIBILITY

Highly reactive reducing agent that forms shock-sensitive, explosive mixtures with many compounds. Explodes on contact with barium oxide, calcium oxide, chromate salts, and many other substances. Decomposes on contact with metal catalysts (platinum black, Raney nickel, etc.), to ammonia, hydrogen, and nitrogen gases, which may ignite or explode.

STORAGE & HANDLING

Gloves: Neoprene, butyl rubber, PVC, nitrile

All work should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Use only in areas free of ignition sources. Store under nitrogen in containers placed in secondary containers in areas separate from oxidizers and acids.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, soak up the hydrazine with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Evacuation and cleanup using respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess hydrazine and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Hydrazine is not suitable for use by students.

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HYDROBROMIC ACID AND HYDROGEN BROMIDE

SYNONYMS	CAS#	Formula
	10035-10-6	HBr

PHYSICAL PROPERTIES

Odor:	Sharp, irritating odor detectable at 2 ppm	**Appearance:**	Colorless oily liquid that fumes in air
Water Solubility:	Miscible with water	**Vapor Density:**	2.71 (air = 1.0)
Flash Point:	NA	**Vapor Pressure:**	18384 mmHg at 20°C
Autoignition:	NA	**bp/mp:**	-67 °C/ -87°C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	900 mg/kg	**TLV-TWA (ACGIH):**	3 ppm (10 mg/m^3; ceiling)
LC_{50} inhal. (rat):	2,858 ppm (1 h)	**PEL (OSHA) :**	3 ppm (10 mg/m^3)
LD50 skin (rabbit):	91 mg/kg		

HEALTH AND SYMPTOMS

General	HBr is highly a corrosive substance that can cause severe burns upon contact with all body tissues. The odor is a good indicator of the molecule's presence. Hydrogen bromide has not been found to be carcinogenic or to show reproductive or developmental toxicity in humans.
Skin	Skin contact with the aqueous acid or HBr gas can produce severe burns.
Eyes	The aqueous acid and gas are strong irritants and lachrymators. Contact of concentrated hydrobromic acid or concentrated HBr vapor with the eyes may cause severe injury, resulting in permanent impairment of vision and possible blindness.
Ingestion	Ingestion can lead to severe burns of the mouth, throat, and gastrointestinal system and can be fatal.
Inhalation	Inhalation of hydrogen bromide gas can cause extreme irritation and injury to the upper respiratory tract and lungs, and exposure to high concentrations may cause death.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Noncombustible, but contact with metals may produce highly flammable hydrogen gas.

REACTIVITY & INCOMPATIBILITY

Hydrobromic acid and hydrogen bromide react violently with many metals with the generation of highly flammable hydrogen gas, which may explode. Reaction with oxidizers such as permanganates, chlorates, chlorites, and hypochlorites may produce chlorine or bromine.

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STORAGE & HANDLING

Gloves: Neoprene

Splash goggles and rubber gloves should be worn when handling this acid. Store in a well-ventilated location separate from incompatible metals. Water should never be added to HBr because splattering may result. Containers of hydrobromic acid should be stored in secondary plastic trays to avoid corrosion of metal storage shelves due to drips or spills. Cylinders of hydrogen bromide should be stored in cool, dry locations, separated from alkali metals and other incompatible substances.

CLEANUP & DISPOSAL

Carefully neutralize spills of hydrobromic acid with a suitable agent such as powdered sodium bicarbonate, further dilute with absorbent material, place in an appropriate container, and dispose of properly. Dilution with water before applying the solid adsorbent may be an effective means of reducing exposure to hydrogen bromide vapor. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Leaks of HBr gas are evident from the formation of dense white fumes on contact with the atmosphere. Small leaks can be detected by holding an open container of concentrated ammonium hydroxide near the site of the suspected leak; dense white fumes confirm a leak is present. In case of the accidental release of hydrogen bromide gas, such as from a leaking cylinder or associated apparatus, evacuate the area and eliminate the source of the leak if this can be done safely. Remove cylinder to a fume hood or remote area if it cannot be shut off. Full respiratory protection and protective clothing may be required to deal with a hydrogen bromide release. In many localities, hydrobromic acid or the residue from a spill may be disposed of down the drain after appropriate dilution and neutralization. Otherwise, hydrobromic acid and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines. Excess hydrogen bromide in cylinders should be returned to the manufacturer.

ADDITIONAL CONSIDERATIONS

HBr is poisonous and corrosive and is not suitable for use by students.

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HYDROCHLORIC ACID AND HYDROGEN CHLORIDE

SYNONYMS	CAS#	Formula
Muriatic acid	7647-01-0	HCl

PHYSICAL PROPERTIES

Odor:	Sharp, irritating odor detectable at 0.25 to 10 ppm	**Appearance:**	Colorless oily liquid that fumes in air
Water Solubility:	Miscible with water	**Vapor Density:**	1.27 (air = 1.0)
Flash Point:	NA	**Vapor Pressure:**	NA
Autoignition:	NA	**bp/mp:**	-85 °C/-114 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	900 mg/kg	**TLV-TWA (ACGIH):**	5 ppm (7.5 mg/m^3; ceiling)
LC_{50} inhal. (rat):	3,124 ppm (1 h)	**PEL (OSHA) :**	5 ppm (7 mg/m^3; ceiling)

HEALTH AND SYMPTOMS

General	Hydrochloric acid and hydrogen chloride gas are highly corrosive substances that may cause severe burns upon contact with any body tissue. The odor is a good indicator of the molecule's presence.
Skin	Skin contact results in severe burns.
Eyes	The aqueous acid and gas are strong eye irritants and lachrymators. Contact of concentrated hydrochloric acid or concentrated HCl vapor with the eyes may cause severe injury, resulting in permanent impairment of vision and possible blindness,
Ingestion	Ingestion can cause severe burns of the mouth, throat, and gastrointestinal system and can be fatal.
Inhalation	Inhalation of hydrogen chloride gas can cause severe irritation and injury to the upper respiratory tract and lungs, and exposure to high concentrations may cause death.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Noncombustible, but contact with metals may produce highly flammable hydrogen gas.

REACTIVITY & INCOMPATIBILITY

Hydrochloric acid and hydrogen chloride react violently with many metals, with the generation of highly flammable hydrogen gas, which may explode. Reaction with oxidizers such as permanganates, chlorates, chlorites, and hypochlorites may produce chlorine or bromine.

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STORAGE & HANDLING

Gloves: Neoprene

Splash goggles and rubber gloves should be worn when handling this acid. Containers of HCl should be stored in a well-ventilated location in a secondary plastic tray to avoid corrosion of metal storage shelves due to drips or spills. Water should never be added to HCl because splattering may result; always add acid to water.

CLEANUP & DISPOSAL

Neutralize spills of HCl with powdered sodium bicarbonate. Dilution with water before applying the solid adsorbent may be an effective means of reducing exposure to hydrogen chloride vapor. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Leaks of HCl gas are evident from the formation of dense white fumes on contact with the atmosphere. Small leaks can be detected by holding an open container of concentrated ammonium hydroxide near the site of the suspected leak; dense white fumes confirm that a leak is present. In case of accidental release of hydrogen chloride gas, such as from a leaking cylinder or associated apparatus, evacuate the area and eliminate the source of the leak if this can be done safely. Remove cylinder to a fume hood or remote area if it cannot be shut off. Full respiratory protection and protective clothing may be required to deal with a hydrogen chloride release. In many localities, hydrochloric acid or the residue from a spill may be disposed of down the drain after appropriate dilution and neutralization. Otherwise, hydrochloric acid and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines. Excess hydrogen chloride in cylinders should be returned to the manufacturer.

ADDITIONAL CONSIDERATIONS

Hydrochloric acid and hydrogen chloride are poisonous and corrosive and are not suitable for use by students.

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HYDROGEN

SYNONYMS	CAS#	Formula
Water gas	1333-74-0	H_2

PHYSICAL PROPERTIES

Odor:	Odorless gas	**Appearance:**	Colorless gas
Water Solubility:	Slightly soluble in water (0.17 mg/100 mL)	**Vapor Density:**	0.069 (air = 1.0)
Flash Point:	NA	**Vapor Pressure:**	Critical temp. = −239.9 °C; noncondensible above this temperature
Autoignition:	500 to 590 °C	**bp/mp:**	bp −252.8 °C/mp −259.2 °C

TOXICITY	EXPOSURE LIMITS	
	TLV-TWA (ACGIH):	None established; simple asphyxiant

HEALTH AND SYMPTOMS

General	Hydrogen is practically nontoxic.
Skin	Skin contact with liquid hydrogen can cause frostbite.
Eyes	Contact with liquid hydrogen can cause frostbite.
Ingestion	NA
Inhalation	In high concentrations this gas is a simple asphyxiant, and ultimate loss of consciousness may occur when oxygen concentrations fall below 18%.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	NA
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 4

Hydrogen is a highly flammable gas that burns with an almost invisible flame and low heat radiation. Hydrogen forms explosive mixtures with air. These explosive mixtures of hydrogen with air (or oxygen) can be ignited by a number of finely divided metals (such as common hydrogenation catalysts). In the event of fire, shut off the flow of gas and extinguish with carbon dioxide, dry chemical, or halon extinguishers. Warming of liquid hydrogen contained in an enclosed vessel to above its critical temperature can cause bursting of that container.

REACTIVITY & INCOMPATIBILITY

Hydrogen is a reducing agent and reacts explosively with strong oxidizers such as halogens (fluorine, chlorine, bromine, iodine) and interhalogen compounds.

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STORAGE & HANDLING

In particular, hydrogen cylinders should be clamped or otherwise supported in place and used only in areas free of ignition sources and separate from oxidizers. Expansion of hydrogen released rapidly from a compressed cylinder will cause evolution of heat due to its negative Joule-Thompson coefficient.

CLEANUP & DISPOSAL

Excess hydrogen cylinders should be returned to the vendor. Excess hydrogen gas present over reaction mixtures should be carefully vented to the atmosphere under conditions of good ventilation after all ignition sources have been removed.

ADDITONAL CONSIDERATIONS

Flammable gas, not suitable for use by students.

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HYDROGEN CYANIDE

SYNONYMS	CAS#	Formula
Hydrocyanic acid, prussic acid	74-90-8	$HC\equiv N$

PHYSICAL PROPERTIES

Odor:	Bitter almond odor detectable at 1 to 5 ppm; however, 20 to 60% of the population are reported to be unable to detect the odor of HCN	**Appearance:**	Colorless or pale blue liquid or gas
Water Solubility:	Miscible in water in all proportions	**Vapor Density:**	0.94 (air = 1.0)
Flash Point:	−18 °C	**Vapor Pressure:**	750 mmHg at 25 °C
Autoignition:	538 °C	**bp/mp:**	26 °C/−13 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	10 mg/kg	**TLV-TWA (ACGIH):**	10 ppm (11 mg/m^3)—skin
LC_{50} inhal. (rat):	63 ppm (40 min)	**PEL (OSHA):**	10 ppm (11 mg/m^3)—skin
LD_{50} skin (rabbit):	1,500 mg/kg		

HEALTH AND SYMPTOMS

General	Fatal by all routes of exposure. The acute toxicity of hydrogen cyanide is high, and exposure by inhalation, ingestion, or eye or skin contact can be rapidly fatal. Symptoms observed at low levels of exposure (e.g., inhalation of 18 to 36 ppm for several hours) include weakness, headache, confusion, nausea, and vomiting. Effects of chronic exposure to hydrogen cyanide are nonspecific and rare. Because there is wide variation in the ability of different individuals to detect the odor of HCN, this substance is regarded as having poor warning properties. Effects of chronic exposure to hydrogen cyanide are nonspecific and rare.
Skin	Aqueous solutions of HCN are readily absorbed through the skin, and absorption of 50 mg can be fatal.
Eyes	Aqueous solutions of HCN are readily absorbed through the eyes, and absorption of 50 mg can be fatal.
Ingestion	Ingestion of 50 to 100 mg of HCN can be fatal.
Inhalation	Inhalation of 270 ppm can cause immediate death, and 100 to 200 ppm can be fatal in 30 to 60 minutes.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

Extremely flammable liquid and vapor

NFPA rating (flammability) = 4; LEL = 5.6%; UEL = 40%

Hydrogen cyanide is a highly flammable liquid. Liquid HCN contains a stabilizer (usually phosphoric acid), and old samples may explode if the acid stabilizer is not maintained at a sufficient concentration.

REACTIVITY & INCOMPATIBILITY

HCN can polymerize explosively if heated above 50 °C or in the presence of trace amounts of alkali.

STORAGE & HANDLING

Gloves: Viton or butyl rubber

Specific medical procedures for treating cyanide exposure are available but usually must be administered by properly trained personnel. Consult your environmental, health, and safety office or its equivalent before beginning work with hydrogen cyanide. In particular, work with HCN should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Never work alone with hydrogen cyanide. HCN should be used only in areas free of ignition sources. Containers of HCN should be protected from physical damage and stored in areas separate from ignition sources and other materials. Hydrogen cyanide should not be stored for extended periods (>90 days) unless testing confirms product quality.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources. Cleanup should be conducted wearing appropriate chemical-resistant clothing and respiratory protection. Excess hydrogen cyanide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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HYDROGEN FLUORIDE AND HYDROFLUORIC ACID

SYNONYMS	CAS#	Formula
	7664-39-3	HF

PHYSICAL PROPERTIES

Odor:	Acrid, irritating odor	**Appearance:**	Colorless, clear, fuming liquid
Water Solubility:	Miscible with water	**Vapor Density:**	
Flash Point:	Noncombustible	**Vapor Pressure:**	Anhydrous HF: 775 mmHg at 20 °C Hydrofluoric acid: 14 mmHg at 20 °C
Autoignition:	NA	**bp/mp:**	Anhydrous HF: 20 °C/−83 °C

TOXICITY		EXPOSURE LIMITS	
LD$_{50}$ oral (rat):	Humans, 50 ppm (0.5 h)	**TLV-TWA (ACGIH):**	3 ppm (2.6 mg/m^3; ceiling as fluoride)
		PEL (OSHA):	3 ppm (as fluoride)

HEALTH AND SYMPTOMS

General	Anhydrous hydrogen fluoride and hydrofluoric acid are extremely corrosive to all tissues of the body. HF has not been reported to be a human carcinogen. No acceptable animal test reports are available to define the developmental or reproductive toxicity of this substance.
Skin	Skin contact results in painful deep-seated burns that are slow to heal. Burns from dilute (<50%) HF solutions do not usually become apparent until several hours after exposure; more concentrated solutions and anhydrous HF cause immediate painful burns and tissue destruction. HF burns pose unique dangers distinct from other acids such as HCl and H_2SO_4: undissociated HF readily penetrates the skin, damaging underlying tissue; fluoride ion can then cause destruction of soft tissues and decalcification of the bones.
Eyes	Hydrofluoric acid and HF vapor can cause severe burns to the eyes, which may lead to permanent damage and blindness. At 10 to 15 ppm, HF vapor is irritating to the eyes, skin, and respiratory tract.
Ingestion	Ingestion of HF can produce severe injury to the mouth, throat, and gastrointestinal tract and may be fatal.
Inhalation	Exposure to higher concentrations can result in serious damage to the lungs, and fatal pulmonary edema may develop after a delay of several hours. Brief exposure (5 min) to 50 to 250 ppm may be fatal to humans.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Hydrogen fluoride is not a combustible substance

REACTIVITY & INCOMPATIBILITY

HF reacts with glass, ceramics, and some metals. Reactions with metals may generate potentially explosive hydrogen gas.

STORAGE & HANDLING

Gloves: Neoprene

All work with HF should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and neoprene gloves should be worn at all times to prevent eye and skin contact. Containers of HF should be stored in secondary containers made of polyethylene in areas separate from incompatible materials. Work with anhydrous HF should be undertaken using special equipment and only by well-trained personnel familiar with first-aid procedures.

CLEANUP & DISPOSAL

In the event of a spill of dilute hydrofluoric acid, soak up the acid with an HF-compatible spill pillow or neutralize with lime, transfer material to a polyethylene container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Releases of anhydrous HF require specially trained personnel. Excess hydrogen fluoride and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Hydrogen fluoride is corrosive and is not suitable for use by students.

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HYDROGEN PEROXIDE

SYNONYMS	CAS#	Formula
Hydrogen dioxide	7722-84-1	HOOH

PHYSICAL PROPERTIES

Odor:	Slightly pungent, irritating odor	**Appearance:**	Colorless liquid
Water Solubility:	Miscible in all proportions in water	**Vapor Density:**	1.15 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	1 mmHg at 15.3 °C 5 mmHg at 30 °C
Autoignition:	None	**bp/mp:**	150 °C/−0.4 °C

TOXICITY		EXPOSURE LIMITS	
LD$_{50}$ oral (rat):	75 mg/kg (70%)	**TLV-TWA (ACGIH):**	1 ppm (1.4 mg/m^3) (90%)
LC$_{50}$ inhal. (rat):	>2,000 ppm (90%)	**PEL (OSHA):**	1 ppm (1.4 mg/m^3) (90%)
LD$_{50}$ skin (rabbit):	700 mg/kg (90%), 9,200 mg/kg (70%)		

HEALTH AND SYMPTOMS

General	Extremely corrosive liquid and vapor that can cause severe injury via skin and eye contact, inhalation, or ingestion.
Skin	Contact with aqueous concentrations of less than 50% causes skin irritation, but more concentrated solutions of H_2O_2 are corrosive to the skin.
Eyes	At greater than 10% concentration, hydrogen peroxide is corrosive to the eyes and can cause severe irreversible damage and possibly blindness.
Ingestion	Hydrogen peroxide is moderately toxic by ingestion.
Inhalation	Hydrogen peroxide is slightly toxic by inhalation. Repeated inhalation exposures produce nasal discharge, bleached hair, and respiratory tract congestion, with some deaths occurring in rats and mice exposed to concentrations greater than 67 ppm.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = 40%; UEL = 100%

Hydrogen peroxide is not flammable, but concentrated solutions may undergo violent decomposition in the presence of trace impurities or upon heating.

REACTIVITY & INCOMPATIBILITY

Contact with many organic compounds can lead to immediate fires or violent explosions (consult *Bretherick* for references and examples). Hydrogen peroxide reacts with certain organic functional groups (ethers, acetals, etc.) to form peroxides, which may explode upon concentration. Reaction

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with acetone generates explosive cyclic dimeric and trimeric peroxides. Explosions may also occur on exposure of hydrogen peroxide to metals such as sodium, potassium, magnesium, copper, iron, and nickel.

STORAGE & HANDLING

Gloves: Nitrile, PVC, natural rubber

Use extreme care when carrying out reactions with hydrogen peroxide because of the fire and explosion potential (immediate or delayed). The use of safety shields is advisable, and is essential for experiments involving concentrated (>50%) solutions of hydrogen peroxide. Sealed containers of hydrogen peroxide can build up dangerous pressures of oxygen, owing to slow decomposition.

CLEANUP & DISPOSAL

Excess hydrogen peroxide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your institution's waste disposal guidelines. For more information on disposal procedures, see Chapter 8 of this book.

ADDITIONAL CONSIDERATIONS

None

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HYDROGEN SULFIDE

SYNONYMS	CAS#	Formula
Hydrosulfuric acid, sulfur hydride	7783-06-4	H_2S

PHYSICAL PROPERTIES			
Odor:	Strong rotten egg odor detectable at 0.001 to 0.1 ppm (mean = 0.0094 ppm); olfactory fatigue occurs quickly at high concentrations	**Appearance:**	Colorless gas
Water Solubility:	Slightly soluble in water (0.03 g/100 mL at 20 °C)	**Vapor Density:**	8.8 (air = 1.0)
Flash Point:	< −82.4 °C	**Vapor Pressure:**	20 atm at 25 °C
Autoignition:	260 °C	**bp/mp:**	−61 °C/−83 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat)	444 ppm (580 mg/m^3)	**TLV-TWA (ACGIH)**	10 ppm (14 mg/m^3)
LC_{LO} inhal. (human)	800 ppm (1,110 mg/m^3; 5 min)	**STEL (ACGIH)**	15 ppm (21 mg/m^3)
		PEL (OSHA	20 ppm (ceiling) (28 mg/m^3)

HEALTH AND SYMPTOMS	
General	Hydrogen sulfide has not been shown to be carcinogenic or to have reproductive or developmental effects in humans. Although the odor of hydrogen sulfide is detectable at very low concentrations, it rapidly causes olfactory fatigue at higher levels, and therefore is not considered to have adequate warning properties.
Skin	Iodine in crystalline form or in concentrated solutions is a severe skin irritant; it is not easily removed from the skin, and the lesions resemble thermal burns.
Eyes	Low concentrations of H_2S (20 to 150 ppm) can cause eye irritation, which may be delayed in onset.
Ingestion	Ingestion of gas is unlikely.
Inhalation	The acute toxicity of hydrogen sulfide by inhalation is moderate. A 5-minute exposure to 800 ppm has resulted in death. Inhalation of 1,000 to 2,000 ppm may cause coma after a single breath. Exposure to lower concentrations may cause headache, dizziness, and upset stomach.

FIRST AID	
Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

Extremely flammable liquid and vapor

NFPA rating (flammability) = 4; LEL = 4.3%; UEL = 45.5%

Combustion products (sulfur oxides) are also toxic by inhalation. In the event of a hydrogen sulfide fire, stop the flow of gas if possible without risk of harmful exposure and let the fire burn itself out.

REACTIVITY & INCOMPATIBILITY

Hydrogen sulfide is incompatible with strong oxidizers. It will attack many metals, forming sulfides. Liquid hydrogen sulfide will attack some forms of plastic, rubber, and coatings. H_2S reacts violently with a variety of metal oxides, including the oxides of chromium, mercury, silver, lead, nickel, and iron.

STORAGE & HANDLING

Gloves: Butyl rubber, PVC, neoprene

Cylinders of hydrogen sulfide should be stored and used in a continuously ventilated gas cabinet or fume hood. Local fire codes should be reviewed for limitations on quantity and storage requirements.

CLEANUP & DISPOSAL

To respond to a release, use appropriate protective equipment and clothing. Positive-pressure air-supplied respiratory protection is required. Close cylinder valve and ventilate area. Remove cylinder to a fume hood or remote area if it cannot be shut off. Excess hydrogen sulfide should be returned to the manufacturer, according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Hydrogen sulfide is poisonous and flammable and is not suitable for use by students.

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IODINE

SYNONYMS	CAS#	Formula
	7553-56-2	I_2

PHYSICAL PROPERTIES

Odor:	Sharp, characteristic odor	**Appearance:**	Blue-violet to black crystalline solid
Water Solubility:	Slightly soluble in water (0.03 g/100 mL at 20 °C)	**Vapor Density:**	8.8 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	0.3 mmHg at 20 °C
Autoignition:		**bp/mp:**	185 °C/114 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	14,000 mg/kg	**TLV-TWA (ACGIH):**	0.1 ppm (ceiling, 1 mg/m^3)
LC_{50} inhal. (rat):	80 ppm (800 mg/m^3; 1 h)	**PEL (OSHA):**	0.1 ppm (ceiling, 1 mg/m^3)

HEALTH AND SYMPTOMS

General	Chronic absorption of iodine may cause insomnia, inflammation of the eyes and nose, bronchitis, tremor, rapid heartbeat, diarrhea, and weight loss. Iodine has not been found to be carcinogenic or to show reproductive or developmental toxicity in humans. Chronic absorption of iodine may cause insomnia, inflammation of the eyes and nose, bronchitis, tremor, rapid heartbeat, diarrhea, and weight loss.
Skin	Iodine in crystalline form or in concentrated solutions is a severe skin irritant; it is not easily removed from the skin, and the lesions resemble thermal burns.
Eyes	In an experimental investigation, four human subjects tolerated 0.57 ppm iodine vapor for 5 minutes without eye irritation, but all experienced eye irritation in 2 minutes at 1.63 ppm.
Ingestion	Iodine is more toxic by the oral route in humans than in experimental animals; ingestion of 2 to 3 g of the solid may be fatal in humans.
Inhalation	The acute toxicity of iodine by inhalation is high. Exposure may cause severe breathing difficulties, which may be delayed in onset; headache, tightness of the chest, and congestion of the lungs may also result.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Iodine is noncombustible and in itself represents a negligible fire hazard when exposed to heat or flame. However, when heated, it will increase the burning rate of combustible materials.

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REACTIVITY & INCOMPATIBILITY

Iodine is stable under normal temperatures and pressures. Iodine may react violently with acetylene, ammonia, acetaldehyde, formaldehyde, acrylonitrile, powdered antimony, tetraaminecopper(II) sulfate, and liquid chlorine. Iodine can form sensitive, explosive mixtures with potassium, sodium, and oxygen difluoride; ammonium hydroxide reacts with iodine to produce nitrogen triiodide, which detonates on drying.

STORAGE & HANDLING

Gloves: Viton or PVC

In particular, safety goggles and rubber gloves should be worn when handling iodine, and operations involving large quantities should be conducted in a fume hood to prevent exposure to iodine vapor or dusts by inhalation.

CLEANUP & DISPOSAL

Excess iodine and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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LEAD AND ITS INORGANIC COMPOUNDS

SYNONYMS	CAS#	Formula
	7439-92-1	Pb

PHYSICAL PROPERTIES

Odor:	Odorless	**Appearance:**	Bluish-white, silvery, or gray solid
Water Solubility:	Insoluble (metal; solubility of lead salts varies)	**Vapor Density:**	8.8 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	0.3 mmHg at 20 °C
Autoignition:	NA	**bp/mp:**	1,740 °C/327 °C

TOXICITY		EXPOSURE LIMITS	
LD_{LO} oral (pigeon):	160 mg/kg	**TLV-TWA (ACGIH):**	0.05 mg/m^3
		PEL (OSHA):	0.05 mg/m^3
		PEL (action level):	0.03 mg/m^3

HEALTH AND SYMPTOMS

General	The acute toxicity of lead and inorganic lead compounds is moderate to low. Symptoms of exposure include decreased appetite, insomnia, headache, muscle and joint pain, colic, and constipation. Lead can accumulate in the soft tissues and bones, with the highest accumulation in the liver and kidneys, and elimination is slow. Lead has shown developmental and reproductive toxicity in both male and female animals and humans. Lead is listed by IARC in Group 2B ("possible human carcinogen") and by the National Toxicology Program as "reasonably anticipated to be a carcinogen," but is not considered to be a "select carcinogen" under the criteria of the OSHA Laboratory Standard.
Skin	Inorganic lead compounds are not significantly absorbed through the skin.
Eyes	May cause irritation.
Ingestion	Chronic exposure to inorganic lead via ingestion can result in damage to the peripheral and central nervous system, anemia, and chronic kidney disease.
Inhalation	Chronic exposure to inorganic lead via inhalation can result in damage to the peripheral and central nervous system, anemia, and chronic kidney disease.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Lead powder is combustible when exposed to heat or flame.

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REACTIVITY & INCOMPATIBILITY

Violent reactions of lead with sodium azide, zirconium, sodium acetylide, and chlorine trifluoride have been reported. Reactivity of lead compounds varies depending on structure.

STORAGE & HANDLING

Gloves: Viton, butyl rubber, PVC

Lead should be handled in the laboratory using the "basic prudent practices" described in Chapter 6. In particular, work with lead dust, molten lead, and lead salts capable of forming dusts should be conducted in a fume hood to prevent exposure by inhalation.

CLEANUP & DISPOSAL

Excess lead and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines. For more information on disposal procedures, see Chapter 8 of this volume.

ADDITIONAL CONSIDERATIONS

Lead and its inorganic salts can often be replaced with copper inorganic salts.

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LITHIUM ALUMINUM HYDRIDE

SYNONYMS	CAS#	Formula
LAH, lithium tetrahydroaluminate	16853-85-3	$LiAlH_4$

PHYSICAL PROPERTIES

Odor:	Odorless solid	**Appearance:**	White to gray crystalline solid
Water Solubility:	Reacts vigorously with water	**Vapor Density:**	Not available
Flash Point:	Not available	**Vapor Pressure:**	Not available
Autoignition:	Ignites in moist or heated air	**mp:**	125 °C

TOXICITY	EXPOSURE LIMITS	
	TLV-TWA (ACGIH):	2 mg (Al)/m^3

HEALTH AND SYMPTOMS

General	Lithium aluminum hydride is highly corrosive to the skin, eyes, and mucous membranes. Contact with moisture forms lithium hydroxide, which can cause severe burns. No chronic effects of lithium aluminum hydride have been identified.
Skin	See General.
Eyes	See General.
Ingestion	Ingestion of this substance may cause aching muscles, nausea, vomiting, dizziness, and unconsciousness and may be fatal. Ingestion can result in gas embolism due to the formation of hydrogen.
Inhalation	Powdered LAH forms dusts that can pose an inhalation hazard.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 3; LEL = NA; UEL = NA

Lithium aluminum hydride is a highly flammable solid and may ignite in moist or heated air. Exposure to water results in the release of hydrogen, which can be ignited by the heat from the exothermic reaction. Lithium aluminum hydride should not be used as a drying agent for solvents because fires can easily result (LAH decomposes at about 125° C, a temperature easily reached at a flask's surface in a heating mantle). The decomposition products of LAH can be quite explosive, and the products of its reaction with carbon dioxide have been reported to be explosive. Use dry chemical powder or sand to extinguish fires involving lithium aluminum hydride. ***Never use water or carbon dioxide extinguishers on an LAH fire.***

REACTIVITY & INCOMPATIBILITY

Lithium aluminum hydride reacts violently with water, acids, oxidizers, alcohols, and many oxygenated organic compounds, including, in particular, peroxides, hydroperoxides, and peracids. LAH reacts with many metal halides to produce metal hydride products, which are flammable and toxic.

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STORAGE & HANDLING

Gloves: Butyl rubber

Work with LAH should be conducted in a fume hood under an inert gas such as nitrogen or argon in areas free of ignition sources under an inert atmosphere. Safety glasses, impermeable gloves, and a fire-retardant laboratory coat are required. A dry-powder fire extinguisher or pail of sand (and shovel) must be available in areas where LAH is to be handled or stored. LAH hydride should be stored in tightly sealed containers in a cool, dry area separate from combustible materials. Dry LAH powder should never be exposed to water or moist air. Lithium aluminum hydride can be a finely powdered reagent that produces a reactive dust on handling. Grinding lithium aluminum hydride prior to use can cause explosions and should not be employed.

CLEANUP & DISPOSAL

In the event of a spill, instruct others to maintain a safe distance; while wearing a face shield and goggles, laboratory coat, and butyl rubber gloves, cover the spilled material with sand. Scoop the resulting mixture into a container suitable for treatment or disposal as discussed below. Small amounts of excess LAH can be destroyed by forming a suspension or solution in an inert solvent such as diethyl ether or hexane, cooling in an ice bath, and slowly and carefully adding ethyl acetate dropwise with stirring. This should be followed by the addition of a saturated aqueous solution of ammonium chloride. Excess lithium aluminum hydride and the products of the treatment described above should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Lithium aluminum hydride is not suitable for use by students.

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MERCURY

SYNONYMS

SYNONYMS	CAS#	Formula
Quicksilver, hydrargyrum	7439-97-6	Hg

PHYSICAL PROPERTIES

Odor:	Odorless	**Appearance:**	Silvery, mobile liquid
Water Solubility:	Very slightly soluble in water (0.002 g/100 mL at 20 °C)	**Vapor Density:**	6.9 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	0.0012 mmHg at 20 °C
Autoignition:	NA	**bp/mp:**	357 °C/−39 °C

TOXICITY		EXPOSURE LIMITS	
LC_{50} inhal. (rat)	29 mg/m^3 (30 h)	**TLV-TWA (ACGIH):**	0.025 mg/m^3—skin
		PEL (OSHA):	0.1 mg/m^3 (ceiling)

HEALTH AND SYMPTOMS

General	The acute toxicity of mercury varies significantly with the route of exposure. There are no warning properties for exposure to mercury vapor, which is colorless, odorless, and tasteless. Toxicity caused by repeated or prolonged exposure to mercury vapor or liquid is characterized by emotional disturbances, inflammation of the mouth and gums, general fatigue, memory loss, headaches, tremors, anorexia, and weight loss. Mercury has not been shown to be a human carcinogen or reproductive toxin.
Skin	Skin absorption of mercury and mercury vapor adds to the toxic effects of vapor inhalation. At low levels the onset of symptoms is insidious; fine tremors of the hand, eyelids, lips, and tongue are often the presenting complaints. Mercury has been reported to be capable of causing sensitization dermatitis.
Eyes	May case irritation to the eyes.
Ingestion	There are too little data available to determine the effect.
Inhalation	Inhalation of high concentrations of mercury causes severe respiratory irritation, digestive disturbances, and marked kidney damage.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Mercury is not combustible.

REACTIVITY & INCOMPATIBILITY

Mercury is a fairly unreactive metal that is highly resistant to corrosion. It can dissolve a number of metals, such as silver, gold, and tin, forming amalgams. Mercury can react violently with acetylene and ammonia.

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STORAGE & HANDLING

Gloves: Viton, butyl rubber, nitrile, neoprene

Precautions should be taken to prevent spills of mercury because drops of the liquid metal can easily become lodged in floor cracks, behind cabinets, and equipment, etc., with the result that the mercury vapor concentration in the laboratory may then exceed the safe and allowable limits. Containers of mercury should be kept tightly sealed and stored in secondary containers (such as a plastic pan or tray) in a well-ventilated area. When breakage of instruments or apparatus containing significant quantities of Hg is possible, the equipment should be placed in a plastic tray or pan that is large enough to contain the mercury in the event of an accident. Transfers of mercury between containers should be carried out in a fume hood over a tray or pan to confine any spills.

CLEANUP & DISPOSAL

In the event of a spill, collect the mercury using the procedures described in Chapter 6, place in an appropriate container, and dispose of properly. Respiratory protection will be necessary in the event of a large spill, release in a confined area, or spill under conditions of higher than normal temperatures. Excess mercury should be collected for recycling, and waste material containing mercury should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Mercury is poisonous and not suitable for use by students

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METHANOL

SYNONYMS	CAS#	Formula
Methyl alcohol, wood alcohol	67-56-1	CH_3OH

PHYSICAL PROPERTIES

Odor:	Faint alcohol odor detectable at 4 to 6,000 ppm (mean = 160 ppm)	**Appearance:**	Colorless liquid
Water Solubility:	Miscible with water in all proportions	**Vapor Density:**	1.1 (air = 1.0)
Flash Point:	11 °C	**Vapor Pressure:**	96 mmHg at 20 °C
Autoignition:	385 °C	**bp/mp:**	65 °C/−98 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	5,628 mg/kg	**TLV-TWA (ACGIH):**	200 ppm (260 mg/m^3)—skin
LC_{50} inhal. (rat):	>145,000 ppm (1 h)	**STEL (ACGIH):**	250 ppm (328 mg/m^3)
LD_{50} skin (rabbit):	15,840 mg/kg	**PEL (OSHA):**	200 ppm (260 mg/m^3)

HEALTH AND SYMPTOMS

General	The acute toxicity of methanol by ingestion, inhalation, and skin contact is low. Ingestion of methanol or inhalation of high concentrations can produce headache, drowsiness, blurred vision, nausea, vomiting, blindness, and death. In humans, 60 to 250 mL is reported to be a lethal dose. Methanol is not considered to have adequate warning properties. Methanol has not been found to be carcinogenic in humans. Information available is insufficient to characterize the reproductive hazard presented by methanol. In animal tests, the compound produced developmental effects only at levels that were maternally toxic; hence, it is not considered to be a highly significant hazard to the fetus. Tests in bacterial or mammalian cell cultures demonstrate no mutagenic activity.
Skin	Prolonged or repeated skin contact can cause irritation and inflammation; methanol can be absorbed through the skin in toxic amounts.
Eyes	Contact of methanol with the eyes can cause irritation and burns.
Ingestion	Ingestion of methanol or inhalation of high concentrations can produce headache, drowsiness, blurred vision, nausea, vomiting, blindness, and death.
Inhalation	Ingestion of methanol or inhalation of high concentrations can produce headache, drowsiness, blurred vision, nausea, vomiting, blindness, and death.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating (flammability) = 3; LEL = 6%; UEL = 36%

Burns with an invisible flame in daylight; its vapor can travel a considerable distance to an ignition source and flash back. Methanol–water mixtures will burn unless very dilute. Carbon dioxide or dry chemical extinguishers should be used for methanol fires.

REACTIVITY & INCOMPATIBILITY

Methanol can react violently with strong oxidizing agents such as chromium trioxide, with strong mineral acids such as perchloric, sulfuric, and nitric acids, and with highly reactive metals such as potassium. Sodium and magnesium metal react vigorously with methanol.

STORAGE & HANDLING

Gloves: Butyl rubber, PVC, nitrile, neoprene

Methanol should be handled in the laboratory using the basic prudent practices described in Chapter 6, supplemented by the additional precautions for dealing with extremely flammable substances (Chapter 6, section 6.F). In particular, methanol should be used only in areas free of ignition sources, and quantities greater than 1 L should be stored in tightly sealed metal containers in areas separated from oxidizers.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, soak up the methanol with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess methanol and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Ethanol can often be used in place of methanol.

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METHYL ETHYL KETONE

SYNONYMS	CAS#	Formula
2-Butanone, methyl acetone, MEK, butan-2-one	78-93-3	$CH_3COCH_2CH_3$

PHYSICAL PROPERTIES

Odor:	Sweet/sharp odor detectable at 2 to 85 ppm (mean = 16 ppm)	**Appearance:**	Colorless liquid
Water Solubility:	Highly soluble in water (25.6 g/100 mL at 20 °C)	**Vapor Density:**	2.5 (air = 1.0)
Flash Point:	−9 °C	**Vapor Pressure:**	71.2 mmHg at 20 °C
Autoignition:	516 °C	**bp/mp:**	80 °C/−86 °C

TOXICITY		EXPOSURE LIMITS	
LD$_{50}$ oral (rat):	2,737 mg/kg	**TLV-TWA (ACGIH):**	200 ppm (590 mg/m^3)
LC$_{50}$ inhal. (rat):	23,500 mg/m^3 (8 h)	**STEL (ACGIH):**	300 ppm(885 mg/m^3)
LD50 skin (rabbit):	6,480 mg/kg	**PEL (OSHA):**	200 ppm (590 mg/m^3)

HEALTH AND SYMPTOMS

General	The acute toxicity of methyl ethyl ketone is low. Exposure to high concentrations can cause headache, dizziness, drowsiness, vomiting, and numbness of the extremities. Irritation of the eyes, nose, and throat can also occur. Methyl ethyl ketone is considered to have adequate warning properties. Methyl ethyl ketone has exhibited developmental toxicity in some animal tests, but has not been found to be carcinogenic or to show reproductive or developmental toxicity in humans.
Skin	Repeated or prolonged skin exposure to methyl ethyl ketone can cause defatting of the skin, leading to cracking, secondary infection, and dermatitis.
Eyes	See General.
Ingestion	See General.
Inhalation	See General.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating (flammability) = 3; LEL = 1.9%; UEL = 11%

Methyl ethyl ketone is extremely flammable, and its vapor can travel a considerable distance to an ignition source and flash back. MEK vapor forms explosive mixtures with air. Carbon dioxide or dry chemical extinguishers should be used for MEK fires.

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REACTIVITY & INCOMPATIBILITY

Fires and/or explosions may result from the reaction of methyl ethyl ketone with strong oxidizing agents and very strong bases.

STORAGE & HANDLING

Gloves: Butyl rubber

MEK should be used only in areas free of ignition sources, and quantities greater than 1 L should be stored in tightly sealed metal containers in areas separate from oxidizers.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, soak up the methyl ethyl ketone with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess methyl ethyl ketone and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Methyl ethyl ketone is not suitable for use by students.

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METHYL IODIDE

SYNONYMS	CAS#	Formula
Iodomethane	74-88-4	CH_3I

PHYSICAL PROPERTIES

Odor:	Sweet, ethereal odor (no threshold data available); inadequate warning properties.	**Appearance:**	Colorless liquid; may darken upon exposure to light.
Water Solubility:	2 g/100 mL	**Vapor Density:**	4.9 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	400 mmHg at 25 °C
Autoignition:	NA	**bp/mp:**	42 °C/−66 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	150 mg/kg	**TLV-TWA (ACGIH):**	ppm(11 mg/m^3)—skin
LC_{50} inhal. (rat):	1,300 mg/m^3 (4 h)	**PEL (OSHA):**	5 ppm (28 mg/m^3)—skin
LD_{50}skin (rat):	800 mg/kg		

HEALTH AND SYMPTOMS

General	The acute toxicity of methyl iodide is moderate by ingestion, inhalation, and skin contact. Methyl iodide is an acute neurotoxin. Symptoms of exposure (which may be delayed for several hours) can include nausea, vomiting, diarrhea, drowsiness, slurred speech, visual disturbances, and tremor. Massive overexposure may cause pulmonary edema, convulsions, coma, and death. There is limited evidence for the carcinogenicity of methyl iodide to experimental animals; it is not classified as an OSHA “select carcinogen.”
Skin	This substance is readily absorbed through the skin and may cause systemic toxicity as a result. Methyl iodide is moderately irritating upon contact with the skin.
Eyes	Methyl iodide is moderately irritating upon contact with the eyes.
Ingestion	See General.
Inhalation	See General.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Noncombustible. High vapor pressure may cause containers to burst at elevated temperatures.

REACTIVITY & INCOMPATIBILITY

Methyl iodide may react vigorously with alkali metals and strong oxidizing agents.

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STORAGE & HANDLING

Gloves: Viton

Methyl iodide should be handled using the "basic prudent practices."

CLEANUP & DISPOSAL

In the event of a spill, soak up methyl iodide with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess methyl iodide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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NICKEL CARBONYL

SYNONYMS	CAS#	Formula
Tetracarbonylnickel	13463-39-3	$Ni(CO)_4$

PHYSICAL PROPERTIES

Odor:	Sooty odor detectable at 0.5 to 3 ppm	**Appearance:**	Colorless liquid
Water Solubility:	0.0018 g/100 mL at 20 °C	**Vapor Density:**	5.89 (air = 1.0)
Flash Point:	<−20 °C	**Vapor Pressure:**	321 mmHg at 20 °C
Autoignition:	Explodes above 60 °C	**bp/mp:**	43 °C/−25 °C

TOXICITY		EXPOSURE LIMITS	
LC_{50} inhal. (rat):	35 ppm (240 mg/m^3; 30 min)	**TLV-TWA (ACGIH):**	0.05 mg/m^3
		PEL (OSHA):	0.001 ppm (0.007 mg/m^3)

HEALTH AND SYMPTOMS

General	Repeated or prolonged exposure to nickel carbonyl has been associated with an increased incidence of cancer of the lungs and sinuses. Nickel carbonyl is listed by IARC in Group 2B (“possible human carcinogen”), is listed by the National Toxicology Program as “reasonably anticipated to be a carcinogen,” and is classified as a “select carcinogen" under the criteria of the OSHA Laboratory Standard. Nickel carbonyl is not regarded as having adequate warning properties.
Skin	See General
Eyes	See General
Ingestion	See General
Inhalation	The acute toxicity of nickel carbonyl by inhalation is high. Acute toxic effects occur in two stages, immediate and delayed. Headache, dizziness, shortness of breath, vomiting, and nausea are the initial symptoms of overexposure; the delayed effects (10 to 36 h) consist of chest pain, coughing, shortness of breath, bluish discoloration of the skin, and in severe cases, delirium, convulsions, and death. Recovery is protracted and characterized by fatigue on slight exertion.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating = 3; LEL = 2%; UEL =NA

Highly flammable liquid that may ignite spontaneously and explodes when heated above 60 °C. Carbon dioxide, water, or dry chemical extinguishers should be used for nickel carbonyl fires.

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REACTIVITY & INCOMPATIBILITY

In the presence of air, nickel carbonyl forms a deposit that becomes peroxidized and may ignite. Nickel carbonyl is incompatible with mercury, nitric acid, chlorine, and other oxidizers, which may cause fires and explosions. Products of decomposition (nickel oxide and carbon monoxide) are less toxic that nickel carbonyl itself.

STORAGE & HANDLING

All work should be conducted in a fume hood to prevent exposure by inhalation and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Only use in areas free of ignition sources. Containers of nickel carbonyl should be stored in secondary containers in a dark area separate from oxidizers.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, soak up the nickel carbonyl with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection will be necessary in the event of a large spill or release in a confined area. Excess nickel carbonyl and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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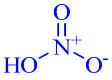
NITRIC ACID

SYNONYMS	CAS#	Formula
Conc. nitric acid is 68 to 70% HNO_3 by wt White fuming nitric acid is 97.5% HNO_3, 2% H_2O, <0.5% NO_x by wt Red fuming nitric acid contains 85% HNO_3, <5% H_2O, and 6 to 15% NO	7697-37-2	

PHYSICAL PROPERTIES

Odor:	Suffocating fumes detectable at <5.0 ppm	**Appearance:**	Colorless, yellowish, or reddish-brown fuming liquid
Water Solubility:	Miscible with water in all proportions	**Vapor Density:**	>1 (air = 1.0)
Flash Point:	Not flammable	**Vapor Pressure:**	White fuming nitric acid: 57 mmHg at 25 °C 70% nitric acid: 49 mmHg at 20 °C
Autoignition:	Explodes above 60 °C	**bp/mp:**	Concentrated: 122 °C White fuming: 83 °C/−42 °C

TOXICITY		EXPOSURE LIMITS	
LC_{50} inhal. (rat):	2,500 ppm (1 h)	**TLV-TWA (ACGIH):**	2 ppm (5.2 mg/m^3)
		STEL (ACGIH):	4 ppm (10 mg/m^3)
		PEL (OSHA):	2 ppm (5 mg/m^3)

HEALTH AND SYMPTOMS

General	Concentrated nitric acid and its vapors are highly corrosive to the eyes, skin, and mucous membranes. An oral dose of 10 mL can be fatal in humans. Tests in animals demonstrate no carcinogenicity or developmental toxicity for nitric acid. Tests for mutagenic activity or for reproductive hazards have not been performed.
Skin	Dilute solutions cause mild skin irritation and hardening of the epidermis. Contact with concentrated nitric acid stains the skin yellow and produces deep painful burns.
Eyes	Eye contact can cause severe burns and permanent damage.
Ingestion	Ingestion of nitric acid may result in burning and corrosion of the mouth, throat, and stomach.
Inhalation	High concentrations can lead to severe respiratory irritation and delayed effects, including pulmonary edema, which may be fatal.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.

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Ingestion Seek medical attention immediately.

Inhalation If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Not a combustible substance, but a strong oxidizer. Contact with easily oxidizible materials including many organic substances may result in fires or explosions.

REACTIVITY & INCOMPATIBILITY

Nitric acid is a powerful oxidizing agent and ignites on contact or reacts explosively with a variety of organic substances including acetic anhydride, acetone, acetonitrile, many alcohols, thiols, and amines, dichloromethane, DMSO, and certain aromatic compounds including benzene. Nitric acid corrodes steel and reacts violently with many bases, reducing agents, alkali metals, copper, phosphorus, and ammonia.

STORAGE & HANDLING

Gloves: Butyl rubber

Splash goggles and rubber gloves should be worn when handling this acid, and containers of nitric acid should be stored in a well-ventilated location separated from organic substances and other combustible materials.

CLEANUP & DISPOSAL

In the event of a spill, soak up nitric acid with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess and waste material should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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NITROGEN DIOXIDE

SYNONYMS	CAS#	FORMULA
Nitrogen peroxide	10102-44-0	NO_2

PHYSICAL PROPERTIES			
Odor:	Pungent, acrid odor detectable at 0.12 ppm	**Appearance**	Yellow-brown liquid to reddish brown gas
Water Solubility:	Miscible with water in all proportions	**Vapor Density:**	1.58 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	720 mmHg at 20 °C
Autoignition:	Explodes above 60 °C	**bp/mp:**	21 °C/−11 °C

TOXICITY		EXPOSURE LIMITS	
LC_{50} inhal. (rat):	88 ppm (4 h)	**TLV-TWA (ACGIH)**	3 ppm (5.6 mg/m^3)
		STEL (ACGIH)	5 ppm (9.4 mg/m^3)
		PEL (OSHA	5 ppm (9 mg/m^3; ceiling

HEALTH AND SYMPTOMS	
General	The acute toxicity of nitrogen dioxide by inhalation is high. It produces genetic damage in bacterial and mammalian cell cultures; however, most studies in animals indicate that it does not produce heritable genetic damage. Animal testing indicates that nitrogen dioxide does not have carcinogenic or reproductive effects. Nitrogen dioxide can be detected below the permissible exposure limit by its odor and irritant effects and is regarded as a substance with adequate warning properties.
Skin	High concentrations are corrosive to the skin.
Eyes	Nitrogen dioxide at concentrations of 10 to 20 ppm is mildly irritating to the eyes; higher concentrations of the gas and liquid NO_2-N_2O_4 are highly corrosive to the skin, eyes, and mucous.
Ingestion	Ingestion of gas is unlikely.
Inhalation	Inhalation may cause shortness of breath and pulmonary edema progressing to respiratory illness, reduction in the blood's oxygen carrying capacity, chronic lung disorders, and death; symptoms may be delayed for hours and may recur after several weeks. Toxic effects may occur after exposure to concentrations of 10 ppm for 10 minutes and include coughing, chest pain, frothy sputum, and difficulty in breathing. Brief exposure to 200 ppm can cause severe lung damage and delayed pulmonary edema, which may be fatal.

FIRST AID	
Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Nitrogen dioxide is not combustible but is a strong oxidizing agent and will support combustion. Cylinders of NO_2 gas exposed to fire or intense heat may vent rapidly or explode.

REACTIVITY & INCOMPATIBILITY

Nitrogen dioxide–nitrogen tetroxide is a powerful oxidizer and can cause many organic substances to ignite. This substance may react violently with alcohols, aldehydes, acetonitrile, DMSO, certain hydrocarbons, and chlorinated hydrocarbons. Metals react vigorously and alkali metals ignite in NO_2.

STORAGE & HANDLING

Cylinders of nitrogen dioxide should be stored and used in a continuously ventilated gas cabinet or fume hood.

CLEANUP & DISPOSAL

In the event of a release of nitrogen dioxide, use appropriate protective equipment and clothing. Positive-pressure air-supplied respiratory protection may be required in cases involving a large release of nitrogen dioxide gas. If a cylinder is the source of the leak and the leak cannot be stopped, remove the leaking cylinder to a fume hood or a safe place, if possible, in the open air, and repair the leak or allow the cylinder to empty. Excess nitrogen dioxide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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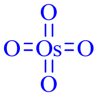
OSMIUM TETROXIDE

SYNONYMS	CAS#	FORMULA
Osmic acid, perosmic oxide, osmium(IV) oxide	20816-12-0	 $\mathrm{O{=}\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{Os}}{=}O}$

PHYSICAL PROPERTIES

Odor:	Acrid, chlorinelike odor detectable at 2 ppm (20 mg/m^3)	**Appearance:**	Colorless to pale yellow-green crystals
Water Solubility:	7 g/100 mL	**Vapor Density:**	8.8 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	7 mmHg at 20 °C
Autoignition:	NA	**bp/mp:**	130 °C (but sublimes at lower temperature)/40 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	14 mg/kg	**TLV-TWA (ACGIH):**	0.0002 ppm (0.002 mg/m^3)
LC_{50} inhal. (rat):	40 ppm (4 h)	**STEL (ACGIH):**	0.0006 ppm (0.006 mg/m^3)
		PEL (OSHA):	0.0002 ppm (0.002 mg/m^3)

HEALTH AND SYMPTOMS

General	The acute toxicity of osmium tetroxide is high, and it is a severe irritant of the eyes and respiratory tract. Exposure to osmium tetroxide via inhalation, skin contact, or ingestion can lead to systemic toxic effects involving liver and kidney damage. Chronic exposure to osmium tetroxide can result in an accumulation of osmium compounds in the liver and kidney and damage to these organs. Osmium tetroxide has been reported to cause reproductive toxicity in animals; this substance has not been shown to be carcinogenic or to show reproductive or developmental toxicity in humans. Osmium tetroxide is regarded as a substance with poor warning properties.
Skin	Contact of the vapor with skin can cause dermatitis, and direct contact with the solid can lead to severe irritation and burns.
Eyes	Exposure to osmium tetroxide vapor can damage the cornea of the eye. Irritation is generally the initial symptom of exposure to low concentrations of osmium tetroxide vapor, and lacrimation, a gritty feeling in the eyes, and the appearance of rings around lights may also be noted. In most cases, recovery occurs in a few days. Concentrations of vapor that do not cause immediate irritation can have an insidious cumulative effect; symptoms may not be noted until several hours after exposure. Contact of the eyes with concentrated solutions of this substance can cause severe damage and possible blindness.
Ingestion	Exposure to osmium tetroxide via ingestion can lead to systemic toxic effects involving liver and kidney damage.
Inhalation	Inhalation can cause headache, coughing, dizziness, lung damage, and difficult breathing and may be fatal.

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FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

REACTIVITY & INCOMPATIBILITY

Osmium tetroxide reacts with hydrochloric acid to form chlorine gas.

STORAGE & HANDLING

Gloves: 4H, SilverShield

In particular, all work with osmium tetroxide should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Osmium tetroxide as solid or solutions should be stored in tightly sealed containers, and these should be placed in secondary containers.

CLEANUP & DISPOSAL

In the event of a spill, mix osmium tetroxide with an absorbent material such as vermiculite or dry sand (avoid raising dust), place in an appropriate container, and dispose of properly. Evacuation and cleanup using respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess osmium tetroxide solutions can be rendered safer by reaction with sodium sulfite to produce insoluble osmium dioxide. Ethanol will also react to produce the dioxide. Corn oil or sodium sulfide may also be used to deactivate osmium tetroxide. Osmium-containing waste should be placed in a tightly sealed, labeled container and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Osmium tetroxide is not suitable for use by students.

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OXYGEN

SYNONYMS	CAS#	Formula
GOX, gas only; LOX, liquid only	7782-44-7	O_2

PHYSICAL PROPERTIES

Odor:	Odorless gas	**Appearance:**	Colorless gas
Water Solubility:	Slightly soluble in water (0.004 g/100 mL at 25°C)	**Vapor Density:**	1.11 (air = 1.0)
Flash Point:	NA	**Vapor Pressure:**	>760 mmHg at 20 °C
Autoignition:	NA	**bp/mp:**	−183 °C/−219 °C

TOXICITY	EXPOSURE LIMITS	
	PEL (OSHA):	OSHA recommends a minimum oxygen concentration of 19.5% for human occupancy

HEALTH AND SYMPTOMS

General	Oxygen is nontoxic under the usual conditions of laboratory use.
Skin	Liquid oxygen can cause severe “burns” and tissue damage on contact with the skin due to extreme cold.
Eyes	Liquid oxygen can cause severe “burns” and tissue damage on contact
Ingestion	Ingesting gas is unlikely.
Inhalation	Breathing pure oxygen at 1 atm may produce cough and chest pains within 8 to 24 h, and concentrations of 60% may produce these symptoms in several days.

FIRST AID

Skin	If in contact with liquid oxygen, seek medical attention immediately.
Eyes	If in contact with liquid oxygen, seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is in distress, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Oxygen itself is nonflammable, but at concentrations greater than 25% supports and vigorously accelerates the combustion of flammable materials. Some materials (including metals) that are noncombustible in air will burn in the presence of oxygen.

REACTIVITY & INCOMPATIBILITY

Oxygen is incompatible with combustible materials, including many lubricants and elastomers. Oil, greases, and other readily combustible substances should never be allowed to come in contact with O_2 cylinders, valves, regulators, and fittings. Contact of liquid oxygen with many organic substances can lead to an explosion.

STORAGE & HANDLING

Oxygen should be handled in the laboratory using the “basic prudent practices” described in this volume.

CLEANUP & DISPOSAL

Excess liquid oxygen should be allowed to evaporate in a well-ventilated outdoor area. Vent oxygen gas to outside location. Locations should be remote from work areas, open flames, or sources of ignition and combustibles. Return empty and excess cylinders of oxygen to manufacturer.

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ADDITIONAL CONSIDERATIONS

None

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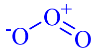
OZONE

SYNONYMS	CAS#	Formula
	10028-15-6	

PHYSICAL PROPERTIES

Odor:	Colorless to bluish gas	**Appearance:**	Pungent odor, detectable at 0.01 to 0.04 ppm; sharp disagreeable odor at 1 ppm
Water Solubility:	0.00003 g/100 mL at 20 °C	**Vapor Density:**	1.65 (air = 1.0)
Flash Point:	NA	**Vapor Pressure:**	NA
Autoignition:	NA	**bp/mp:**	−112 °C/−193 °C

TOXICITY		EXPOSURE LIMITS	
LC_{50} inhal. (rat)	4.8 ppm (4 h)	**TLV-TWA (ACGIH)**	0.1 ppm (0.2 mg/m^3)
		STEL (ACGIH)	0.3 ppm (0.6 mg/m^3)
		PEL (OSHA	0.1 ppm (0.2 mg/m^3)

HEALTH AND SYMPTOMS

General	Ozone is a highly toxic gas that is extremely irritating by all routes of exposure. An ozone leak can be detected by its characteristic pungent odor. At concentrations above 0.04 ppm the ability to smell ozone may decrease. Animal studies indicate that chronic exposure to ozone may result in pulmonary damage, leading to chronic lung impairment. Exposure to 100 ppm of ozone for 1 hour can be lethal to humans. Animal studies indicate that chronic exposure to ozone may result in pulmonary damage, leading to chronic lung impairment. Continual daily exposure to ozone can cause premature aging.
Skin	See General.
Eyes	Can cause lacrimation. See General.
Ingestion	See General.
Inhalation	Inhalation of 1 ppm ozone may cause headaches and irritation of the upper and lower respiratory tract. The first symptoms of exposure include irritation of the eyes, dryness of throat, and coughing; these symptoms disappear after exposure ceases. Exposure at higher levels may lead to lacrimation, vomiting, upset stomach, labored breathing, lowering of pulse rate and blood pressure, lung congestion, tightness in the chest, and pulmonary edema, which can be fatal.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Ozone by itself is not flammable. Liquid ozone and concentrated solutions are extremely hazardous and can explode on warming or when shocked.

REACTIVITY & INCOMPATIBILITY

Ozone is a powerful oxidant and can react explosively with readily oxidizable substances and reducing agents. Explosions can occur when ozone is exposed to bromine, hydrogen bromide, hydrogen iodide, nitrogen oxides, lithium aluminum hydride, metal hydrides, hydrazine, alkyl metals, stilbene, ammonia, arsine, and phosphine. Ozone reacts with alkenes and other unsaturated organic compounds to form ozonides, many of which are highly unstable and explosive. Ozone combines with many aromatic compounds and ethers to form shock-sensitive and explosive products.

STORAGE & HANDLING

All work should be conducted in a fume hood to prevent exposure by inhalation. Care should be taken to ensure adequate ventilation in the area where the ozone generation equipment is located. Because of the possibility of the generation of explosive ozonides, ozonolysis reactions should always be conducted in a fume hood behind a safety shield.

CLEANUP & DISPOSAL

A procedure for the treatment of excess ozone should be included in the experimental plan. Small to moderate amounts of excess ozone can be vented to the fume hood or other exhaust system. Excess ozone should be passed through a series of traps containing a 1 to 2% solution of potassium iodide or other reducing agent before venting to the fume hood.

ADDITIONAL CONSIDERATIONS

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PALLADIUM ON CARBON

SYNONYMS	CAS#	Formula
Pd/C	7440-05-3	Pd/C

PHYSICAL PROPERTIES

Odor:	Odorless	**Appearance:**	Black powder
Water Solubility:	Insoluble in water	**Vapor Density:**	1.65 (air = 1.0)
Flash Point:	NA	**Vapor Pressure:**	NA
Autoignition:	NA	**bp/mp:**	−112 °C/−193 °C

TOXICITY / EXPOSURE LIMITS

LD_{50} oral (rat): 200 mg/kg (palladium chloride)
LC_{50} inhal. (rat): 6 mg/kg (palladium chloride)

HEALTH AND SYMPTOMS

General	Palladium compounds are believed to have low toxicity because of their poor absorption by the body. There is some evidence that chronic exposure to palladium particles in dust can have toxic effects on the blood and respiratory systems. Finely divided carbon is irritating to mucous membranes and the upper respiratory tract.
Skin	May cause skin irritation and sensitization. Liquids may cause burns.
Eyes	May cause irritation. Liquids may cause burns.
Ingestion	May cause irritation. Liquids may cause burns.
Inhalation	May cause irritation. Liquids may cause burns.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = NA; LEL = NA; UEL = NA

Palladium on carbon catalysts containing adsorbed hydrogen are pyrophoric, particularly when dry and at elevated temperatures. Palladium on carbon catalysts prepared by formaldehyde reduction are less pyrophoric than those reduced with hydrogen. Finely divided carbon, like most materials in powder form, is capable of creating a dust explosion.

REACTIVITY & INCOMPATIBILITY

Catalysts prepared on high-surface-area supports are highly active and readily cause ignition of hydrogen–air and solvent–air mixtures. For example, methanol is known for easy ignition in contact with palladium on carbon catalysts because of its high volatility. Addition of catalyst to a tetrahydroborate solution may cause ignition of liberated hydrogen.

STORAGE & HANDLING

In particular, palladium on carbon should always be handled under an inert atmosphere (preferably argon), and reaction vessels should be flushed with inert gas before the catalyst is added. Dry catalyst should never be added to an organic solvent in the presence of air. Palladium on carbon recovered from catalytic hydrogenation reactions by filtration requires careful handling because it

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is usually saturated with hydrogen and will ignite spontaneously on exposure to air. The filter cake should never be allowed to dry, and the moist material should be added to a large quantity of water and disposed of properly.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, wet the palladium on carbon with water, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large release in a confined area. Excess palladium on carbon and waste material containing this substance should be covered in water, placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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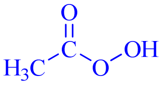
PERACETIC ACID

SYNONYMS	CAS#	FORMULA
Peroxyacetic acid; acetyl hydroperoxide	79-21-0	 $H_3C-C(=O)-O-OH$

PHYSICAL PROPERTIES

Odor:	Acrid odor	**Appearance:**	Colorless liquid
Water Solubility:	Miscible with water	**Vapor Density:**	2.6 (air = 1.0)
Flash Point:	40.5 °C (open cup)	**Vapor Pressure:**	Low
Autoignition:	Explodes when heated to 110 °C	**bp/mp:**	105 °C (40% solution in acetic acid)/0.1 °C

TOXICITY		EXPOSURE LIMITS
LD_{50}oral (rat):	1540 mg/kg	
LD_{50}skin (rabbit):	1,410 mg/kg	

HEALTH AND SYMPTOMS

General	The acute toxicity of peracetic acid is low. However, peracids are extremely irritating to the skin, eyes, and respiratory tract. There is some evidence that this compound is a weak carcinogen from animal studies (mice). Peracetic acid has not been found to be carcinogenic or to show reproductive or developmental toxicity in humans. Data on other peracids suggest peracetic acid may show the worst chronic and acute toxicity of this class of compounds. Other commonly available peracids, such as perbenzoic acid and *m*-chloroperbenzoic acid (MCPBA) are less toxic, less volatile, and more easily handled than the parent substance.
Skin	Skin contact with the 40% solution in acetic acid can cause serious burns.
Eyes	Eye contact with the 40% solution in acetic acid can cause serious burns.
Ingestion	Ingestion of the 40% solution in acetic acid can cause serious burns to the mouth and throat.
Inhalation	Inhalation of high concentrations of mists of peracetic acid solutions can lead to burning sensations, coughing, wheezing, and shortness of breath.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Flammable liquid and vapor

NFPA rating (flammability) = 2; LEL = NA; UEL = NA

Pure peracetic acid is extremely shock sensitive. The heat generated in the oxidation reaction can induce ignition, at which point combustion is accelerated. Most peracids are highly flammable and can accelerate the combustion of other flammable materials if present in a fire. Use dry-chemical or halon extinguishers for fires. Containers of peracetic acid heated in a fire may

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explode.

REACTIVITY & INCOMPATIBILITY

Peracids such as peracetic acid are strong oxidizing agents and react exothermically with easily oxidized substrates. Violent reactions may occur, for example, with ethers, metal chloride solutions, olefins, and some alcohols and ketones. Shock-sensitive peroxides may be generated by the action of peracids on these substances as well as on carboxylic anhydrides. Some metal ions, including iron, copper, cobalt, chromium, and manganese, may cause runaway peroxide decomposition. Peracetic acid is also reportedly sensitive to light.

STORAGE & HANDLING

Reactions should be carried out behind a safety shield. Use only in areas free of ignition sources and store in tightly sealed containers in areas separated from oxidizable compounds and flammable substances. Other commonly available peracids, such as perbenzoic acid and *m*-chloroperbenzoic acid (MCPBA), are less toxic, less volatile, and more easily handled than peracetic acid.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, soak up the peracetic acid solution with a spill pillow or a noncombustible absorbent material such as vermiculite, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess and waste should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines. Peracid waste should be kept separate from incompatible material.

ADDITIONAL CONSIDERATIONS

None

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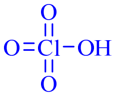
PERCHLORIC ACID (AND INORGANIC PERCHLORATES)

SUBSTANCE & SYNONYMS	CAS#	FORMULA
Commercially available as an aqueous solution containing ~72% $HClO_4$ by weight	7601-90-3	 $\mathrm{O{=}\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{Cl}}{-}OH}$

PHYSICAL PROPERTIES

Odor:	Odorless	**Appearance:**	Colorless liquid
Water Solubility:	Miscible with water	**Vapor Density:**	3.5 (air = 1.0)
Flash Point:	40.5 °C (open cup)	**Vapor Pressure:**	6.8 mmHg at 25 °C
Autoignition:	Explodes when heated to 110 °C	**bp/mp:**	203 °C/−18 °C

TOXICITY

EXPOSURE LIMITS

LD_{50}oral (rat)	1,100 mg/kg
LD_{50} oral (dog)	400 mg/kg

HEALTH AND SYMPTOMS

General	The acute toxicity of perchloric acid is moderate. Highly corrosive to all tissues causing severe irritation and burns to the eyes, mucous membranes, and upper respiratory tract. Perchloric acid has not been shown to be carcinogenic or to cause reproductive or developmental toxicity in humans.
Skin	See General.
Eyes	See General.
Ingestion	See General.
Inhalation	See General.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Perchloric acid is noncombustible. The anhydrous (dehydrated) acid presents a serious explosion hazard. It is unstable and can decompose explosively at ordinary temperatures or in contact with many organic compounds. Many heavy metal perchlorates and organic perchlorate salts are extremely sensitive explosives; the ammonium, alkali metal, and alkali earth perchlorates are somewhat less hazardous. Mixtures of perchlorates with many oxidizable substances are explosive.

REACTIVITY & INCOMPATIBILITY

Cold 70% perchloric acid is a strong acid but is not considered to be a strong oxidizing agent; however, more concentrated solutions are good oxidizers. Temperature increases the oxidizing power of perchloric acid, and hot concentrated solutions are very dangerous. Evaporation of a spill of the 70% solution may lead to the formation of more dangerous concentrations. Reaction of 70% perchloric acid with cellulose materials such as wood, paper, and cotton can produce

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fires and explosions. Oxidizable organic compounds including alcohols, ketones, aldehydes, ethers, and dialkyl sulfoxides can react violently with concentrated perchloric acid. All perchlorates are potentially hazardous when in contact with reducing agents.

STORAGE & HANDLING

Gloves: Nitrile, neoprene, PVC

In particular, splash goggles and rubber gloves should be worn when handling perchloric acid, and containers of the acid should be stored in a well-ventilated location separated from organic substances and other combustible materials. Work with >85% perchloric acid requires special precautions and should be carried out only by specially trained personnel.

CLEANUP & DISPOSAL

In the event of a spill, dilute the perchloric acid with water to a concentration of <5%, absorbed with sand or vermiculite, place in an appropriate container, and dispose of properly. Organic absorbants must not be used. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess perchloric acid and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Perchloric acid is not suitable for use by students.

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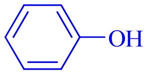
PHENOL

SYNONYMS	CAS#	Formula
Carbolic acid; hydroxybenzene	108-95-2	

PHYSICAL PROPERTIES			
Odor:	Sweet, medicinal odor detectable at 0.06 ppm	**Appearance:**	White crystalline solid
Water Solubility:	8.4 g/100 mL	**Vapor Density:**	3.24 at bp (air = 1.0)
Flash Point:	79 °C	**Vapor Pressure:**	0.36 mmHg at 20 °C
Autoignition:	715 °C	**bp/mp:**	182 °C/41 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	317 mg/kg	**TLV-TWA (ACGIH):**	5 ppm (19 mg/m^3)—skin
LD_{50}skin (rabbit):	850 mg/m^3	**PEL (OSHA):**	5 ppm (19 mg/m^3)—skin

HEALTH AND SYMPTOMS	
General	Phenol is a corrosive and moderately toxic substance that affects the central nervous system and can cause damage to the liver and kidneys. Exposure to phenol vapor can cause severe irritation of the eyes, nose, throat, and respiratory tract. Acute overexposure by any route may lead to nausea, vomiting, muscle weakness, and coma. Chronic exposure to phenol may cause vomiting, diarrhea, dizziness, difficulty in swallowing, headache, skin discoloration, and injury to the liver. There is some evidence from animal studies that phenol may be a reproductive toxin. Phenol has not been shown to be a carcinogen in humans. There is some evidence from animal studies that phenol may be a reproductive toxin. Phenol is regarded as a substance with good warning properties.
Skin	Corrosive, moderately toxic substance readily absorbed through skin; can cause severe burns to the skin. Phenol is irritating to the skin but has a local anesthetic effect, so that no pain may be felt on initial contact. A whitening of the area of contact generally occurs, and later severe burns may develop. Phenol is rapidly absorbed through the skin, and toxic or even fatal amounts can be absorbed through relatively small areas.
Eyes	Corrosive, moderately toxic substance readily absorbed through skin; can cause severe burns to the eyes. Exposure to phenol vapor can cause severe irritation of the eyes, nose, throat, and respiratory tract. Contact of phenol with the eyes may cause severe damage and possibly blindness.
Ingestion	Ingestion of phenol leads to burning of the mouth and throat and rapid development of digestive disturbances and the systemic effects described above. As little as 1 g can be fatal to humans.
Inhalation	See General.

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FIRST AID

Skin	Immediately flush with water and continue to do so for at least 30 minutes Remove contaminated clothing. Do not rub or wipe the affected area. As soon as possible after the water rinse, apply polyethylene glycol (PEG) to the area. Apply PEG repeatedly, and continue to do so during transport for medical attention. Obtain immediate medical attention. Destroy all contaminated clothing.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Combustible solid

NFPA rating (flammability) = 2; LEL = 1.3%; UEL = 8.6%

Phenol is a combustible solid (NFPA rating = 2). When heated, phenol produces flammable vapors that are explosive at concentrations of 3 to 10% in air. Carbon dioxide or dry chemical extinguishers should be used to fight phenol fires.

REACTIVITY & INCOMPATIBILITY

Phenol may react violently with strong oxidizing agents.

STORAGE & HANDLING

Phenol should be handled in the laboratory using “basic prudent practices”. Because of its corrosivity and ability to penetrate the skin, all work with phenol and its solutions should be conducted while wearing impermeable gloves, appropriate protective clothing, and splash goggles. Operations with the potential to produce dusts or aerosols of phenol or its solutions should be carried out in a fume hood.

CLEANUP & DISPOSAL

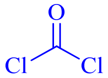
Gloves: Neoprene, natural rubber, 4H, SilverShield

In the event of a spill, remove all ignition sources, soak up the phenol with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Care should be taken not to walk in spills of phenol or solutions of phenol because this substance can readily penetrate leather. Excess phenol and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

PHOSGENE

SYNONYMS	CAS#	Formula
Carbonyl chloride; chloroformyl chloride; carbon oxychloride	75-44-5	

PHYSICAL PROPERTIES

Odor:	Sweet, haylike odor at lower levels, pungent at higher levels; detectable at 0.1 to 5.7 ppm	**Appearance:**	Colorless gas
Water Solubility:	0.0003 g/100 mL	**Vapor Density:**	3.4 at bp (air = 1.0)
Flash Point:	White phosphorus: 30 °C	**Vapor Pressure:**	1,180 mmHg at 20 °C
Autoignition:	White phosphorus: 29 °C Red phosphorus: 260 °C	**bp/mp:**	279 °C/44 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):		**TLV-TWA (ACGIH):**	0.1 ppm (0.4 mg/m^3)
LC_{50} inhal. (rat):	341 ppm (1,364 mg/m^3; 30 min)	**PEL (OSHA):**	0.1 ppm (0.4 mg/m^3)

HEALTH AND SYMPTOMS

General	Phosgene is a highly toxic, irritating, and corrosive gas to all body tissues; inhalation can cause fatal respiratory damage. Phosgene is not regarded as a substance with adequate warning properties. Phosgene has not been found to be carcinogenic or to show reproductive or developmental toxicity in humans.
Skin	The liquid can cause severe burns to the skin.
Eyes	Vapor is irritating to the eyes at 4 ppm. Liquid can cause burns.
Ingestion	Irritation of the throat occurs at 3 ppm.
Inhalation	Exposure to 20 to 30 ppm for as little as 1 minute may cause severe irritation of the upper and lower respiratory tract, with symptoms including burning throat, nausea, vomiting, chest pain, coughing, shortness of breath, and headache. Brief exposure to 50 ppm can be fatal within a few hours. After 4 to 72 hours, severe respiratory distress may occur in which pulmonary edema progresses to pneumonia and cardiac failure.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

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REACTIVITY & INCOMPATIBILITY

Phosgene reacts with water to form HCl and carbon dioxide.

STORAGE & HANDLING

All work should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Containers of phosgene solutions should be stored in secondary containers, and phosgene cylinders should be stored in a cool, well-ventilated area separated from incompatible materials.

CLEANUP & DISPOSAL

In case of the accidental release of phosgene gas, such as from a leaking cylinder or associated apparatus, evacuate the area and eliminate the source of the leak if this can be done safely. Remove cylinder to a fume hood or remote area if it cannot be shut off. In the event of a spill of a phosgene solution, soak up the solution with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Full respiratory protection and protective clothing will be necessary in the event of a spill or release in a confined area. Excess and waste should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

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SYNONYMS	**CAS#**	**Formula**
White phosphorus, yellow phosphorus	7723-14-0	P_4

PHYSICAL PROPERTIES

Odor:	Acrid fumes when exposed to air	**Appearance:**	White to yellow, waxy soft solid
Water Solubility:	0.0003 g/100 mL	**Vapor Density:**	4.4 at 279 °C (air = 1.0)
Flash Point:	White phosphorus: 30 °C	**Vapor Pressure:**	0.03 mmHg at 20 °C
Autoignition:	White phosphorus: 29 °C Red phosphorus: 260 °C	**bp/mp:**	279 °C/44 °C

TOXICITY		**EXPOSURE LIMITS**	
LD_{50}oral (rat):	3 mg/kg	**TLV-TWA (ACGIH):**	0.02 ppm (0.1 mg/m^3)
		PEL (OSHA):	0.1 mg/m^3

HEALTH AND SYMPTOMS

General	White phosphorus is a highly toxic substance by all routes of exposure. Red phosphorus is much less toxic than the white allotrope; however, samples of red phosphorus may contain the white form as an impurity. Phosphorus ignites and burns spontaneously when exposed to air, and the resulting vapors are highly irritating to the eyes and respiratory tract. Early signs of chronic systemic poisoning by phosphorus are reported to include anemia, loss of appetite, gastrointestinal distress, chronic cough, a garliclike odor to the breath, and pallor. A common response to severe chronic poisoning is damage of the jaw ("phossy jaw”) and other bones.
Skin	Contact of the solid with the skin produces deep painful burns, and eye contact can cause severe damage.
Eyes	Phosphorus ignites and burns spontaneously when exposed to air, and the resulting vapors are highly irritating to the eyes and respiratory tract.
Ingestion	Ingestion of phosphorus leads (after a delay of a few hours) to symptoms including nausea, vomiting, belching, and severe abdominal pain. Apparent recovery may be followed by a recurrence of symptoms. Death may occur after ingestion of 50 to 100 mg due to circulatory, liver, and kidney effects.
Inhalation	See General.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = NA; LEL = NA; UEL = NA

White phosphorus ignites spontaneously upon contact with air, producing an irritating, dense white smoke of phosphorus oxides. Use water to extinguish phosphorus fires.

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REACTIVITY & INCOMPATIBILITY

White phosphorus reacts with a number of substances to form explosive mixtures. For example, dangerous explosion hazards are produced upon reaction of phosphorus with many oxidizing agents, including chlorates, bromates, many nitrates, chlorine, bromine, peracids, organic peroxides, chromium trioxide, potassium permanganate, alkaline metal hydroxides (phosphine gas is liberated), and with sulfur, sulfuric acid, and many metals, including the alkali metals, copper, and iron. Red phosphorus is much less reactive than the white allotrope but may ignite or react explosively with strong oxidizing agents.

STORAGE & HANDLING

Work with white phosphorus should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Phosphorus should be stored under water in secondary containers in areas separated from oxidizing agents and other incompatible substances. The less dangerous red form of phosphorus can be handled using the “basic prudent practices” described in this book.

CLEANUP & DISPOSAL

In the event of a spill, douse with water and cover with wet sand or earth; collect material in a suitable container and dispose of properly. Respiratory protection may be necessary in the event of a spill or release in a confined area. Excess phosphorus and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines. For more information on disposal procedures, see Chapter 8 of this volume.

ADDITIONAL CONSIDERATIONS

None

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POTASSIUM

SYNONYMS	**CAS#**	**Formula**
Kalium	7440-09-7	K

PHYSICAL PROPERTIES

Odor:	Odorless	**Appearance:**	Silvery white metal that loses its luster on exposure to air or moisture
Water Solubility:	Explodes on contact with water	**Vapor Density:**	NA
Flash Point:	NA	**Vapor Pressure:**	Negligible at 20 °C
Autoignition:	25 °C or below in air or oxygen	**bp/mp:**	765.5 °C/63 °C

TOXICITY	**EXPOSURE LIMITS**

HEALTH AND SYMPTOMS

General	Contact of metallic potassium with the skin, eyes, or mucous membranes causes severe burns; thermal burns may also occur due to ignition of the metal and liberated hydrogen.
Skin	Potassium reacts with the moisture on skin and other tissues to form highly corrosive potassium hydroxide.
Eyes	See General.
Ingestion	See General.
Inhalation	See General.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 3; LEL = NA; UEL = NA

Potassium metal may ignite spontaneously on contact with air at room temperature. Potassium reacts explosively with water to form potassium hydroxide; the heat liberated generally ignites the hydrogen formed and can initiate the combustion of potassium metal itself. Potassium fires must be extinguished with a class D dry chemical extinguisher or by the use of sand, ground limestone, dry clay or graphite, or Met-L-X-type solids. ***Water or CO_2 extinguishers must never be used on potassium fires.***

REACTIVITY & INCOMPATIBILITY

Potassium is one of the most potent reducing reagents known. The metal reacts explosively with water, oxygen, and air to form potassium hydroxide and/or potassium oxide. Potassium reacts violently with many oxidizing agents and organic and inorganic halides and can form unstable and explosive mixtures with elemental halogens. Explosive mixtures form when potassium reacts with halogenated hydrocarbons such as carbon tetrachloride and upon reaction with carbon monoxide,

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carbon dioxide, and carbon disulfide. Potassium stored under mineral oil can form shock-sensitive peroxides if oxygen is present, and so the metal must always be stored and handled under inert gases such as dry nitrogen or argon. It dissolves with such exothermicity in other metals such as mercury that the molten alloy may melt Pyrex glassware. Note that chunks of potassium are less reactive than the very dangerous dispersions and sands.

STORAGE & HANDLING

Safety glasses, impermeable gloves, and a fire-retardant laboratory coat should be worn at all times. Potassium metal should be handled under the surface of an inert liquid such as mineral oil, xylene, or toluene. Use only in areas free of ignition sources and store under inert atmosphere in mineral. Potassium metal that has formed a yellow oxide coating should be disposed of immediately; do not attempt to cut such samples with a knife since the oxide coating may be explosive.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, quench the resulting potassium fire with a dry chemical extinguishing medium, sweep up, place in an appropriate container under an inert atmosphere, and dispose of properly. Respiratory protection may be necessary in the event of a spill or release in a confined area. Excess potassium and waste material containing this substance should be placed in an appropriate container under an inert atmosphere, clearly labeled, and handled according to your organization's waste disposal guidelines. Experienced personnel can destroy small scraps of potassium by carefully adding *tert*-butyl alcohol or 1-butanol to a beaker containing the metal scraps covered in an inert solvent such as xylene or toluene.

ADDITIONAL CONSIDERATIONS

Potassium is not suitable for use by students.

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POTASSIUM HYDRIDE, SODIUM HYDRIDE

SYNONYMS	CAS#	Formula
Kalium	7693-26-7	KH
	7646-69-7	NaH

PHYSICAL PROPERTIES

Water Solubility:	Reacts violently with water	**Appearance:**	White to brownish-gray crystalline powders (white-gray or white-beige dispersion in mineral oil)
Flash Point:	NA	**Vapor Density:**	NA
Autoignition:	Ignites spontaneously at room temperature in moist air	**Vapor Pressure:**	NA
		bp/mp:	Solid NaH decomposes at 800 °C

TOXICITY	EXPOSURE LIMITS

HEALTH AND SYMPTOMS

General	Reacts violently with water, liberating highly flammable hydrogen gas. Contact of these hydrides with the skin, eyes, or mucous membranes causes severe burns; thermal burns may also occur due to ignition of the liberated hydrogen gas.
Skin	Sodium hydride and potassium hydride react with the moisture on skin and other tissues to form highly corrosive sodium and potassium hydroxide.
Eyes	See General.
Ingestion	See General.
Inhalation	See General.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 3; LEL = NA; UEL = NA

Will ignite on contact with moist air. The mineral oil dispersions do not ignite spontaneously on exposure to the atmosphere. Use class D dry chemical extinguisher or sand, ground limestone, dry clay or graphite, or “Met-L-X-type solids. *Water or CO_2 extinguishers must never be used on sodium and potassium hydride fires.*

REACTIVITY & INCOMPATIBILITY

React violently with water, liberating hydrogen, which can ignite. Explosions can result from contact with strong oxidizers. Potassium hydride is generally more reactive than sodium hydride and may react violently with oxygen, CO, dimethyl sulfoxide, alcohols, and acids.

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STORAGE & HANDLING

Safety glasses, impermeable gloves, and a fire-retardant laboratory coat should be worn at all times when working with these substances. Use only in areas free of ignition sources and store as mineral oil dispersions under an inert gas such as argon.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, quench the metal hydride, whether burning or not, with a dry chemical extinguishing medium, sweep up, place in an appropriate container under an inert atmosphere, and dispose of properly. Respiratory protection may be necessary in the event of a spill or release in a confined area. Excess potassium or sodium hydride and waste material containing these substances should be placed in an appropriate container under an inert atmosphere, clearly labeled, and handled according to your organization's waste disposal guidelines.

Experienced personnel can destroy small quantities of sodium hydride and potassium hydride by the careful dropwise addition of *tert*-butyl alcohol or isopropyl alcohol to a suspension of the metal hydride in an inert solvent such as toluene under an inert atmosphere such as argon. Great care must be taken in the destruction of potassium hydride because of its greater reactivity. The resulting mixture of metal alkoxide should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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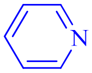
PYRIDINE

SYNONYMS	CAS#	Formula
Azabenzene; azine	110-86-1	

PHYSICAL PROPERTIES

Odor:	Nauseating odor detectable at 0.23 to 1.9 ppm (mean = 0.66 ppm)	**Appearance:**	Colorless or pale yellow liquid
Water Solubility:	Miscible with water	**Vapor Density:**	2.72 at bp (air = 1.0)
Flash Point:	20 °C	**Vapor Pressure:**	18 mmHg at 20 °C
Autoignition:	482 °C	**bp/mp:**	115 °C/−42 °C

TOXICITY		EXPOSURE LIMITS	
LD$_{50}$ oral (rat):	891 mg/kg	**TLV-TWA (ACGIH):**	5 ppm (15 mg/m^3)
LD$_{50}$ skin (rabbit):	1,121 mg/m^3	**PEL (OSHA):**	5 ppm (15 mg/m^3)

HEALTH AND SYMPTOMS

General	The acute toxicity of pyridine is low. Chronic exposure to pyridine can result in damage to the liver, kidneys, and central nervous system. Pyridine has not been found to be carcinogenic or to show reproductive or developmental toxicity in humans.
Skin	Pyridine irritates the eyes and skin and is readily absorbed, leading to systemic effects.
Eyes	Pyridine irritates the eyes and skin and is readily absorbed, leading to systemic effects.
Ingestion	Ingestion of pyridine can result in liver and kidney damage. Pyridine causes olfactory fatigue, and its odor does not provide adequate warning of the presence of harmful concentrations.
Inhalation	Inhalation causes irritation of the respiratory system and may affect the central nervous system, causing headache, nausea, vomiting, dizziness, and nervousness.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating (flammability) = 3; LEL = 1.8%; UEL = 12.4%

Pyridine is a highly flammable liquid, and its vapor can travel a considerable distance and flash back. Pyridine vapor forms explosive mixtures with air at concentrations of 1.8 to 12.4% (by volume). Carbon dioxide or dry chemical extinguishers should be used for pyridine fires.

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REACTIVITY & INCOMPATIBILITY

Pyridine may react violently with dinitrogen tetroxide, acid chlorides and anhydrides, perchloric acid, and strong oxidizing agents.

STORAGE & HANDLING

Gloves: Butyl rubber , PVA

Pyridine should be handled in the laboratory using the “basic prudent practices” described in this book. In particular, pyridine should be used only in areas free of ignition sources, and quantities greater than 1 L should be stored in tightly sealed metal containers in areas separate from oxidizers.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, soak up the pyridine with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess pyridine and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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SILVER AND ITS COMPOUNDS

SYNONYMS	CAS#	Formula
Argentum	7440-22-4	Ag

PHYSICAL PROPERTIES

Odor:	Odorless	**Appearance:**	White metallic solid
Water Solubility:	Insoluble in water	**Vapor Density:**	2.72 at bp (air = 1.0)
Flash Point:	20 °C	**Vapor Pressure:**	18 mmHg at 20 °C
Autoignition:	482 °C	**bp/mp:**	2,200 °C/961 °C

TOXICITY

EXPOSURE LIMITS

TLV-TWA (ACGIH)	1 mg/m^3 (silver metal) 0.01 mg/m^3 (soluble silver compounds, as Ag)
PEL (OSHA):	0.01 mg/m^3

HEALTH AND SYMPTOMS

General	The acute toxicity of silver metal is low. The acute toxicity of soluble silver compounds depends on the counterion and must be evaluated case by case. For example, silver nitrate is strongly corrosive and can cause burns and permanent damage to the eyes and skin. Chronic exposure to silver or silver salts can cause a local or generalized darkening of the mucous membranes, skin, and eyes known as argyria. The other chronic effects of silver compounds must be evaluated individually.
Skin	See General.
Eyes	See General.
Ingestion	See General.
Inhalation	See General.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the individual to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Silver and most soluble silver compounds are not combustible. However, silver nitrate and certain other silver compounds are oxidizers and can increase the flammability of combustible materials. Silver acetylide, azide, fulminate, oxalate mixtures, styphnate, tartarate mixtures, and tetrazene are all explosives and must be handled as such.

REACTIVITY & INCOMPATIBILITY

Contact of metallic silver and silver compounds with acetylene may cause formation of silver acetylide, which is a shock-sensitive explosive. Contact with ammonia may cause formation of compounds that are explosive when dry. Contact with strong hydrogen peroxide solutions causes violent decomposition with the formation of oxygen gas. Many silver compounds are light sensitive, and many have significant reactivities or incompatibilities, which should be evaluated before use.

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STORAGE & HANDLING

Gloves: Viton, butyl rubber, PVC, neoprene

Individual silver compounds should be evaluated on a case-by-case basis. Most silver compounds should be protected from light during storage or while in use.

CLEANUP & DISPOSAL

In the event of a spill, sweep up the silver or silver compounds or soak up with a nonreactive absorbent material or spill pillow, place in an appropriate container and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess silver, silver compounds, and waste material containing these substances should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines. Collection for silver recovery should be considered.

ADDITIONAL CONSIDERATIONS

None

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SODIUM

SYNONYMS	CAS#	Formula
Natrium	7440-23-5	Na

PHYSICAL PROPERTIES

Odor:	Odorless	**Appearance:**	Soft, silvery-white metal
Water Solubility:	Reacts violently with water	**Vapor Density:**	2.72 at bp (air = 1.0)
Flash Point:	20 °C	**Vapor Pressure:**	1.2 mmHg at 400 °C
Autoignition:	>115 °C in air	**bp/mp:**	881.4 °C/97.8 °C

TOXICITY	EXPOSURE LIMITS	
	TLV-TWA (ACGIH):	1 mg/m3 (silver metal) 0.01 mg/m3 (soluble silver compounds, as Ag)
	PEL (OSHA):	0.01 mg/m^3

HEALTH AND SYMPTOMS

General	Sodium reacts with the moisture on skin and other tissues to form highly corrosive sodium hydroxide. Contact of metallic sodium with the skin, eyes, or mucous membranes causes severe burns; thermal burns may also occur due to ignition of the metal and liberated hydrogen.
Skin	See General.
Eyes	See General.
Ingestion	See General.
Inhalation	See General.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the individual to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating (flammability) = 3; LEL = NA; UEL = NA

Spontaneously ignites when heated above 115 °C in air that has even modest moisture content, and any sodium vapor generated is even more flammable. Sodium reacts violently on contact with water and often ignites or explodes the hydrogen formed. Sodium fires must be extinguished with a class D dry chemical extinguisher or by the use of sand, ground limestone, dry clay or graphite, or "Met-L-X-type solids. *Water or CO_2 extinguishers must never be used on sodium fires.*

REACTIVITY & INCOMPATIBILITY

Sodium is a potent reducing agent and reacts violently with water to form hydrogen and sodium hydroxide. It also reacts violently with mineral acids and halogens and reacts exothermically with oxidizing agents, organic and inorganic halides, and protic media. Shock-sensitive mixtures can form upon reaction of sodium with halogenated hydrocarbons such as carbon tetrachloride and chloroform. Sodium also reacts to generate shock-sensitive products with sulfur oxides and

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phosphorus, and reacts with incandescence with many metal oxides such as mercurous and lead oxides. Sodium dissolves in many other metals such as mercury and potassium with great evolution of heat. The reactivity of a sample of sodium is largely related to its surface area. Thus, reactions involving large pieces of sodium metal (especially those with some oxide or hydroxide coating) may be slow and controlled, but similar reactions involving clean, high-surface-area sodium dispersions may be vigorous or violent.

STORAGE & HANDLING

A fire-retardant laboratory coat should be worn at all times when working with sodium, and the metal should be handled under the surface of an inert liquid such as mineral oil, xylene, or toluene. Sodium should be used only in areas free of ignition sources and should be stored under mineral oil in tightly sealed metal containers under an inert gas such as argon.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, cover the sodium with a dry chemical extinguishing agent, sweep up, place in an appropriate container under an inert atmosphere, and dispose of properly. Respiratory protection may be necessary in the event of a spill or release in a confined area. Excess sodium and waste material containing this substance can be placed in an appropriate container under an inert atmosphere, clearly labeled, and handled according to your organization's waste disposal guidelines. Experienced personnel can destroy small scraps of sodium by carefully adding 95% ethanol to a beaker containing the metal scraps covered in an inert solvent such as xylene or toluene. The resulting mixture should then be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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SODIUM AZIDE

SYNONYMS	CAS#	FORMULA
Hydrazoic acid, sodium salt	26628-22-8	$^-N{=}N^+{=}N^-\ Na^+$

PHYSICAL PROPERTIES

Odor:	Odorless solid	**Appearance:**	Colorless crystalline solid
Water Solubility:	41.7 g/100 mL at 17 °C	**Vapor Density:**	NA
Flash Point:	NA	**Vapor Pressure:**	NA
Autoignition:	NA	**bp/mp:**	Solid decomposes at 275 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	27 mg/kg	**TLV-TWA (ACGIH):**	0.29 mg/m^3 (ceiling)
LD_{50} skin (rabbit):	20 mg/kg	**PEL (OSHA):**	None

HEALTH AND SYMPTOMS

General	The acute toxicity of sodium azide is high. Symptoms of exposure include lowered blood pressure, headache, hypothermia, and in the case of serious overexposure, convulsions and death. Chronic, low-level exposure may cause nose irritation, episodes of falling blood pressure, dizziness, and bronchitis. Sodium azide has not been found to be carcinogenic in humans.
Skin	Solutions of sodium azide can be absorbed through the skin.
Eyes	May cause eye irritation.
Ingestion	Ingestion of 100 to 200 mg in humans may result in headache, respiratory distress, and diarrhea. Target organs are primarily the central nervous system and brain. Symptoms of acute exposure to hydrazoic acid include eye irritation, headache, dramatic decrease in blood pressure, weakness, pulmonary edema, and collapse.
Inhalation	Sodium azide rapidly hydrolyzes in water to form hydrazoic acid, a highly toxic gas that can escape from solution, presenting a serious inhalation hazard. Symptoms of acute exposure to hydrazoic acid include eye irritation, headache, dramatic decrease in blood pressure, weakness, pulmonary edema, and collapse.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the individual to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Flammability hazard is low, but violent decomposition can occur when heated to 275 °C. Decomposition products include oxides of nitrogen and sodium oxide.

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REACTIVITY & INCOMPATIBILITY

Sodium azide should not be allowed to come into contact with heavy metals or their salts, because it may react to form heavy metal azides, which are notorious shock-sensitive explosives. Do not pour sodium azide solutions into a copper or lead drain. Sodium azide reacts violently with carbon disulfide, bromine, nitric acid, dimethyl sulfate, and a number of heavy metals, including copper and lead. Reaction with water and acids liberates highly toxic hydrazoic acid, which is a dangerous explosive. Sodium azide is reported to react with CH_2Cl_2 in the presence of DMSO to form explosive products.

STORAGE & HANDLING

Work with sodium azide should be conducted in a fume hood to prevent exposure by inhalation, and appropriate impermeable gloves and splash goggles should be worn at all times to prevent skin and eye contact. Containers of sodium azide should be stored in secondary containers in a cool, dry place separated from acids.

CLEANUP & DISPOSAL

In the event of a spill, cover sodium azide with sand, sweep up, and place in a container for disposal. Soak up spilled solutions with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess sodium azide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Sodium azide is not suitable for use by students.

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SODIUM CYANIDE, POTASSIUM CYANIDE

SYNONYMS	CAS#	FORMULA
	143-33-9	$NaCN$
	151-50-8	KCN

PHYSICAL PROPERTIES

Odor:	The dry salts are odorless, but reaction with atmospheric moisture produces HCN, whose bitter almond odor is detectable at 1 to 5 ppm	**Appearance:**	White solids
Water Solubility:	NaCN: 37 g/100 mL KCN: 41 g/100 mL	**Vapor Density:**	NA
Flash Point:	Noncombustible	**Vapor Pressure:**	Negligible
Autoignition:	NA	**bp/mp:**	NaCN: 1,496 °C/564 °C KCN: 1,625 °C/634 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	NaCN: 6.4 mg/kg KCN: 5 mg/kg	**TLV-TWA (ACGIH):**	5 mg/kg (KCN)—skin

HEALTH AND SYMPTOMS

General The acute toxicity of these metal cyanides is high. Ingestion of NaCN or KCN or exposure to the salts or their aqueous solutions by eye or skin contact can be fatal; exposure to as little as 50 to 150 mg can cause immediate collapse and death. Twenty to sixty percent of the population is reported to be unable to detect the odor of HCN. Therefore, these compounds are not regarded as having good warning properties. Effects of chronic exposure to sodium cyanide or potassium cyanide are nonspecific and rare.

Skin See General.

Eyes See General.

Ingestion See General.

Inhalation Poisoning can occur by inhalation of mists of cyanide solutions and by inhalation of HCN produced by the reaction of metal cyanides with acids and with water. Symptoms of nonlethal exposure to cyanide include weakness, headache, dizziness, rapid breathing, nausea, and vomiting.

FIRST AID

Specific medical procedures for treating cyanide exposure are available but usually must be administered by properly trained personnel.

Skin Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.

Eyes Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.

Ingestion Seek medical attention immediately.

Inhalation If the individual is overcome by fumes, move the individual to fresh air and seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Sodium cyanide and potassium cyanide are noncombustible solids. Reaction with acids liberates flammable HCN.

REACTIVITY & INCOMPATIBILITY

Reaction with acid produces highly toxic and flammable hydrogen cyanide gas. Reaction with water can produce dangerous amounts of HCN in confined areas.

STORAGE & HANDLING

Gloves: Viton, butyl rubber, nitrile, neoprene, PVC

Work with cyanides should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact. Cyanide salts should be stored in a cool, dry location, separated from acids.

CLEANUP & DISPOSAL

Consult your environmental safety office or its equivalent before beginning work with cyanides. In the event of a spill, remove all ignition sources in case of HCN generation, soak up the sodium cyanide or potassium cyanide with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess sodium or potassium cyanide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

Cyanide salts are not suitable for use by students, and access to these chemicals should be carefully controlled.

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SODIUM HYDROXIDE, POTASSIUM HYDROXIDE

SYNONYMS	CAS#	Formula
Sodium hydrate, caustic soda, lye, caustic	1310-73-2	NaOH
Potassium hydrate, caustic potash	1310-58-3	KOH

PHYSICAL PROPERTIES

Odor:	Odorless	**Appearance:**	Soft, silvery-white metal
Water Solubility:	NaOH: Highly soluble in water (109 g/100 mL); KOH: Highly soluble in water	**Vapor Density:**	2.72 at bp (air = 1.0)
Flash Point:	20 °C	**Vapor Pressure:**	1.2 mmHg at 400 °C
Autoignition:	>115 °C in air	**bp/mp:**	NaOH: 1390 °C/318 °C; KOH: 1,320 °C/360 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat):	NaOH: 140 to 340 mg/kg; KOH: 365 mg/kg	**TLV-TWA (ACGIH):**	2 mg/m^3; ceiling
LD_{50}skin (rabbit):	NaOH: 1,350 mg/kg; KOH: 1,260 mg/kg	**PEL (OSHA):**	2 mg/m^3; 2 mg/m^3

HEALTH AND SYMPTOMS

General	The alkali metal hydroxides are highly corrosive substances; contact of solutions, dusts, or mists with the skin, eyes, and mucous membranes can lead to severe damage.
Skin	Skin contact with the solid hydroxides or concentrated solutions can cause rapid tissue destruction and severe burns. In contrast to acids, hydroxides do not coagulate protein (which impedes penetration), and metal hydroxide burns may not be immediately painful while skin penetration occurs to produce severe and slow-healing burns. Potassium hydroxide is somewhat more corrosive than sodium hydroxide. Contact with even dilute solutions will also cause skin irritation and injury, the severity of which will depend on the duration of contact. Repeated or prolonged contact may cause dermatitis. Sodium hydroxide and potassium hydroxide have not been found to be carcinogenic or to show reproductive or developmental toxicity in humans.
Eyes	Eye exposure to concentrated sodium hydroxide or potassium hydroxide solutions can cause severe eye damage and possibly blindness.
Ingestion	Ingestion of concentrated solutions of sodium hydroxide or potassium hydroxide can cause severe abdominal pain, as well as serious damage to the mouth, throat, esophagus, and digestive tract.
Inhalation	Inhalation of sodium/potassium hydroxide dust or mist can cause irritation and damage to the respiratory tract, depending on the concentration and duration of exposure. Exposure to high concentrations may result in delayed pulmonary edema.

FIRST AID

Skin	In the event of skin contact, immediately wash with soap and water and remove contaminated clothing.

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Eyes In case of eye contact, promptly wash with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.

Ingestion If ingested seek medical attention immediately.

Inhalation If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Sodium hydroxide and potassium hydroxide are not flammable as solids or aqueous solutions.

REACTIVITY & INCOMPATIBILITY

The concentrated compounds can react vigorously with acids with evolution of heat, and dissolution in water is highly exothermic. Reaction with aluminum and other metals may lead to evolution of hydrogen gas. Prolonged contact with chloroform, trichloroethylene, and tetrachloroethanes can produce explosive products. Many organic compounds such as propylene oxide, allyl alcohol, glyoxal, acetaldehyde, acrolein, and acrylonitrile can violently polymerize on contact with concentrated base. Reaction with nitromethane and nitrophenols produces shock-sensitive explosive salts. The hydroxides absorb moisture and carbon dioxide from the air to form the bicarbonates. Aqueous solutions also absorb carbon dioxide to form bicarbonate. Solutions stored in flasks with ground glass stoppers may leak air and freeze the stoppers, preventing removal.

STORAGE & HANDLING

Gloves: Butyl rubber, neoprene

Operations with metal hydroxide solutions that have the potential to create aerosols should be conducted in a fume hood to prevent exposure by inhalation. When mixing with water, always add caustics slowly to the water and stir continuously. Containers of hydroxides should be stored in a cool, dry location, separated from acids and incompatible substances.

CLEANUP & DISPOSAL

If neutralization and drain disposal is not permitted, excess hydroxide and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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SULFUR DIOXIDE

SYNONYMS	CAS#	Formula
Sulfurous oxide, sulfur oxide, sulfurous anhydride	7446-09-5	$O{=}S{=}O$

PHYSICAL PROPERTIES

Odor:	Pungent odor detectable at 0.3 to 5 ppm	**Appearance:**	Colorless gas or liquid under pressure
Water Solubility:	10 g/100 mL at 20 °C	**Vapor Density:**	2.26 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	1,779 mmHg at 21 °C
Autoignition:	>115 °C in air	**bp/mp:**	−10.0 °C/−75.5 °C

TOXICITY		EXPOSURE LIMITS	
LC_{50}inhal. (rat)	2,520 ppm (6,590 mg/m^3; 1 h)	**TLV-TWA (ACGIH):**	2 ppm (5.2 mg/m^3)
LC_{LO} inhal. (human)	1,000 ppm (2,600 mg/m^3; 10 min)	**STEL (ACGIH):**	5 ppm (13 mg/m^3)
		PEL (OSHA):	5 ppm (13 mg/m^3)

HEALTH AND SYMPTOMS

General	Intensely irritating to the skin, eyes, and respiratory tract; moderate acute toxicity. Sulfur dioxide gas is a severe corrosive irritant of the eyes, mucous membranes, and skin. Its irritant properties are due to the rapidity with which it forms sulfurous acid on contact with moist membranes. Exposure to concentrations of 10 to 50 ppm for 5 to 15 minutes causes irritation of the eyes, nose, and throat, choking, and coughing. Some individuals are extremely sensitive to the effects of sulfur dioxide, whereas experienced workers may become adapted to its irritating properties. Sulfur dioxide is regarded as a substance with good warning properties except in the case of individuals with reactive respiratory tracts and asthmatics. Sulfur dioxide has not been shown to be carcinogenic or to have reproductive or developmental effects in humans. Chronic exposure to low levels of sulfur dioxide has been shown to exacerbate pulmonary disease.
Skin	Liquid SO_2 on the skin produces skin burns from the freezing effect of rapid evaporation.
Eyes	Exposure of the eyes to liquid sulfur dioxide from pressurized containers can cause severe burns, resulting in the loss of vision.
Ingestion	Ingestion of a gas is unlikely.
Inhalation	Inhalation of high concentrations may cause death as a result of respiratory paralysis and pulmonary edema. Exposure to 400 to 500 ppm is immediately dangerous, and 1,000 ppm for 10 minutes is reported to have caused death in humans. When sulfur dioxide is inhaled, most of it is absorbed in the upper respiratory passages, where most of its effects then occur. Exposure to concentrations of 10 to 50 ppm for 5 to 15 minutes causes irritation of the eyes, nose, and throat, choking, and coughing. Some individuals are extremely sensitive to the effects of sulfur dioxide, whereas experienced workers may become adapted to its irritating properties. Sulfur dioxide is regarded as a substance with good warning properties except in the case of individuals with reactive respiratory tracts and asthmatics.

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FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

REACTIVITY & INCOMPATIBILITY

Contact with some powdered metals and with alkali metals such as sodium or potassium may cause fires and explosions. Liquid sulfur dioxide will attack some forms of plastic, rubber, and coatings.

STORAGE & HANDLING

Gloves: Viton, PVC

Sulfur dioxide should be handled in the laboratory using the “basic prudent practices.”

CLEANUP & DISPOSAL

Leaks of sulfur dioxide may be detected by passing a rag dampened with aqueous NH_3 over the suspected valve or fitting. White fumes indicate escaping SO_2 gas. To respond to a release, use appropriate protective equipment and clothing. Positive-pressure air-supplied respiratory protection is required. Close cylinder valve and ventilate area. Remove cylinder to a fume hood or remote area if it cannot be shut off. If in liquid form, allow to vaporize. Excess sulfur dioxide should be returned to the manufacturer if possible, according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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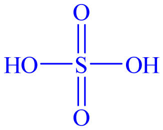
SULFURIC ACID

SYNONYMS	CAS#	Formula
Oil of vitriol	7664-93-9	

PHYSICAL PROPERTIES

Odor:	Odorless	**Appearance:**	Clear, colorless, oily liquid
Water Solubility:	10 g/100 mL at 20 °C	**Vapor Density:**	3.4 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	<0.3 mmHg at 25 °C
Autoignition:	>115 °C in air	**bp/mp:**	300 to 338 °C (loses SO_3 above 300 °C)/11 °C

TOXICITY		**EXPOSURE LIMITS**	
LD_{50} oral (rat):	2,140 mg/kg	**TLV-TWA (ACGIH):**	1 mg/m^3
LC_{50} inhal. (rat):	347 mg/m^3 (1 h)	**STEL (ACGIH):**	3 mg/m^3
		PEL (OSHA):	1 mg/m^3

HEALTH AND SYMPTOMS

General	Highly corrosive; causes severe burns on eye and skin contact and upon inhalation of sulfuric acid mist. Chronic exposure to sulfuric acid mist may lead to bronchitis, skin lesions, conjunctivitis, and erosion of teeth. Animal testing with sulfuric acid did not demonstrate carcinogenic, mutagenic, embryotoxic, or reproductive effects.
Skin	Concentrated sulfuric acid is a highly corrosive liquid that can cause severe, deep burns upon skin contact. The concentrated acid destroys tissue because of its dehydrating action, while dilute H_2SO_4 acts as a skin irritant because of its acid character.
Eyes	Eye contact with concentrated H_2SO_4 causes severe burns, which can result in permanent loss of vision; contact with dilute H_2SO_4 results in more transient effects from which recovery may be complete. Sulfuric acid mist severely irritates the eyes, respiratory tract, and skin.
Ingestion	Ingestion of sulfuric acid may cause severe burns to the mucous membranes of the mouth and esophagus.
Inhalation	Because of its low vapor pressure, the principal inhalation hazard from sulfuric acid involves breathing in acid mists, which may result in irritation of the upper respiratory passages and erosion of dental surfaces. Higher inhalation exposures may lead to temporary lung irritation with difficulty breathing.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Sulfuric acid is noncombustible but can cause finely divided combustible substances to ignite. Sulfuric acid reacts with most metals, especially when dilute, to produce flammable and potentially explosive hydrogen gas.

REACTIVITY & INCOMPATIBILITY

May react violently with water and with many organic compounds because of its action as a powerful dehydrating, oxidizing, and sulfonating agent. Ignition or explosions may occur on contact of sulfuric acid with many metals, carbides, chlorates, perchlorates, permanganates, bases, and reducing agents. Sulfuric acid reacts with a number of substances to generate highly toxic products. Examples include the reaction of H_2SO_4 with formic or oxalic acid (CO formation), with cyanide salts (HCN formation), and sodium bromide (SO_2 and Br_2 formation).

STORAGE & HANDLING

Gloves: Butyl rubber, neoprene

Splash goggles and rubber gloves should be worn when handling this acid, and containers of sulfuric acid should be stored in a well-ventilated location, separated from organic substances and other combustible materials. Containers of sulfuric acid should be stored in secondary plastic trays to avoid corrosion of metal storage shelves due to drips or spills. Water should never be added to sulfuric acid because splattering may result; always add acid to water.

CLEANUP & DISPOSAL

Carefully neutralize small spills of sulfuric acid with a suitable agent such as sodium carbonate, further dilute with absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess sulfuric acid and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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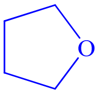
TETRAHYDROFURAN

SYNONYMS	CAS#	Formula
THF, oxacyclopentane, tetramethylene oxide	109-99-9	

PHYSICAL PROPERTIES

Odor:	Ethereal, detectable at 2 to 50 ppm	**Appearance:**	Colorless liquid
Water Solubility:	Miscible with water	**Vapor Density:**	2.5 (air = 1.0)
Flash Point:	−14 °C	**Vapor Pressure:**	160 mmHg at 25 °C
Autoignition:	321 °C	**bp/mp:**	66 °C/−108 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50}oral (rat):	2,880 mg/kg	**TLV-TWA (ACGIH):**	200 ppm (590 mg/m^3)
LC_{50}inhal. (rat):	21,000 ppm (3 h)	**STEL (ACGIH):**	250 ppm (737 mg/m^3)
		PEL (OSHA):	200 ppm (590 mg/m^3)

HEALTH AND SYMPTOMS

General	Since the odor threshold for THF is well below the permissible exposure limit, this substance is regarded as having good warning properties. At vapor levels of 100 to 200 ppm, THF irritates the eyes and upper respiratory tract. At high concentrations (25,000 ppm), THF vapor can produce anesthetic effects. Limited animal testing indicates that THF is not carcinogenic and shows developmental effects only at exposure levels producing other toxic effects in adult animals. Bacterial and mammalian cell culture studies demonstrate no mutagenic activity with THF.
Skin	Liquid THF is a severe eye irritant and a mild skin irritant, but is not a skin sensitizer.
Eyes	See General.
Ingestion	The acute toxicity of THF by ingestion is low
Inhalation	The acute toxicity of THF by inhalation is low.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating (flammability) = 3; LEL = 2%; UEL = 11.8%

Vapor can travel a considerable distance to an ignition source and flash back. A 5% solution of THF in water is flammable. THF vapor forms explosive mixtures with air at concentrations of 2

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to 12% (by volume). Carbon dioxide or dry chemical extinguishers should be used for THF fires. THF can form shock- and heat-sensitive peroxides, which may explode on concentration by distillation or evaporation. Always test samples of THF for the presence of peroxides before distilling or allowing it to evaporate. THF should never be distilled to dryness.

REACTIVITY & INCOMPATIBILITY

THF can form potentially explosive peroxides upon long exposure to air. THF may react violently with strong oxidizers and reacts vigorously with bromine and titanium tetrachloride. Polymerization can occur in the presence of cationic initiators such as certain Lewis acids and strong protic acids.

STORAGE & HANDLING

Gloves: Butyl rubber

THF should be handled in the laboratory using the “basic prudent practices” described in Chapter 6, supplemented by the additional precautions for dealing with extremely flammable substances (Chapter 6, section 6.F). In particular, THF should be used only in areas free of ignition sources, and quantities greater than 1 L should be stored in tightly sealed metal containers in areas separate from oxidizers. Containers of THF should be dated when opened and tested periodically for the presence of peroxides.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, soak up the THF with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess THF and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

THF is not suitable for use by students.

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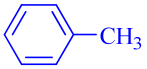
TOLUENE

SYNONYMS	CAS#	Formula
Methylbenzene, toluol, phenylmethane	108-88-3	

PHYSICAL PROPERTIES

Odor:	Aromatic, benzenelike odor detectable at 0.16 to 37 ppm (mean = 1.6 ppm)	**Appearance:**	Colorless liquid
Water Solubility:	Miscible with water	**Vapor Density:**	3.14 (air = 1.0)
Flash Point:	4 °C	**Vapor Pressure:**	22 mmHg at 20 °C
Autoignition:	480 °C	**bp/mp:**	66 °C/−108 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50}oral (rat):	2,650 to 7,530 mg/kg	**TLV-TWA (ACGIH)**	50 ppm (188 mg/m^3)—skin
LC_{50}inhal. (rat):	26,700 ppm (1 h)	**STEL (ACGIH)**	150 ppm (560 mg/m^3)
LD_{50}skin (rabbit):	12,124 mg/kg	**PEL (OSHA):**	200 ppm (750 mg/m^3)

HEALTH AND SYMPTOMS

General	The acute toxicity of toluene is low. Toluene may cause eye, skin, and respiratory tract irritation. The chronic effects of exposure to toluene are much less severe than those of benzene. No carcinogenic effects were reported in animal studies. Equivocal results were obtained in studies to determine developmental effects in animals. Toluene was not observed to be mutagenic in standard studies. . Because of its odor and irritant effects, toluene is regarded as having good warning properties.
Skin	Toluene is a skin irritant and may cause redness and pain when trapped beneath clothing or shoes; prolonged or repeated contact with toluene may result in dry and cracked skin.
Eyes	See General.
Ingestion	Ingestion of toluene may cause nausea and vomiting and central nervous system depression. Contact of liquid toluene with the eyes causes temporary irritation.
Inhalation	Short-term exposure to high concentrations of toluene (e.g., 600 ppm) may produce fatigue, dizziness, headaches, loss of coordination, nausea, and stupor; 10,000 ppm may cause death from respiratory failure.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid and vapor

NFPA rating (flammability) = 3; LEL = NA; UEL = NA

explosive mixtures with air at concentrations of 1.4 to 6.7% (by volume). Hazardous gases

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Vapor can travel a considerable distance to an ignition source and flash back. Toluene vapor forms produced in fire include carbon monoxide and carbon dioxide. Carbon dioxide and dry chemical extinguishers should be used to fight toluene fires.

REACTIVITY & INCOMPATIBILITY

Contact with strong oxidizers may cause fires and explosions.

STORAGE & HANDLING

Gloves: Butyl rubber, 4H, SilverShield

Toluene should be handled in the laboratory using the “basic prudent practices” described in Chapter 6, supplemented by the additional precautions for dealing with highly flammable substances (Chapter 6, section 6.F). In particular, toluene should be used only in areas free of ignition sources, and quantities greater than 1 L should be stored in tightly sealed metal containers in areas separated from oxidizers.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, soak up the toluene with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess toluene and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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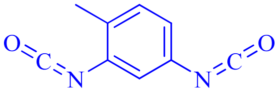
TOLUENE DIISOCYANATE

SYNONYMS	CAS#	Formula
TDI; 2,4-toluene diisocyanate; 2,4-diisocyanato-1-methyl benzene	584-84-9	

PHYSICAL PROPERTIES			
Odor:	Sharp, pungent odor detectable at 0.02 to 0.4 ppm	**Appearance:**	Colorless to pale yellow liquid
Water Solubility:	Insoluble in water (reacts exothermically)	**Vapor Density:**	6.0 (air = 1.0)
Flash Point:	132 °C	**Vapor Pressure:**	.05 mmHg at 25 °C
Autoignition:	>619 °C	**bp/mp:**	bp 251 °C, mp 21 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50}oral (rat):	4,130 mg/kg	**TLV-TWA (ACGIH)**	0.005 ppm (0.036 mg/m^3
LC_{50}inhal. (rat):	14 ppm/4 h (100 mg/m^3; 4 h)	**STEL (ACGIH)**	0.02 ppm (0.14 mg/m^3)
LD_{50}skin (rabbit):	>10 g/kg	**PEL (OSHA**	0.02 ppm(ceiling 0.14 mg/m^3)

HEALTH AND SYMPTOMS	
General	Toluene diisocyanate is listed in IARC Group 2B (“possible human carcinogen”), is listed by the National Toxicology Program as “reasonably anticipated to be a carcinogen,” and is classified as a “select carcinogen" under the criteria of the OSHA Laboratory Standard. The odor of TDI does not provide an adequate warning to avoid overexposure. The odor of TDI does not provide an adequate warning to avoid overexposure.
Skin	Skin irritation and sensitization can also occur.
Eyes	Eye contact can cause irritation with permanent damage if untreated.
Ingestion	The oral acute toxicity of this substance is low.
Inhalation	The acute toxicity of toluene diisocyanate by inhalation is high. Exposure to TDI can cause lung damage and decreased breathing capacity. Symptoms of exposure may include coughing, tightness of the chest, chest pain, nausea, vomiting, abdominal pain, headache, and insomnia. Toluene diisocyanate has caused sensitization of the respiratory tract, manifested by acute asthmatic reaction upon return to work after a period of time away from exposure. Initial symptoms include coughing during the night, with difficult or labored breathing.

FIRST AID	
Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

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FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 1; LEL = 0.9%; UEL = 9.5%

Carbon dioxide or dry chemical extinguishers should be used for TDI fires.

REACTIVITY & INCOMPATIBILITY

Contact with strong oxidizers may cause fires and explosions. Contact with water, acids, bases, and amines can lead to reactions that liberate heat and CO_2 and cause violent foaming and spattering. TDI will attack some forms of plastic, rubber, and coatings.

STORAGE & HANDLING

Gloves: Butyl rubber, 4H, SilverShield

In particular, work with TDI should be conducted in a fume hood to prevent exposure by inhalation, and splash goggles and impermeable gloves should be worn at all times to prevent eye and skin contact.

CLEANUP & DISPOSAL

In the event of a spill, remove all ignition sources, soak up the TDI with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Do not use water during cleanup. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess TDI and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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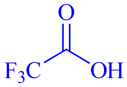
TRIFLUOROACETIC ACID

SYNONYMS	CAS#	Formula
TFA, trifluoroethanoic acid	76-05-1	

PHYSICAL PROPERTIES

Odor:	Sharp, pungent odor	**Appearance:**	Colorless liquid
Water Solubility:	Miscible with water	**Vapor Density:**	3.9 (air = 1.0)
Flash Point:	Noncombustible	**Vapor Pressure:**	107 mmHg at 25 °C
Autoignition:	>619 °C	**bp/mp:**	72 °C/−15 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50}oral (rat):	200 mg/kg		
LC_{50}inhal. (rat):	2,000 ppm (4 h)		

HEALTH AND SYMPTOMS

General	Trifluoroacetic acid is a highly corrosive substance. Contact of the liquid with the skin, eyes, and mucous membranes can cause severe burns, and ingestion can result in serious damage to the digestive tract. TFA vapor is highly irritating of the eyes and respiratory tract. Symptoms of overexposure to TFA vapor include a burning feeling, coughing, headache, nausea, and vomiting. Trifluoroacetic acid has not been found to be carcinogenic or to show reproductive or developmental toxicity in humans.
Skin	See General.
Eyes	See General.
Ingestion	See General.
Inhalation	Inhalation of high concentrations can lead to severe destruction of the upper respiratory tract and may be fatal as a result of pulmonary edema.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = 0; LEL = NA; UEL = NA

Trifluoroacetic acid is not combustible. Nevertheless, the presence of trifluoroacetic acid at the site of a fire would be of great concern because of its high vapor pressure and extreme corrosiveness.

REACTIVITY & INCOMPATIBILITY

Mixing trifluoroacetic acid and water evolves considerable heat.

STORAGE & HANDLING

Trifluoroacetic acid should be handled in the laboratory using basic prudent practices. In particular, trifluoroacetic acid should be stored in an acid cabinet away from other classes of compounds. Because of its high vapor pressure, fumes of trifluoroacetic acid can destroy labels on other bottles if the container is not tightly sealed.

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CLEANUP & DISPOSAL

Carefully neutralize small spills of TFA with a suitable agent such as sodium carbonate, dilute with absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Trifluoroacetic acid and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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TRIMETHYLALUMINUM (and related organoaluminum compounds)

SYNONYMS	CAS#	Formula
Trimethylalane, trimethylaluminium	75-24-1	$(CH_3)_3Al$

PHYSICAL PROPERTIES

Odor:	Corrosive odor and “taste” may be detectable from trimethylaluminum fires	**Appearance:**	Colorless pyrophoric liquid
Water Solubility:	React explosively with water	**Vapor Density:**	Not available
Flash Point:	−18 °C	**Vapor Pressure:**	12 mmHg at 25 °C
Autoignition:	Spontaneously ignites in air (even as a frozen solid)	**bp/mp:**	bp 125 to 126 °C/mp 15 °C

TOXICITY	EXPOSURE LIMITS	
	TLV-TWA (ACGIH):	2 mg (Al)/m^3

HEALTH AND SYMPTOMS

General	Alkylaluminum reagents are corrosive substances, and contact is extremely destructive to the eyes, skin, and mucous membranes. Trimethylaluminum and related alkylaluminum reagents are pyrophoric materials that can react explosively with the moisture in tissues, causing severe burns. The heat of reaction can also ignite the methane gas generated, resulting in thermal burns.
Skin	See General.
Eyes	See General.
Ingestion	See General.
Inhalation	Inhalation of trimethylaluminum and other volatile alkylaluminum compounds may cause severe damage to the respiratory tract and can lead to fatal pulmonary edema.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	If the individual is overcome by fumes, move the person to fresh air and seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

Highly flammable liquid or vapor

NFPA rating (flammability) = 3; LEL = NA; UEL = NA

Trimethylaluminum is pyrophoric and burns violently on contact with air or water. Other alkylaluminum reagents show similar behavior, although most are not as volatile as trimethylaluminum. *Water or CO_2 fire extinguishers must not be used to put out fires involving trialkylaluminum reagents*. Instead, dry chemical powders such as bicarbonate, Met-L-X, or inert smothering agents such as sand or graphite should be used to extinguish fires involving trialkylaluminum compounds.

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REACTIVITY & INCOMPATIBILITY

Trialkylaluminum reagents are highly reactive reducing and alkylating agents. They react violently with air, water, alcohols, halogenated hydrocarbons, and oxidizing agents. These reagents are often supplied as solutions in hydrocarbon solvents, which are less hazardous than the pure liquids

STORAGE & HANDLING

Gloves: PVC

Safety glasses, impermeable gloves, and a fire-retardant laboratory coat should be worn at all times when working with these compounds. Trialkylaluminum reagents should be handled only under an inert atmosphere.

CLEANUP & DISPOSAL

Any spill of trialkylaluminum will likely result in fire. Remove all ignition sources, put out the trialkylaluminum fire with a dry chemical extinguisher, sweep up the resulting solid, place in an appropriate container under an inert atmosphere, and dispose of it properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess trialkylaluminum reagents and waste material containing these substances should be placed in an appropriate container under an inert atmosphere, clearly labeled, and handled according to your organization's waste disposal guidelines. Alternately, small quantities of trialkylaluminum reagents can be destroyed in the laboratory by experienced personnel by slow addition of *tert*-butyl alcohol to a solution of the reagent in an inert solvent such as toluene under an inert atmosphere such as argon. The resulting mixture should then be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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TRIMETHYLTIN CHLORIDE (and other organotin compounds)

SYNONYMS	CAS#	Formula
Chlorotrimethylstannane	1066-45-1	C_3H_9ClSn

PHYSICAL PROPERTIES

Odor:	Strong unpleasant stench; no threshold data available	**Appearance:**	White crystalline solid
Water Solubility:	Insoluble in water	**Vapor Density:**	Not available
Flash Point:	97 °C	**Vapor Pressure:**	12 mmHg at 25 °C
Autoignition:	Spontaneously ignites in air (even as a frozen solid)	**bp/mp:**	37 to 39 °C

TOXICITY		EXPOSURE LIMITS	
LD_{50} oral (rat)	12.6 mg/kg	**TLV-TWA (ACGIH)**	0.1 mg tin/m^3
		STEL (ACGIH)	0.2 mg tin/m^3
		PEL (OSHA	0.1 mg tin/m^3

HEALTH AND SYMPTOMS

General	Trimethyltin chloride and other organotin compounds are highly toxic by ingestion, inhalation, or skin contact Organotin compounds can affect the central nervous system. The degree of toxicity is greatest for compounds with three or four alkyl groups attached to tin. Di and monoalkyltin compounds are moderately toxic. The toxicity diminishes as the size of the alkyl groups increases. Organotin compounds have been shown to cause reproductive effects in laboratory animals.
Skin	Can cause irritation and burns.
Eyes	Can cause irritation and burns.
Ingestion	See General.
Inhalation	See General.

FIRST AID

Skin	Immediately flush with water and remove contaminated clothing. Wash clothing before reuse.
Eyes	Immediately flush with copious amounts of water for 15 minutes (lifting upper and lower lids occasionally) and obtain medical attention.
Ingestion	Seek medical attention immediately.
Inhalation	Move the person to fresh air. If the individual is overcome by fumes, seek medical attention at once.

FLAMMABILITY & EXPLOSIVITY

NFPA rating (flammability) = ; LEL = NA; UEL = NA

Not a significant fire hazard. Emits toxic fumes in fire.

REACTIVITY & INCOMPATIBILITY

Trimethyltin chloride and other organotin halides react with water to produce hydrogen halides. Organotin hydrides react with water to produce hydrogen gas, which is flammable and explosive.

STORAGE & HANDLING

Because of its high acute toxicity, trimethyltin chloride should be handled using the basic prudent practices in Chapter 6, supplemented by additional precautions for work with compounds of high acute toxicity. Other alkyltin compounds should be handled using basic prudent practices.

The information in this LCSS has been compiled by a committee of the National Research Council from literature sources and MSDSs and is believed to be accurate as of February 2011. This summary is intended for use by trained laboratory personnel in conjunction with the NRC report *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards*. It is advisable to consult comprehensive references in addition to these summaries. This information should not be used as a guide to the nonlaboratory use of this chemical.

CLEANUP & DISPOSAL

In the event of a spill, sweep up the organotin compound or soak up with a spill pillow or absorbent material, place in an appropriate container, and dispose of properly. Respiratory protection may be necessary in the event of a large spill or release in a confined area. Excess trimethyltin chloride or other organotin compound and waste material containing this substance should be placed in an appropriate container, clearly labeled, and handled according to your organization's waste disposal guidelines.

ADDITIONAL CONSIDERATIONS

None

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