HIGH SCHOOL SCIENCE SAFETY RESOURCE MANUAL

DISCLAIMER

The materials in this manual have been compiled from sources believed to be reliable and to represent the best current opinions on the subject in order to provide a basic safety manual for use in Newfoundland and Labrador schools. This manual is intended to serve as a starting point for good practices and does not purport to specify minimum legal standards. No warranty, guarantee, or representation is made by the Department of Education as to the accuracy or sufficiency of the information contained herein. This manual is intended to provide basic guidelines for safe practices. Therefore, it cannot be assumed that all necessary warnings and precautionary measures are contained in this document and that other or additional measures may not be required.

TABLE OF CONTENTS

INTRODUCTION 1

SECTION I: GENERAL SAFETY CONSIDERATIONS

- Safety Equipment 7
- First Aid 9
- Fire Hazards 12
- Chemical Hazards 15
- The Workplace Hazardous Materials Information System 19
- Chemical Spills 20
- Chemical Storage 22
- Disposal of Chemical Wastes 24
- Biological Hazards 26
- Electrical Hazards 28
- Mechanical Hazards 29
- Radiation Hazards 31
- General Safety Rules 32

SECTION II: SPECIFIC HAZARDS ASSOCIATED WITH CORE HIGH SCHOOL SCIENCE ACTIVITIES

- Biology 2211/3211 37
- Chemistry 2202/3202 40
- Physics 2204/3204 49
- Earth Science/Geology 50

REFERENCES 51

SECTION III: APPENDICES

- Appendix A 59

INTRODUCTION

The study of science involves both theoretical and practical aspects; the student learns in the classroom what is already known or thought about a science and, in the laboratory, experimental methods for discovering new knowledge. Both aspects are important; however, it is in the laboratory that safety problems can arise. A major concern of science educators today is how to provide students with the exposure to laboratory activities which is essential to learning a science while maintaining a safe student environment. The information in this manual is intended to help educators to provide a safe science laboratory environment for their students.

Responsibilities for Laboratory Safety

The responsibility for providing students with a safe science laboratory environment lies with four groups - the school board and superintendent, the school administration and principal, the science teachers and the students themselves. Responsibilities for each of these groups are outlined below.

Responsibilities of School Boards and Superintendents

The school boards and superintendents must ensure that schools under their jurisdiction comply with safety regulations, and must initiate plans to attain this goal. Measures to be taken include the provision of in-service training so that staff may increase their knowledge of safety measures and ability to maintain a safe laboratory environment and the provision of the required safety equipment for school science laboratories and any special facilities necessary to ensure the safety of handicapped students. School boards should also ensure that individual school administrations comply with safety guidelines in their schools.

Responsibilities of School Administration and Principals

Individual school administrations and principals have the responsibility to ensure that safety practices are being followed in their schools. They must ensure that science laboratory activities are being taught and supervised only by teachers with the required expertise to teach such activities safely. Substitute teachers with less than the required expertise should not supervise laboratory activities. The school administration should support in-service training to improve the safety knowledge of teachers, including training in first aid and cardiopulmonary resuscitation (CPR), and enforce disciplinary measures if safety guidelines are not being followed. Science classes should be of an appropriate size to allow teachers to adequately supervise laboratory activities and teachers should be provided with the necessary resources and equipment to ensure safety in the laboratory, including a copy of this manual. Suitable provision should be made to ensure the safety of handicapped students. Regular periodic safety inspections should be carried out and problems should be dealt with at the school level, where possible, or a written request for correction of problems which are not correctable at the school level should be directed to the school board.

Responsibilities of Science Teachers

Teachers have a responsibility to provide for the safety of their students. A professional teacher is expected to be able to reasonably foresee the potential problems and hazards associated with an activity and to take reasonable precautions to prevent foreseeable accidents. Science teachers must instruct students in the proper and safe way to carry out science lab activities and must supervise their students to see that their instructions are followed. Students must be instructed in their safety responsibilities at the beginning of each science course and must return to the teacher a written confirmation, signed by their parent or guardian, that they have read, understood and accepted their safety responsibilities. Teachers should ensure that equipment used in science laboratories is in safe working order and should report, in writing, any faulty equipment or other hazards to the school administration. Dated, written records should be kept of any accidents or injuries related to laboratory activities and reports of such incidents should be made to the school administration immediately. Teachers should take note of students who have medical conditions such as epilepsy, asthma or severe allergies and who may require special attention. An up-to-date first aid course should be taken by all science teachers. In case of his or her absence from the classroom, a teacher must provide a lesson plan which may be carried out safely by a substitute teacher. If a teacher wants to perform any laboratory activity outside of the accepted curriculum for a science course, he or she must make sure the activity can be carried out in accord with the safety requirements of the school and get approval for the activity from higher authorities.

Responsibilities of Science Students

Science students must listen to and obey the instructions of the teacher in the science lab and behave safely and responsibly. Students must not perform any experimental activity in the lab without the express permission of the teacher or without the teacher's supervision. Any dangerous situations or accidents must be reported to the teacher at once.

Outline of this Manual

This manual is divided into three sections. Section I contains information on general safety considerations that teachers may use in carrying out laboratory activities safely. It contains the following sections:

** Safety Equipment
** First Aid
** Fire Hazards
** Chemical Hazards
** The Workplace Hazardous Materials Information System
** Chemical Spills
** Chemical Storage
** Disposal of Chemical Wastes
** Biological Hazards
** Electrical Hazards
** Mechanical Hazards
** Radiation Hazards
** General Safety Rules

Section II of the manual contains information on specific hazards associated with core curriculum activities for high school courses in Biology, Chemistry, Physics and Earth Science/Geology. Section III contains an appendix listing the chemicals used in core high school science laboratory activities, with information about their hazards and safe handling procedures. It is envisioned that the manual will be updated as new information becomes available and the binder format will allow updating of individual sections as required.

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SECTION I

GENERAL SAFETY CONSIDERATIONS

SAFETY EQUIPMENT

The following safety equipment should be available in high school science laboratories. Information regarding possible suppliers is provided in the section on Safety in the Chemistry Laboratory of the Chemistry 2202 and 3202 Curriculum Guides.

** A fire extinguisher. A small (*ca*. 1 kg) ABC type dry chemical extinguisher or a small (*ca*. 2 kg) carbon dioxide extinguisher should be adequate to handle most small lab fires. These should be serviced or replaced immediately after use. If reactive metals (alkali or alkaline earth metals such as sodium or calcium) are being used, a bucket of DRY sand, a five pound supply of sodium chloride or a class D dry chemical extinguishing material should be available in case of fire.

** A fire blanket. A large wall-mounted blanket may be used to smother a clothing fire. Old asbestos blankets are heavy, inflexible and may release asbestos fibers into the air. Any still present in schools should be replaced with fiberglass or fireproofed wool-rayon blankets.

** An eye wash station. This should provide a gentle but copious flow of clean water at a comfortable temperature for at least 15 minutes. If a plumbed-in eye wash fountain is not available, a free-standing or wall-mounted unit may be used, but it must contain enough water for 15 minutes of copious flow and the water must be changed regularly and/or treated to prevent the growth of microorganisms. Note that portable eyewash stations have been reported to contain Acanthamoebae, which can cause serious eye infections and loss of infected eyes.

** A safety shower. This is best placed near an exit away from any chemicals and should be activated by a pull cord or chain accessible to a person of any height or in a wheelchair. Showers should be operated periodically to flush the lines and to ensure that they are functioning properly.

** A first aid kit. The contents of the Newfoundland Regulation First Aid Kit are itemized in the section of this manual on First Aid. The kit should be checked periodically, ensuring that any items which have been used are replaced. Such items as band-aids tend to be used quickly and may need frequent replenishment.

** A fume hood. This should contain a sink and be well-lit. The inside surface of the hood should be of a light color, and if necessary, may be painted with a chemical resistant paint. The controls for water, gas supply, etc. should be outside the hood, facilitating rapid and safe shut-off if a hazardous situation develops in the hood. The face air velocity (the rate at which air is pulled into the hood through the front opening) should be between 0.40 and 0.50 meters per second when the front sash is opened to a height of 30 cm (12 in). This should be measured with a velometer periodically to monitor the performance of the hood.

** A safety shield. This should be a clear plastic (polycarbonate is preferred because of its strength and resistance to scratching), free standing screen to be placed between the students and any potentially hazardous demonstration. The shield should be large enough to screen the equipment involved in any high school science demonstration and should be fastened securely when used to prevent an explosion from knocking over the screen, exposing students to hazard.

** A glass disposal container. A metal pail or a cardboard box labelled "BROKEN GLASS - HANDLE WITH CARE" may be used for disposal of glass and other sharp objects. If a cardboard box is used, it can be sealed when full and disposed of with ordinary garbage. The bottom of the box should be taped securely and lined with cardboard and heavy plastic to prevent injury from protruding pieces of glass and to prevent water on wet broken glass from soaking and weakening the cardboard. Sharp objects like razor blades, dissection needles or syringe needles should be sealed in a labelled metal container for disposal.

** A face shield. This is to be worn by the teacher when conducting hazardous demonstrations.

** Chemical spill kits. Spill kits should be available to handle spills of acids, bases, organic solvents and mercury. For more information on handling spills, see the section of this manual on Chemical Spills.

** A pair of chemical-resistant rubber gloves for use when cleaning up spills or handling corrosive or toxic chemicals.

** Heat-resistant gloves and safety tongs for use when handling hot objects.

** A safety stepstool for use in reaching high storage areas.

** A plastic dustpan and brush for cleaning up spilled solids, broken glass, etc.

SAFETY EQUIPMENT FOR STUDENTS

** Students must wear eye protection (safety glasses or goggles) when there is any possibility of injury from splashed chemicals or flying debris. If safety goggles are to be shared by a number of students, the goggles should be sterilized between uses with ultraviolet radiation or a disinfectant solution. Prescription glasses will provide some protection, if clip-on or slide-on side shields are placed on the earpieces to prevent splashes from entering the eye from the side. Contact lenses must NOT be worn in the chemical laboratory as fumes and vapours may be trapped behind the lens, irritating and possibly damaging the cornea. As well, if a chemical is splashed in the eye, the lens may prevent it being washed completely out of the eye, leading to serious injury.

** Laboratory coats or aprons are strongly recommended for use in the laboratory, to protect clothing and to promote an attitude of respect for the potential hazards involved in laboratory work. Lab coats should be made of 100% cotton, not polyester, nylon or other synthetics.

** Disposable gloves should be available for students to wear when handling corrosive chemicals, chemicals that are toxic when absorbed through the skin, biological stains or potentially infectious material. Note that some disposable gloves are permeable to some organic solvents and will provide no protection against skin exposure to these solvents.

FIRST AID

In this section, some general first aid procedures for common minor laboratory accidents are described. However, this information is limited and is no substitute for completion of an emergency first aid course from an organization such as St. John Ambulance or the Canadian Red Cross. Such courses are highly recommended for all high school science teachers.

Due to the possibility of infection, disposable gloves should be worn whenever there is a chance of contact with body fluids such as blood.

Thermal burns

Minor burns caused by contact with hot glassware or equipment are among the most common laboratory accidents. The best treatment is the immediate immersion of the burned part in cold water to relieve pain and decrease damage to underlying tissues. Do not apply ointment to the burn or break blisters. Cover the burn with a clean dressing and, if necessary, obtain medical attention.

Cuts

Minor cuts and scratches may be cleaned with cold water and covered with a clean bandage. If foreign material (for example, glass) is in the wound, get medical attention. For more serious cuts where bleeding is severe, elevate the affected part and apply pressure to the wound, using a sterile pad if possible, to control the bleeding. Get medical attention as quickly as possible.

Splashes of Corrosive or Dangerous Chemicals

If the skin is splashed, immediately rinse the splashed area with water for at least 15 minutes. If clothing is contaminated, remove it as quickly as possible, while continuing to flush the skin with water under the safety shower or, if the splashed area is small, in the sink. If the skin is unbroken or unburned, wash the affected area with soap and water after the 15 minutes of flushing. Remove jewelry which could prevent the elimination of traces of the chemical. If necessary, obtain medical assistance for damage to skin or for hypothermia caused by long exposure to a cold water shower. Some substances can be absorbed through the skin into the body, causing toxic effects. If the splashed person feels ill, seek medical assistance.

If the eyes are splashed, immediately rinse them with a copious flow of water, ideally from an eye wash fountain, for at least 15 minutes. While flushing the eyes, hold the eyelids open and roll the eyes or blink the eyes constantly so that the chemical can be washed out thoroughly and quickly. Obtain medical assistance.

Ingestion of Poisons

Call the Poison Control Center (722-1110 at the Janeway Child Health Center in St. John's) and follow their advice. Find out what was ingested and read the label to determine if an antidote is listed. Do not induce vomiting unless advised to do so by a physician or the Poison Control Center. Obtain medical assistance immediately.

Shock

Whenever an injury occurs, there is the possibility of shock. A shock victim may be pale, have cold, sweaty skin and be breathing rapidly. Reassure the victim and keep him or her warm, with a blanket. If possible, have the victim lie down with feet slightly elevated. Do not give the victim food or fluids. Obtain medical assistance immediately.

Electrical Shock

Do not touch a person in contact with an electrical circuit. Make sure that the current has been turned off or that contact is broken before approaching a victim of electrical shock. Breathing and heart action may have stopped, in which case artificial respiration or cardiopulmonary resuscitation (CPR) by trained persons may be required. Obtain medical assistance immediately.

Individual Medical Problems

Teachers should be aware of any students who may have medical conditions such as epilepsy, allergies or asthma and know what to do in case of an attack.

CONTENTS OF THE NEWFOUNDLAND REGULATION FIRST AID KIT

1 standard safety oriented first aid manual (St. John Ambulance)

1 first aid record book

12 safety pins

1 splinter tweezers, blunt nose

1 pair scissors, 10 cm

6 sterile bandage compresses, 10 cm x 10 cm

32 sterile pads, 7.5 cm x 7.5 cm

32 sterile adhesive dressings, 2.5 cm x 7.5 cm

6 triangular bandages, 95 cm x 95 cm

2 rolls of adhesive tape, 2.5 cm x 5 m

1 Size .01 x 4.5 tubular finger bandage with applicator

10 finger tip dressings

10 knuckle pad dressings

2 50 mL bottles of 3% hydrogen peroxide (antiseptic)

Other suggestions:

1 camel-hair brush	250 g absorbent cotton
1 basin	10 ammonia inhalants
1 eye cup	1 tourniquet
1 dropper bottle	6 wooden splints
4 x 3 g tubes of ophthalmic ointment	1 instant cold pack, small (10 cm x 15 cm)
180 mL merthiolate	1 poison antidote kit
4 x 30 mL tubes of burn ointment	resuscitation mask
200 g antiseptic soap	disposable gloves

FIRE HAZARDS

In this section, some general aspects of fire safety in high school science laboratories are discussed. For more specific and up-to-date information, refer to the most recent Fire Commissioner's Bulletin #12 on Fire Prevention and Life Safety Code Guidelines for Schools (which should be available in each school) or appropriate sections of the latest edition of the National Fire Code of Canada (which can be accessed through the Office of the Fire Commissioner in St. John's or your local fire department). Your local fire department should be able to help with any specific questions.

Fire is a possible occurrence when the three components of the "fire triangle" are present together - fuel (anything combustible such as wood, clothing, flammable solvents, etc.), an oxidizing agent (most often, but not always, oxygen from the air) and an energy source (a flame, spark etc. to start a fire which often can then produce enough energy to keep itself going). Fires can be prevented by avoiding situations where all three components are present together; if a fire has already started, it can be extinguished by removing one of the components of the triangle.

Sources of Fire Hazards

In high school science laboratories, there are many possible sources of fires. Being aware of these can help a teacher prevent a fire. Some of these sources are listed below:

** Hair and clothing may be ignited by the flame of a bunsen burner. Students should be warned to tie hair back and avoid loose clothing and baseball hats with protruding brims when bunsen burners are to be used.

** Flammable and combustible liquids are a potential source of fire not because they themselves burn but because they give off enough vapour to form a combustible mixture with air.

The fire hazard of a liquid is related to its flashpoint, the lowest temperature at which it gives off enough vapour to be ignited at the surface of the liquid. According to the Workplace Hazardous Materials Information System (WHMIS), flammable liquids have a flashpoint below 37.8EC while combustible liquids have a flashpoint between 37.8EC and 93.3EC. For example, methanol (wood alcohol) has a flashpoint of 12EC and is thus a flammable liquid.

Another indication of the fire hazard of a liquid are its flammable or explosive limits, the lowest and highest concentrations of vapour in air that will burn or explode. For example, the lower flammable limit of methanol is 6.0% by volume; mixtures with less methanol than this are too "lean" to burn (not enough methanol is present). The upper flammable limit of methanol is 36.5% by volume; mixtures with more methanol than this are too "rich" to burn (not enough oxygen is present). Only mixtures of methanol vapour in air that have between 6.0% and 36.5% of methanol vapour by volume can be ignited.

Many flammable and combustible liquids are used in high school science laboratories. Appendix A contains information on the flammability of substances used in high school science activities in Newfoundland and Labrador, as well as information on the disposal of flammable substances. Care should be taken to keep these substances away from open flames, sparks from electrical equipment, ovens, heaters and other heat sources. The quantities of these substances used at any one time should be kept to a minimum and adequate ventilation should be available to prevent the accumulation of vapour. Further discussion of flammable and combustible liquids is found in the section of this manual on Chemical Storage.

** Gases can be a source of fire hazard in two ways:

(a) Flammable gases such as hydrogen, methane and propane may form explosive mixtures with air at relatively low concentrations.

(b) Non-flammable gases such as nitrogen which are stored in steel cylinders under pressure may, when heated by an existing fire, build up enough pressure to rupture and explode the cylinder violently.

Teachers should be aware of activities in which flammable gases such as hydrogen may be produced and carry out such activities with adequate ventilation so that dangerous concentrations of these gases do not build up.

** Combustible solids pose a fire hazard if they are in the form of fine powders or dusts, as the increased surface area will increase the rate of reaction with the oxygen in the air. While such solids as coal dust or grain dust may be more of a problem in industry than in the high school laboratory, finely powdered metals such as aluminum, iron or zinc may ignite in contact with air or water and can be a fire hazard. Pyrophoric materials (substances that spontaneously ignite in air) such as white phosphorus or potassium metal should be avoided.

** Many chemical reactions are highly exothermic and may produce enough energy to start a fire if flammable or combustible substances are present in the reaction mixture as reactants or products. Some mixtures of chemicals (called hypergolic mixtures) produce enough heat to ignite themselves, often very quickly after mixing. Since some of these reactions are popular demonstrations, teachers should find out about fire risks and take adequate precautions to protect students and themselves before carrying out any demonstration which is not part of the core curriculum of a high school science course. Students should never be permitted to mix chemicals except as part of an authorized laboratory activity or under the supervision of a teacher.

** Electrical fires can be caused when too large a current is passed through electrical equipment or wiring, causing it to overheat.

If a fire should occur:

** Get students to safety away from the fire.

** If the fire is SMALL and contained, the teacher can try to extinguish it, staying between the fire and an exit and being prepared to evacuate and sound the fire alarm if the fire gets out of control. If the fire is too large to fight or out of control, the teacher should evacuate the room, closing the door and activating the fire alarm to evacuate the building. When safe from the fire area, the teacher should notify the local fire department, giving his or her name and information about the condition and area of the building affected. The telephone number of the local fire department should be posted prominently. **DO NOT RISK YOUR LIFE FIGHTING A FIRE**.

** If the clothing or hair of a student is on fire, it may be extinguished by dousing with water or smothering with a fire blanket. If a fire blanket is used, roll the blanketed student on the floor to extinguish the flames. This will avoid a "chimney effect" whereby wrapping a student in a blanket may increase burning.

** Small fires of flammable liquids in containers such as beakers may be extinguished by placing a watchglass or a fire-resistant cover over the mouth of the container.

** Different types of extinguishers are available to use against different types of fires. It is important to use the appropriate type of extinguisher on a fire as using the wrong type may make the situation worse. However, extinguishers should not be used on standing beakers and flasks because the force of the stream from the extinguisher could cause the flasks to tip over, spilling burning material and spreading the fire. The types of fires and the extinguishers that should be used for each are listed in the table on the following page.

Type of Fire	Fire Extinguisher
Class A: Fires involving ordinary combustible material like wood, paper, clothing, etc.	Water is best as it cools the burning material and prevents glowing embers from re-igniting. A general purpose dry chemical extinguisher (ABC) may also be used, but is messy and will not provide the same cooling effect as water so that flare-ups may occur. Carbon dioxide extinguishers may be used on small class A fires but the forceful stream of carbon dioxide gas may scatter burning paper etc., spreading the fire.
Class B: Fires involving flammable liquids like solvents, gasoline, grease and oil.	Carbon dioxide or dry chemical extinguishers may be used. These act by excluding oxygen from the fire, thus smothering it. Carbon dioxide extinguishers are not as messy to use as the dry chemical types, but the horn gets very cold in use and should not be touched with bare hands. Carbon dioxide extinguishers should not be used on people as they can cause frostbite and, since carbon dioxide is an asphyxiant, it should not be used in confined spaces without ventilation. Water should NOT be used as most flammable liquids are less dense than water and the fire can be spread as the burning liquid is carried on top of the flowing water.
Class C: Fires involving electrical equipment.	Carbon dioxide or dry chemical extinguishers may be used. Water should NOT be used as it can conduct electricity. If an electrical fire should occur, the electrical power to the burning equipment should be cut off if possible.
Class D: Fires involving combustible metals, like magnesium, sodium, powdered zinc.	Dry sand or a special dry chemical can be applied by scoop to the fire. Water, carbon dioxide and ordinary dry chemical extinguishers should NOT be used on metal fires because they may react with the metals and make the fire worse.

CHEMICAL HAZARDS

We are entirely surrounded by, and completely made up of, chemicals. Most of the chemical substances on earth are innocuous, if not absolutely necessary for life. However, some can cause harm if care is not taken. Although many of the substances commonly encountered in a high school chemistry laboratory are potentially dangerous, an awareness of the possible hazards involved can allow teachers and students to handle these chemicals safely. Two major ways in which chemicals can be harmful to people are through their toxicity and their reactivity.

TOXIC HAZARDS

A toxic substance can interact chemically with the body to produce harm or injury. However, the severity of the injury depends on several factors:

** The dose. In general, the larger the amount of a toxic substance that someone is exposed to, the more damage that can be done and the shorter the time required for damage to occur. For example, ingestion of a small amount of ethanol (for example, a glass of wine) causes little damage, whereas ingesting a large amount can cause unconsciousness and death.

** The duration or frequency of exposure. The amount of harm caused by a given dose of a substance depends upon the length of time someone is exposed to the substance. For example, the longer sulfuric acid is left in contact with the skin, the more damage that can occur. In many cases, toxic effects can be lessened or prevented by decreasing the amount of time one is exposed to the chemical (i.e. by washing the acid off the skin quickly before a bad burn can occur). The frequency of exposure also affects the amount of harm done. Some harmful chemicals can be detoxified and excreted by the body but if exposure is too frequent to allow the body to get rid of the chemical, the amount in the body can accumulate and harmful effects can occur. For example, a small, one-time dose of a lead compound may cause little harm, but repeated ingestion of the same small amount of lead (for example, by eating from plates covered with a lead-containing glaze) can cause serious health effects.

** The route of exposure. Chemicals can enter the body by four routes: inhalation (through the lungs), skin contact, ingestion (through the mouth and digestive system) and through the eyes. In the laboratory, exposure is most often through inhalation or skin contact - contact with eyes and ingestion are rare as long as eating, drinking, chewing gum, smoking and pipetting by mouth are forbidden in the laboratory. The presence of cuts or other openings in the skin make entry of a substance into the bloodstream through the skin easier. The toxicity of a substance will depend upon how exposure to the substance occurs. For example, cool liquid water may cause little or no harm if the skin is exposed (for example in a shower), may cause more harm if a large dose is ingested and can be lethal if inhaled. Even water can be a toxic chemical, under certain conditions.

Effects of Exposure to Harmful Chemicals

Chemicals can have many harmful effects on the human body which depend upon how exposure to the chemicals occurs. Acute exposure (a single, short-term exposure) to a substance may only cause observable effects (acute effects) if the dose of substance is relatively high. However, chronic exposure (repeated or prolonged exposure) to doses too small to cause acute effects may cause serious long-term chronic effects.

Harmful effects can be broadly classified as follows:

Local effects

> Local effects occur directly at the site of contact with the substance. The most severe local effect is a corrosive effect. Corrosive chemicals can destroy exposed body tissue (skin, mucous membranes, eyes) by reacting chemically with it. The effects of exposure to a corrosive substance range from minor irritation to extensive burns and irreversible tissue destruction. Chemicals which can cause corrosive effects include acids, bases, oxidizing and reducing agents and chemicals that react vigorously with water. Corrosive effects are generally acute, occurring quickly after exposure.

Systemic Effects

> Systemic effects occur when a substance is absorbed into the bloodstream and affects an organ or system distant from the point of contact. Toxic substances often have specific effects on specific "target" organs or systems. These systemic effects can be both acute (observed quickly after a short exposure) or chronic (observed gradually over a long period of exposure). A wide range of systemic effects result from exposure to hazardous substances and any part of the body may be affected.
>
> Hazardous substances may be classified by the specific systemic effects they have on the body. Carcinogens cause cancer, mutagens cause mutations and teratogens cause birth defects, all by damaging the DNA. Allergens cause allergies by sensitizing the immune system so that subsequent exposure to a very tiny amount of the allergen can cause symptoms as life-threatening as anaphylactic shock. Neurotoxins cause damage to the brain or nervous system and hepatotoxins cause damage to the liver.

How Toxic is a Substance?

Teachers working with an unfamiliar chemical substance will want information about how toxic it is. Toxicity data has been recorded for many substances, although how toxicity is measured and reported depends upon the hazardous effects of the substance and the route of exposure to it. Several terms are used to report the level of toxicity of a substance:

Lethal Dose Fifty (LD_{50})

> The LD_{50} of a substance is the dose of the substance which causes death in half (50%) of a group of test animals exposed to the substance. Usually, LD_{50} values are reported in units of milligrams of substance per kilogram of body weight of the animal and information about the species of animal tested and the route of exposure (oral, subcutaneous (injected under the skin),

intraperitoneal (injected into the abdomen), etc.) is included. The lower the value of LD_{50}, the more toxic the substance, as less is required to cause death. If the substance being tested is a gas or vapour and the animal is exposed to it by inhalation, the lethal concentration fifty (LC_{50}) is often reported. This is the concentration of substance in air, in units of parts per million (ppm) or milligrams of substance per cubic meter (mg/m^3), that will cause death in 50% of test animals.

The values of LD_{Lo} or LC_{Lo} may also be reported. These refer to the lowest dose (LD_{Lo}) or concentration in air (LC_{Lo}) of a substance which has caused death in a test animal.

Toxic Dose Fifty (TD_{50})

The TD_{50} of a substance is the dose of the substance in milligrams of substance per kilogram of body weight required to show a specific toxic effect in 50% of a group of test animals. Again, if the substance is a gas or vapour, the TC_{50} may be reported as the concentration of the substance in air showing a toxic effect in 50% of a group of test animals. Values of TD_{Lo} and TC_{Lo} may also be reported, and they are analogous to the LD_{Lo} and LC_{Lo} discussed above.

Exposure Limits

Because many workers, especially in an industrial setting, must work with hazardous substances, levels of exposure to these substances which are considered safe to most people have been determined. These are reported as Threshold Limit Values (TLV's), or Permissible Exposure Limits (PEL's), depending on the organization providing the information. These are the maximum concentrations in air of a substance that most people may be exposed to by inhalation without suffering adverse effects. These values give no information about safe limits of exposure through other routes, such as skin contact or ingestion. The time-weighted average TLV (TLV/TWA) is the concentration of substance that a normal person may be exposed to by inhalation for 8 hours a day, 5 days a week for their entire adult life without being harmed. The short term exposure limit TLV (TLV/STEL) is the concentration of substance that a normal person can be exposed to by inhalation for a short period (no more than 15 minutes) without harm, if no more than four exposures a day occur. The ceiling TLV (TLV/C) is the maximum concentration of a substance in air that must not be exceeded even briefly. The lower the values of TLV or PEL, the more dangerous the substance, because the concentration to which someone can be safely exposed is lower.

Handling Toxic Substances Safely

If a teacher is handling an unfamiliar chemical, he or she should find out how toxic the chemical is by looking for its LD_{50}, TLV, etc. values on a material safety data sheet (see the section of this manual on WHMIS) or in a reference such as *Dangerous Properties of Industrial Materials* by Sax (see the list of references at the end of this manual). Any unfamiliar abbreviations or terms used to report toxicity are usually defined in references quoting toxicity information. Appropriate protective measures should then be taken to avoid contact with the substance. For example, if the material is corrosive or absorbed through the skin, avoid any contact with skin or eyes by wearing gloves and safety glasses or goggles. If it is toxic by inhalation, handle it in a fume hood, or, if necessary, wear a respirator. If the chemical is highly toxic (i.e. it has a low LD_{50}, TD_{50} or TLV), a less toxic substitute should be used where possible. Find out what first aid measures to take if contact does accidentally occur. This information is usually on the material safety data sheet for the substance.

REACTIVITY HAZARDS

A hazardous reactive substance undergoes chemical reactions which rapidly and violently release a lot of energy, rapidly-expanding gases or toxic products. Some reactive substances are inherently unstable and will decompose explosively by themselves while others will react violently with other substances, including the oxygen or water vapour normally present in air. If not handled safely, reactive materials can cause explosions or fires and release of clouds of toxic substances (often gases).

Handling Reactive Substances Safely

** Avoid contact with or possession of substances that are inherently unstable and explosive such as organic peroxides, azides, perchlorates and organic nitrates and nitro compounds.

** Avoid contact with or possession of substances that react violently with the oxygen or water in air such as white phosphorus, potassium metal and finely divided metal powders.

** Store chemicals so as to separate those which can react violently with each other (see the section of this manual on Chemical Storage).

** Be aware of possible hazardous reactions between chemicals. Appendix A includes reactivity data and handling precautions for specific chemicals used in core high school science activities.

** Take precautionary measures when performing potentially hazardous reactions as demonstrations. Wear protective gear (gloves, lab coat, goggles, face shield) and carry out reactions which may cause explosions or fires behind a safety shield to protect both yourself and the class. Reactions in which toxic gases may be released should be performed in a fume hood.

THE WORKPLACE HAZARDOUS MATERIALS INFORMATION SYSTEM (WHMIS)

The Workplace Hazardous Materials Information System (WHMIS) was legislated by the Canadian federal and provincial governments on October 31, 1988, to ensure that all workers in Canada have information on the hazards associated with any hazardous materials (referred to in WHMIS legislation as controlled products) that they may contact in the workplace. Controlled products include compressed gases, flammable and combustible material, oxidizing material, poisonous and infectious material, corrosive material and dangerously reactive material. Some substances, including explosives, pesticides, food, drugs, cosmetics and radioactive substances are covered under different legislation and are exempt from WHMIS.

There are three components to WHMIS:

Labelling

> Materials regulated by WHMIS when obtained from a supplier must have supplier labels containing information about what the material is, its hazards, and how to prevent injury when using it (precautionary and first aid measures). If a controlled product is removed from the container in which it came from the supplier and placed in another container (for example, for use by students), the transfer container must be labelled clearly with enough information to enable the safe handling of the material.

Material Safety Data Sheets (MSDS)

> These provide further, more specific information about the hazards of the material, possible health effects and preventative measures. Suppliers of controlled products provide MSDS's for those products and they can be a valuable source of information about a chemical and its hazards. The information on MSDS's must be updated every three years. Teachers should collect up-to date MSDS's for the chemicals in their school and make them available to anyone (students, cleaning staff) who may come into contact with these substances in the laboratory.

Worker Education and Training

> Employers must ensure that their employees are informed about the hazards of any controlled products they may work with and about any procedures necessary to work safely with a controlled product.

Importance of WHMIS to High School Science Teachers

The introduction of WHMIS means that teachers and students will have access to more information, through labels and MSDS's, about hazardous substances that they may use in the laboratory. Teachers can find out more about WHMIS from the Department of Labour of the provincial government.

CHEMICAL SPILLS

The spill of a chemical in the laboratory can be frightening. Although most chemicals used in high school courses are not very hazardous, some, especially acids and bases, can potentially cause serious injury. While it is impossible to prevent all spills from occurring in the high school laboratory, prompt action can prevent serious injury from taking place in the event of a spill.

HANDLING COMMON SPILLS

When cleaning up any spill, make sure the proper protective clothing is worn - gloves, lab coat and safety glasses or goggles. For spills of more hazardous substances or for large spills, rubber boots, a face shield or a respirator may be needed.

Solids

Spills of solids can be swept up with a broom or brush into a plastic dustpan and placed in a waste container for disposal. Do not automatically place all spilled solids in the garbage - some, like strong oxidizing agents or metal powders, may react with paper and other garbage and cause a fire. Dispose of the recovered solid appropriately (see Appendix A). Broken glass that is clean or contaminated with a solid that is permitted in regular garbage should be placed in the glass disposal container. Broken glass contaminated with a hazardous solid requiring special disposal should be placed with the spilled solid for disposal.

Liquids

Liquid spills can be harder to deal with than solid spills because liquids may spread over a wider area, may emit toxic or flammable vapours and can make the floor very slippery. Liquid spills can be dealt with by absorption onto a solid absorbent, such as diatomaceous earth or by neutralization, depending on the chemical spilled and the spill situation.

Acids and Bases

> Spills of aqueous solutions of acids and bases can be absorbed onto a solid absorbent or, if a mineral acid like hydrochloric acid or sulfuric acid is spilled, it can be neutralized and washed down the drain. Neutralize an acid spill by sprinkling it with solid sodium carbonate or sodium bicarbonate - when fizzing (evolution of CO_2) stops, enough neutralizing agent has been added and the spill can then be swept up with a brush into a dustpan, if a large amount of solid is present, and/or mopped up. If broken glass is present in the spill, pick it up with tongs and rinse it in the sink before disposal in the broken glass container. A spill of an aqueous solution of a base like sodium hydroxide or potassium hydroxide can be neutralized with a weak acid like solid citric acid, boric acid or sodium bisulfate. (Of these three, citric acid is probably the best - it has a low toxicity, will neutralize three moles of base per mole and is inexpensive.) Once all the spilled base is neutralized (pH paper can be used to check the spill debris), it may be swept and mopped up like a treated acid spill. Note that these neutralization procedures are only safe for solutions that contain ONLY a mineral acid or a base in water - mixtures containing acids or bases may also contain more hazardous substances that should not be washed down the sink. Spills of such mixtures should be absorbed on a solid absorbent and packaged for disposal. Commercial spill kits for acid and bases are also available.

Organic Liquids

Spills of organic liquids are best absorbed with an absorbent spill pillow or with scoopfuls of dry solid absorbent. If the spill is large, pillows or absorbent may be placed around the edge of the spill to confine it, then, if needed, more pillows or absorbent can be used to absorb the bulk of the spill. Do not use paper towels, as these will increase the rate of evaporation and will cause higher concentrations of vapour, which may be toxic or flammable, to enter the air. When the liquid has been absorbed, shovel the absorbent or pillows into a container for disposal. Remember that although the liquid has been absorbed, it still has the same hazardous properties and must be disposed of appropriately. Contact the nearest regional office of the Environmental Investigations Division of the Department of Environment and Lands (see the section of this manual on Disposal of Chemical Waste for further information) or your local fire department for information on safe disposal of the liquid-soaked absorbent.

Mercury

While mercury metal may not be used in high school laboratory activities, except in a sealed container, small spills of mercury may result from the breakage of mercury thermometers. If mercury is spilled in a school laboratory, it is important to recover it all, as tiny droplets of liquid mercury in floor cracks can produce enough mercury vapour to increase the concentration in the air to levels above its time weighted average threshold limit value of 0.05 mg/m^3 (see the Chemical Hazards section of this manual). Levels of mercury vapour this high in the laboratory may be hazardous over long term exposure. If a mercury spill occurs, use a vacuum apparatus or an inexpensive foam pad mercury collector to pick up the droplets of mercury. Sprinkle the area with a commercial mercury absorbent and leave for 24 hours. Sweep up the absorbent with a disposable broom and place in a labelled container for disposal.

If a student spills a chemical during an experiment:

** Keep students away from the spill. Evacuate the lab if toxic or flammable vapour is present. Extinguish all flames and turn off electrical equipment that may produce a spark in order to avoid ignition of flammable vapour.

** Attend to any students splashed by the spill. Find out what was spilled, flush affected parts of the body with water and get medical attention, if necessary.

** If the spill is large or releases dangerous quantities of toxic or flammable vapours, evacuate the area and call your local fire department for advice. If the spill is fairly small, it can be cleaned up using the guidelines given above. Wear the appropriate protective equipment including chemical-resistant gloves, lab coat and safety glasses or goggles and, if necessary, rubber boots, face shield or respirator.

** If the floor is wet after cleanup, warn students to avoid the area to minimize the danger of slipping.

CHEMICAL STORAGE

Ideally, the chemicals used in high school science activities should be stored in a separate, locked room adjoining the science labs, although this may not be possible in all schools. Students should not have direct access to stored chemicals - if chemicals must be stored in the science lab, make sure they are in locked cupboards. In any case, the storage area should be well-lit, well-ventilated and away from direct sunlight and heat sources. Shelving should be adjustable, but securely attached to the wall or floor and chemicals should not be stored at a height greater than 2.5 m or more than two containers deep. A raised lip on the front of the shelves will help prevent containers from sliding off the shelves and breaking on the floor. A safety stepstool should be used to reach chemicals stored on upper shelves. Chemical storage should be located away from first aid equipment (eye wash stations, safety showers, fire blankets, etc.) so that, in case of an accident, the victim can be attended to away from chemical hazards.

In organizing chemical storage, two things must be considered: the ease of finding a given chemical when it is required and possible reactions between two or more substances which are stored close to each other, leading to a fire, explosion or release of toxic materials. While an alphabetical arrangement of chemicals may make location of a particular substance easier, it can create a situation in which violent reactions can occur between incompatible chemicals stored close to each other. It is safer to store chemicals by **hazard class**, chemicals within a given hazard class being stored alphabetically, if desired. A colour-coded labelling system, possibly implemented by affixing coloured adhesive dots to the labels of the chemicals being stored, can be used to identify each chemical as to its hazard class. The storage hazard classes of each of the chemicals used in the core activities of high school science courses in Newfoundland and Labrador are listed in Appendix A.

Hazard Classes

Flammable and Combustible Substances

These should be stored in a Canada Standards Association (CSA) or Underwriter's Laboratory of Canada (ULC) approved flammables cabinet, or as specified in the most recent Fire Commisioner's Bulletin #12 on Fire Prevention and Life Safety Code Guidelines for Schools or the latest edition of the National Fire Code of Canada. The cabinet should be kept in a cool place and be vented to prevent the buildup of vapours inside it. Flammable and combustible liquids should be stored here, away from strong oxidizing agents.

Acids

Concentrated acids should be stored at floor level, in an acid cabinet or in acid-resistant plastic trays. Nitric acid and acetic acid react with each other and should be stored separately (acetic acid should be stored with the flammables and nitric acid should be stored with the oxidizing agents). Acids should be stored away from bases, active metals (sodium, lithium, calcium, zinc, aluminum, etc.) and chemicals which react with acids to generate toxic gases (cyanides, sulfides, sulfites, etc.)

Bases

Aqueous solutions of bases should be stored, away from acids, in a corrosion-resistant plastic tray at floor level. Concentrated aqueous ammonia ("ammonium hydroxide") should be vented periodically to release pressure. Solid bases such as sodium hydroxide may be stored in general storage.

Oxidizing Agents

Oxidizing agents should be stored separately, away from flammable and combustible materials (including wood, paper and cotton) and reducing agents.

Reducing Agents

Reducing agents, including metals and metal powders, should be stored away from oxidizing agents and acids. Note that some of these substances (alkali metals, for example) also react violently with water, and should be kept away from water sources, including sinks, sprinkler systems and aqueous solutions.

Compressed Gases

Gas cylinders should be stored upright in a cool, well-ventilated place, away from other chemicals and should be secured to a wall or bench to prevent them falling. Small lecture bottles of gases may be mounted in a support with a large base to keep them upright. If a gas cylinder or its valve is damaged, the force of the escaping gas can make the cylinder a dangerous projectile.

General Storage

All other substances may be stored on shelves in alphabetical order, with incompatible chemicals separated. See Appendix A for information on incompatibility of chemicals used in core high school science activities. It is a good idea to store organic and inorganic chemicals separately. Solids should be put on higher shelves than liquids, where possible, to minimize mixing if a liquid is spilled on a shelf.

It is wise to check the chemicals already present in the school and dispose of any hazardous chemicals that are no longer required. Chemicals which have deteriorated (i.e. are in corroded or deformed containers or have become wet or discoloured) should be disposed of, as well. See the section of this manual on Disposal of Chemical Wastes for further information.

When ordering new chemicals, do not order more than the school can use in a year. To save money, several schools may share a large, economy bottle of a chemical. Write on the label of each chemical the date it was received so that substances with a limited shelf life may be disposed of when outdated.

DISPOSAL OF CHEMICAL WASTES

The disposal of chemical wastes is governed in Newfoundland and Labrador by the Waste Material (Disposal) Act and the Environmental Control (Water and Sewer) Regulations. The provincial government Department of Environment and Lands, Environmental Investigations Division administers an Institutional/Laboratory Waste Disposal Program and can provide high school science teachers with help in disposing of small quantities of hazardous waste. Regional offices of the Environmental Investigations Division that can be contacted are listed below.

Office	**Telephone**
Goose Bay (covering all Labrador except Red Bay south)	896-5709
Corner Brook (covering the western region of Newfoundland, Red Bay south, the south coast as far east as Ramea and the Baie Verte peninsula)	637-2446
Grand Falls (covering the central region of Newfoundland as far east as Charlottetown in Terra Nova National Park)	292-4347
Clarenville (covering the region as far east as the Hibernia platform building site)	466-3278
St. John's (covering the Avalon peninsula and the region including Come-ByChance and east)	576-2550

Several companies are licensed to handle the disposal of chemical waste in Newfoundland and Labrador, including Inland Environmental Services and the Safety Compliance Center. Schools can contact these companies for disposal of hazardous waste but the service is expensive and some companies prefer to handle larger quantities of waste than a school usually generates. Schools can save money if they want to use such a service by reducing the volume of waste generated as much as possible and by combining the hazardous waste generated by several schools for one collection by the company. Contact the companies first to find out about the cost and how the wastes should be separated and labelled. It is a good idea to keep an ongoing record of how much of each kind of waste is stored and when it was generated.

Some chemical wastes are not especially hazardous and may be disposed of in the regular garbage or down the sink. Some hazardous wastes may be made more innocuous by simple treatment so that they may be disposed of in the garbage or down the sink. Appendix A contains information on how to dispose of chemicals used in the core high school science activities. However, this information applies only to the pure chemicals or, where applicable, solutions of them in water. Mixtures of chemicals often produce new substances which have different properties than the original reactants and which may not be disposed of in the same way. If teachers are in any doubt about the way to dispose of the products from a lab experiment or a demonstration in which chemicals have been mixed, they should package the waste in a container, labelled with the date and the contents (for example "Products of the mixture of..." (the names and/or chemical formulas of the mixed chemicals, including solvents such as water)) and get professional advice about disposal from the Department of Environment or a disposal company. The waste from different experiments or demonstrations should be bottled separately - you may find that some of these wastes may be disposable down the sink or in the garbage while others may not. If teachers do activities outside the core and must dispose of pure chemicals not listed in Appendix A, they are responsible for finding out a safe way of disposing of these materials. Some sources of information on disposal of chemicals are listed as references at the end of this manual, in the General References section and in the Disposal section. If a chemical requires a complex disposal procedure, consider contacting a professional disposal company to dispose of the chemical. Do not carry out complex disposal procedures unless you are equipped and trained do so safely.

BIOLOGICAL HAZARDS

The hazards described in this section are general hazards that may be encountered in biology laboratory activities.

Handling Microorganisms

** Avoid bacteria, fungi, etc. known to be pathogenic but treat ALL microorganisms with as much care as if they were pathogenic. Even non-pathogenic organisms may cause mild illness.

** Cultures of microorganisms should be grown at or near room temperature. Do not grow cultures at 37EC as this encourages the growth of organisms which are capable of infecting the human body.

** Clean and disinfect all bench surfaces before and after handling any microorganisms. Suitable disinfectants can be obtained commercially. If the bench surface is rough or contains scratches or crevices which can harbour microorganisms, cover it with a smooth covering such as self-adhesive plastic before exposing it to microorganisms.

** Do not culture anaerobic bacteria, soil bacteria or swabs of telephones, doorknobs or any surface which may be contaminated with microorganisms from a human source. These may all contain pathogens which can be hazardous when grown in large numbers.

** Petri dishes containing cultures should be autoclaved before disposal. Disposable petri dishes are recommended as they can be taped shut and thrown away after being sterilized, decreasing the chance of releasing microorganisms to the outside. Do not attempt to wash and re-use disposable petri dishes.

** Do not pipette by mouth - use a pipette bulb or other pipetting device.

** Aerosols (liquid droplets or solid particles suspended in the air) containing microorganisms are a common means of contamination and infection. To prevent aerosol formation, avoid spattering cultures. Do not blow air through pipettes contaminated with cultures and take care when using inoculating loops to minimize volatilization of cultures when placing contaminated loops in a flame or placing hot loops into cultures.

Dissections

** Do not dissect wild or stray animals found dead outside. They may carry diseases which can be passed on to humans.

** Dissecting instruments (scalpels, needles) are sharp and should be used with care. Direct students to always cut down and away from themselves.

** The use of formaldehyde (formalin) to preserve specimens should be avoided as formaldehyde has been found to be carcinogenic to rats. Other preservatives (a 70% solution of ethanol in water or commercially available preservatives) may be used instead. If a specimen preserved in formaldehyde is to be used, remove it from the formaldehyde in a fume hood using gloves or tongs and rinse it thoroughly with water (it can be soaked overnight) before dissection.

** Dissected specimens should be disposed of by incineration or burial. Seal the specimen in a heavy, puncture-resistant plastic bag immediately after use as bacteria may grow on the specimen and contact with it can then cause infection.

Handling live animals

** Do not bring wild or stray animals into the school. They may carry diseases that can be passed on to humans. If animals are to be kept in the school, obtain them from a reputable source.

** Animals must be kept in a clean, comfortable environment and given food and water regularly. Arrangements must be made to care for animals during holidays when the school is closed.

** Do not handle animals excessively or allow students to handle animals without proper instruction and supervision. Use gloves to handle animals and obtain medical treatment for any bites or scratches. Wash hands after handling animals.

Plants

** Many plants are poisonous and should be handled with care. Unless a plant is known absolutely to be safe, treat it as though it were poisonous. Do not allow students to put any part of a plant in or near their mouths. Avoid contact with the juice or sap of plants as some can irritate the skin. Wash hands after handling plants, especially before eating.

Use of Human Tissue or Fluid in Laboratory Activities

** Because of concerns about the possibility of transmitting the viruses causing hepatitis or AIDS through contact with tissue or fluids, activities involving these materials, such as blood typing or observation of cheek epithelial cells, are best omitted.

ELECTRICAL HAZARDS

One of the biggest dangers when dealing with electricity is the risk of electrical shock. The severity of the shock is determined by the amount of electrical current that flows through the body and a lethal shock can be caused by almost any voltage. By Ohm's Law (current = voltage/resistance), the current that flows through the body at a given voltage depends on the resistance of the body, which is mainly due to the skin. The lower the resistance of the body (as, for example, if the skin is wet, even with perspiration), the greater the current that can flow at a given voltage and the more severe the shock that can arise from contact with an electrical circuit.

Another danger arises because the passage of current through a muscle causes it to contract. If someone is grasping a object through which electrical current is passing, the muscles in his or her hand and arm will contract when the current reaches a certain level, eventually making it impossible to let go of the conducting object.

The following precautions will help decrease the risk of shock in activities involving electricity.

** Do not carry out student experiments at voltages greater than 30 V. At this relatively low voltage, even a fairly low body resistance will not allow too great a current to pass through the body in case of accidental contact with the circuit. Fuses or circuit breakers should be used with the laboratory electrical supply to limit the maximum current that can flow through a circuit. Live parts of circuits should be insulated to prevent contact.

** Make sure hands are dry when working with electric circuits. Wet skin has a lower resistance and will allow a higher, more dangerous current to pass. Do not carry out electrical experiments or use electrical equipment near water - i.e. sinks or wet floors or bench surfaces. Stand on an electrically insulating surface, such as a rubber mat or carpet, when working with electrical equipment to increase the resistance of the pathway from the electric source through your body to the floor.

** All electrical equipment used should be approved by a recognized authority such as Canada Standards Association (CSA) or Underwriter's Laboratories of Canada (ULC). Periodically check electrical equipment for dangers such as frayed cords, exposed live wires or leakage of current and repair or replace faulty equipment. Avoid the use of extension cords. If they must be used, make sure they are CSA approved and not frayed or damaged. Do not run extension cords across walkways or aisles.

** Avoid touching a live circuit with both hands. The two portions touched may be at different voltages, causing current to pass between the hands through the chest, possibly disrupting the action of the heart.

** Do not grasp an electrical device that has just been used. It may be hot or carrying a current. When in doubt, approach the device with the back of the hand. Heat will be detected before a bad burn is obtained and, if the device is live, contraction of the muscles will not "freeze" the hand to it.

** The high and low voltage connections of induction cells should be clearly identified.

MECHANICAL HAZARDS

Equipment with rotating parts (motors, centrifuges, vacuum pumps, etc.) can be a source of danger as hair, fingers, etc. may get caught in such equipment, causing injury. To prevent such accidents, students (and teachers) working with this equipment should tie long hair back and avoid loose clothing, hats with protruding brims and jewelry. The equipment should be operated only when the appropriate guards, covers, and lids are in place.

Whenever there is a danger of flying debris, for example when breaking or crushing rock samples or when handling glassware which may explode or implode under pressure or under vacuum, eye protection (safety glasses or goggles) should be worn.

Students using any kind of mechanical equipment should be thoroughly instructed in the use of such equipment. The equipment should be periodically checked to see that it is in good working order. If not, it should not be used until it has been replaced or repaired.

Handling Glassware

Glass is an excellent material for use in the laboratory - it is transparent, strong and non-reactive with most chemicals. However, it can break, often leaving jagged edges that may cut, or shatter if stressed by pressure differences, temperature differences or applied force. Some care must be taken to use glassware safely.

** Before buying glassware for the laboratory, check to see that it can be heated safely. Brands such as Pyrex or Kimax are suitable.

** Hot glassware looks like cold glassware. If you are not sure whether a piece of glass equipment is hot or not, bring the back of your hand close to it. Handle hot glassware with tongs or heat-resistant gloves and place it to cool on a heat-resistant surface, such as a ceramic tile or the base of a ring stand.

** Prevent breakage and spills by making sure glass equipment is well-supported. Clamp flasks when heating them on a ring stand over a bunsen burner. Use several clamps to support distillation equipment, but do not overtighten them as the glassware may be stressed and may break.

** If a glass flask is to be placed under pressure or under vacuum, it should be wrapped with an adhesive tape like masking tape or electrical tape to reduce the danger of flying glass shards in case of an explosion or implosion. Place a safety shield in front of the flask while it is under pressure or under vacuum.

** When inserting glass tubing or thermometers into corks or rubber stoppers, lubricate the glass with glycerol, soapy water or silicone grease, depending on what the apparatus is to be used for. Do not use glycerol if the apparatus may contact nitric acid. Do not force the glass through the stopper, but insert it into the stopper with a gentle twisting motion, protecting your hands with heavy gloves or a towel. Keep your hands close together to minimize the chance of snapping the glass and driving it into your palm. Remove the tubing or thermometer from the stopper soon after use to prevent the glass "freezing" to the stopper. If the glass does stick to the stopper, it may be loosened by allowing water or glycerol to penetrate and lubricate the join, or by fitting a cork borer over the glass between it and the stopper. If this does not work, consider discarding the apparatus, or cut the stopper away from the glass. Loosening of frozen tubing or thermometers should be carried out by teachers, not students.

** Students should not try to remove glass stoppers which have become "frozen" in the necks of reagent bottles, but should seek help from the teacher. Teachers should wear gloves, eye protection and a lab coat while trying to free the stopper. If any material that may spill from the bottle can safely be disposed of in the sink, hold the bottle over the sink while trying to free the stopper. If the material in the bottle is hazardous, take the appropriate precautions to protect yourself and others from exposure to it (i.e. handle it in a fume hood or behind a shield and wear protective gloves, eye protection and a lab coat) or seek further advice. If the material inside the bottle can safely be exposed to water, water may be applied to the joint so that it can seep into and loosen it. Lightly tapping on the joint with the wooden handle of a spatula or a cork ring may help free the stopper. Do not try to force the stopper - it may break. Be especially careful if the material inside the bottle can cause a build-up of pressure inside the bottle - handle it behind a safety shield with gloves, eye protection, a face shield and a lab coat.

** When cutting glass tubing, make a single, deep scratch in the glass with a file. Wet the scratch with a small quantity of water applied with a finger. Protecting your hands with heavy gloves or a towel, place your thumbs on the side of the tubing opposite the scratch so that the thumbnails are together opposite the scratch. Snap the tubing away from you (and others). Firepolish the sharp ends of the tubing by heating them in a flame to round them.

** To bend glass tubing, rotate it in a hot bunsen flame until it softens. Remove the tubing from the flame and immediately bend it before it stiffens. Allow the glass to cool before handling. Remember that the bend will be the weakest part of the tube and most likely to break.

RADIATION HAZARDS

Radiation is the emission of energy from a substance, in the form of electromagnetic waves or a stream of particles. Electromagnetic radiation includes a spectrum of electromagnetic waves, from the highly-energetic, short wavelength gamma rays through X-rays, ultraviolet light, visible light, infrared radiation, microwaves and radio waves with the lowest energy and the longest wavelength. Many radioactive emissions are streams of particles, including alpha particles, beta particles and neutrons.

When body tissue absorbs radiation, the molecules of the tissue are damaged by the energy of the radiation, leading to conditions like radiation burns and cancer. The more energetic the radiation, the more harmful it is. Highly-energetic radiation (including X-rays, gamma rays and alpha, beta and neutron emissions) is called ionizing radiation because it is energetic enough to knock electrons out of atoms and molecules. Non-ionizing radiation, which has lower energy, may still do serious damage to body tissues that absorb it especially if its intensity is high.

Radiation Hazards in High School Science Laboratories

Ultraviolet (UV) Light

If ultraviolet light is used in the laboratory to view rock samples or to sterilize safety goggles, make sure the light does not shine in eyes or on skin. It can cause "sunburn" and eye damage, including conjunctivitis. Protective glasses and an ultraviolet barrier skin cream should be worn when working extensively with ultraviolet light.

Visible Light

If visible light is bright enough, it can cause eye damage. Never allow students to look directly at a bright light source, such as burning magnesium, or the sun. Be careful when using strobe lights or other pulsating light source as these may induce seizures in epileptic students.

Lasers

Even low power lasers can cause eye damage if the beam enters the eye. Do not allow students to look directly at the beam or shine the beam on any reflecting surfaces. If demonstrations are to be done using a laser, keep ambient light levels high so that the pupils of students' eyes are small, reducing the chance of the laser light accidentally hitting the retina. Use only a low power laser and do not allow it to be used without supervision.

Ionizing Radiation from Radioactive Sources

For activities involving radioactive sources, use low-intensity sources containing radioisotopes of the elements uranium, thorium, potassium or rubidium. Do not allow the sources to come into direct contact with the skin and, if sources are in powder form, keep them sealed to prevent contact with skin or ingestion. For further information about the handling of radioactive material, contact the Atomic Energy Control Board, Office of Public Information, P.O. Box 1046, Ottawa, Ontario, K1P 5S9.

GENERAL SAFETY RULES

The following rules should be posted prominently in all high school science laboratories and copies should be given to each student. It is wise to require the student and his/her parent or guardian to sign a "safety contract" stating that the student has read the rules and will abide by them.

** Always listen to the teacher and obey his or her instructions. Do not run or horse around in the lab - you may cause a serious accident.

** Do not chew gum or eat or drink anything in the laboratory.

** Tie long hair back out of the way and do not wear loose clothing or hats with protruding brims. You should wear a laboratory coat or apron to protect your clothing and closed shoes to protect your feet (no open-toed shoes or sandals).

** Wear eye protection (safety glasses or goggles) in all science labs whenever there is a chance of eye injury from chemical splashes or flying debris. ALWAYS wear eye protection in the Chemistry lab when experimental work is going on. Do NOT wear contact lenses in science labs.

** Read the instructions for each activity CAREFULLY before coming to the lab. NEVER try anything opther than the written laboratory instructions without first consulting with the teacher - something unexpected and very dangerous may happen. Do not carry out any laboratory activities unless a teacher is present.

** After the lab, clean off your bench area. Always wash your hands with warm water and soap after the lab.

** Report ALL accidents to the teacher, no matter how small they may seem.

** Know where the safety equipment is located in the lab.

** If a chemical is spilled on your skin, IMMEDIATELY wash it off with lots of water. If a large amount of chemical is spilled on your skin or clothing, rinse it off under the safety shower.

** If a chemical is splashed in your eyes, IMMEDIATELY flush your eyes with water for at least 15 minutes, and contact a doctor.

** If you should discover a fire, notify the teacher IMMEDIATELY. Warn other students to keep away from the area and follow your teacher's directions. If the fire is large, evacuate the room, close the door and pull the fire alarm. Tell the teacher and the firemen, when they arrive, where the fire is and any other relevant information about the situation. If your clothing or hair should catch fire, drop to the floor and roll to extinguish the flames. DO NOT RUN - this can make the fire worse. Yell to catch others' attention so that they can help extinguish the flames with water or a fire blanket. If you see another student whose clothing or hair has ignited, tell the teacher and get clean water or a fire blanket to help them extinguish the flames.

** Never leave a bunsen flame unattended. When the flame is not being used, close off the air inlet to make the flame yellow and visible. The blue bunsen flame is hard to see and an accident may occur if someone does not see the flame.

** If you are not sure whether or not a piece of equipment or glassware is hot, approach it with the back of your hand so that you can detect any heat before grasping it. If you do burn yourself, flush the burn with cold water. Notify the teacher and, if necessary, get medical attention.

** Be very careful with sharp objects like dissecting scalpels, needles and razor blades. When doing dissections with scalpels, always cut down and away from yourself. Do not use cracked or chipped glassware and be careful with glass pipettes and other pointed glassware. If you do cut yourself, rinse the cut with cold water. For a serious cut which is bleeding heavily, apply pressure to the cut. Notify the teacher and, if necessary, get medical attention.

** When pulling electric plugs out of sockets, grasp the plug, not the cord. Report any frayed cords or exposed wires to the teacher and do not touch them.

** Handle all chemicals with respect. Chemicals which may be safe if handled responsibly and correctly may be dangerous if treated carelessly. Do not handle or mix any chemicals unless directed by your teacher. Do not enter the chemical storeroom without permission from the teacher.

** When getting chemicals for use in an experiment, read the label TWICE to make sure you have the right chemical at the correct concentration. Read any safety information on the label as well. Be careful not to contaminate stock bottles of chemicals - use clean spatulas to transfer solids and pour the required amount of any liquids you may need into a labelled, clean beaker, flask or test tube. Do not put dropping pipettes into any stock bottles of liquids. Do not take more of any chemical than you need and do not put excess chemicals back into stock bottles - dispose of them as directed by the teacher.

** Report any spills of chemicals to the teacher.

** Do not pipette by mouth - use a pipette bulb or other pipette filling device.

** When heating or mixing substances in test tubes, make sure the mouth of the test tube is pointed away from yourself and other people. Heat test tubes gently, moving them through the flame.

** Do not dispose of any chemicals in the sink or garbage without the teacher's permission. Some chemicals and mixtures may need to be disposed of in special dumps, as directed by the teacher.

** Dispose of broken glass in the glass disposal container, NOT in the regular garbage. Dispose of other sharp objects as directed by the teacher.

** Dispose of animal remains, dissection specimens and cultures of microorganisms in plastic biohazard bags, as directed by the teacher.

SECTION II

SPECIFIC HAZARDS ASSOCIATED WITH CORE HIGH SCHOOL SCIENCE LABORATORY ACTIVITIES

SPECIFIC HAZARDS ASSOCIATED WITH CORE ACTIVITIES FOR HIGH SCHOOL BIOLOGY COURSES

Some of the general hazards which may be encountered in Biology lab activities are described in the section of this manual on Biological Hazards. This includes such dangers as the use of sharp instruments (scalpels, razor blades) in dissections and contact with infectious materials. Listed below are specific laboratory activities containing hazards which deserve special mention. Laboratory activities not listed have no special hazards beyond those already mentioned elsewhere in this manual or in the textbook.

Teachers should read this entire manual and, when preparing for a specific activity, should refer to the relevant parts of the manual. Teachers should also refer to the information on safety in the Teacher's Edition of the textbook that they are using. Textbooks referred to are *Heath Biology* by J.E. McLaren, L. Rotunda and 'L. Gurley-Dilger (McLaren), *Biology* by K.R. Miller and J. Levine (Miller), and *Biology: The Study of Life* by W.D. Schraer and H.J. Stoltze (Schraer).

BIOLOGY 2211

McLaren:

Measuring Food Energy (p. 645)

> Caution students that the tin can calorimeter may also get hot during the experiment. They should approach it with the back of their hand to check that it is cool before handling it.

Microorganisms in the Environment (p. 695)

> Take the appropriate precautions (see the side of the container) when using household cleaners - some are corrosive. Refer to the precautions in the section of this manual on Biological Hazards, section 1., Handling Microorganisms.

The Role of Light in Photosynthesis (p. 105)

> Remember that ethanol is flammable and the vapours may possibly be ignited by a spark from the hot plate. If a fire occurs in a beaker, cover it with a watchglass to smother it.

Miller:

Observing Osmosis (p. 108)

> Caution students that the Lugol iodine stain can harm skin and eyes. Students should wear safety glasses or goggles. If they get the iodine solution on their skin, they should wash it off. If it splashes in their eyes, they should flush the eyes with water for at least 15 minutes and get medical attention. Students should wash their hands if they come in contact with the sodium nitrate solution, as well.

Examining the Typical Mammalian Body Covering (p. 752)

Instead of students making slides of their own cheek epithelial cells, prepared slides of epithelial cells may be used. See the section of this manual on Biological Hazards, section 5., Use of Human Tissue or Fluid in Laboratory Activities.

Testing Enzyme Activity (p. 78)

Caution students that even dilute acids and bases can irritate the skin and damage the eyes. Students should wear safety glasses or goggles. If any acid or base solution is splashed on the skin, wash it off with water. If any splashes in the eyes, rinse the eyes for at least 15 minutes and get medical attention. In case of an acid or base spill, refer to the section of this manual on Chemical Spills.

A brief comment on the enrichment exercise in the Teacher's Guide, p. 79: Do not place the glowing splint into the hydrogen peroxide solution but in the air space ABOVE the solution. The test is for oxygen gas.

Testing the Nutrient Content of Foods (p. 876)

Caution students that the reagents Benedict's solution, biuret reagent (which contains concentrated (10 M) sodium hydroxide) and Lugol's iodine solution can damage skin and eyes. Students should wear safety glasses or goggles. In case of contact with skin, rinse with water. In case of contact with eyes, flush with water for at least 15 minutes and get medical attention.

Note that in the "recipe" for Lugol's iodine solution (Teacher's Edition), potassium "iodine" should be potassium iodide. Premixed Benedict's solution, biuret reagent and Lugol's iodine solution are commercially available.

Schraer:

Observing Plant and Animal Cells (p. 102)

Instead of students making slides of their own cheek epithelial cells, prepared slides of epithelial cells may be used. See the section of this manual on Biological Hazards, section 5., Use of Human Tissue or Fluid in Laboratory Activities. Caution students that the iodine solution can harm skin and eyes. Students should wear safety glasses or goggles. If they get the iodine solution on their skin, they should wash it off. If it splashes in their eyes, they should flush the eyes with water for at least 15 minutes and get medical attention.

Enzyme Function (p. 72)

Caution students that even dilute acids and bases can irritate the skin and damage the eyes. Students should wear safety glasses or goggles. If any acid or base solution is splashed on the skin, wash it off with water. If any splashes in the eyes, rinse the eyes for at least 15 minutes and get medical attention. In case of an acid or base spill, refer to the section of this manual on Chemical Spills.

Digestion of Starch (p. 168)

Caution students that Benedict's solution and iodine solution can damage skin and eyes. Students should wear safety glasses or goggles. In case of contact with skin, rinse with water. In case of contact with eyes, flush with water for at least 15 minutes and get medical attention.

Control of Human Breathing Rate (p. 232)

Caution students to EXHALE, not inhale, into the limewater. Emphasize that they should stop breathing into the paper bag if they feel faint. Breathing into the bag should be entirely voluntary.

BIOLOGY 3211

McLaren:

No special hazards beyond those mentioned in the textbook or in the Biohazards section of this manual.

Miller:

Examining Patterns of Population Growth in Bacteria (p. 1044)

Make sure students wash their hands after handling the bean infusion. Refer to the section of this manual on Biological Hazards, section 1., Handling Microorganisms.

Observing Onion Root Tips (p. 172)

Caution students that the 25% glacial acetic acid fixative and 5 M hydrochloric acid can damage skin and eyes. Students should wear safety glasses or goggles. If any acid solution is splashed on the skin, rinse with water. If any gets in the eyes, rinse with water for at least 15 minutes and get medical attention. Teachers may want to substitute prepared slides of onion root tips in this activity.

Schraer:

No special hazards beyond those mentioned in the textbook or in the Biohazards section of this manual.

SPECIFIC HAZARDS ASSOCIATED WITH CORE ACTIVITIES FOR HIGH SCHOOL CHEMISTRY COURSES

Many of the general hazards which may be encountered in Chemistry lab activities have been described elsewhere in this manual, including the sections on Chemical Hazards and Fire Hazards. Here are listed specific laboratory activities which contain dangers deserving special mention. Laboratory activities not listed below do not contain hazards beyond those already mentioned in other parts of the manual or in the laboratory activity itself.

Teachers should read this entire manual and, when preparing for a specific laboratory activity, should refer to appropriate sections of the manual again, especially Appendix A, which gives information on the hazards of specific chemicals used in core activities, and the General Safety Rules. Teachers should also refer to information in the Alchem text and supplements and the Chemistry 2202 and 3202 Curriculum Guides about safety measures pertaining to each activity.

CHEMISTRY 2202

Lab A1 - Safety and Efficiency in the Laboratory

Handouts describing the safe and correct use of Bunsen burners and pipettes should be provided to students.

Copper Into Gold - A Taste of Alchemy

Read the safety precautions for this activity given in the Chemistry 2202 Curriculum Guide. When removing the pennies from the zinc - sodium hydroxide mixture, rinse them with water to remove any NaOH before letting students handle them. When blotting the zinc-plated pennies, be careful not to get any zinc on the paper towelling - as it dries and reacts with air, it has been known (in the personal experience of the author) to ignite spontaneously. If zinc does get on the paper towelling, burn it as described in the Curriculum Guide. Dispose of the zinc as described in the Curriculum Guide - it can spontaneously ignite any paper that it may contact in the garbage. This is a safe and fun activity if performed with an awareness of possible hazards. Clean pennies work best - they may be cleaned with sandpaper.

Observing Chemical Changes

Make sure that students use a test tube holder to hold test tubes while heating them in a flame and that test tubes are pointed away from people during heating so that anything ejected from them is less likely to splatter anyone. Do not stir test tubes with a glass rod - the rod may break through the bottom of the test tube, leading to possible cuts or splashes with tube contents. To agitate the contents of the test tube, hold the tube firmly with one hand and flick it gently with a finger of the opposite hand. This works best when the test tube is less than one-third full, so that the contents do not splash out of the tube. Use vinegar (ca. 5% acetic acid in water), NOT glacial acetic acid, which is corrosive.

Two Mixtures - Solutions and Suspensions

Stopper the test tubes before shaking them. Do not allow students to place their finger over the mouth of the open test tube before shaking - potassium chromate, especially, is toxic and contact with skin should be avoided. Care should be taken when evaporating the water from the filtrates - the liquid may boil vigorously if heated too strongly and splash out of the dish.

Boiling Temperature

The biggest safety concerns here are burns from boiling water, steam or hot equipment. Caution students to be careful and know what to do if a burn occurs.

Lab A2 - Properties and Applications of Elements

Do not use the powdered form of any of the elements - the metals should be in the form of ribbon, wire or lumps and the non-metals sulfur and carbon should be in lump form. This will decrease the danger of inhaling dust or of powdered metals igniting in air. Do not use an open sample of mercury - its vapour pressure is high enough at room temperature to be harmful by inhalation. If mercury is to be displayed, use a sealed sample, preferably a sample embedded in plastic. White phosphorus, arsenic, fluorine, chlorine and bromine are hazardous and should be avoided unless permanently sealed samples or samples embedded in plastic are available. Samples of chlorine or bromine in sealed glass containers should be stored and displayed in a fume hood. Red phosphorus can be substituted for the spontaneously flammable white phosphorus.

Properties of Common Acids

When demonstrating the reactions of acids, remember that they are corrosive. Metals used for demonstrating reaction with acids may be zinc, magnesium and copper (to show that not all metals react with acids). Do not react copper with nitric acid outside of a fume hood, as toxic NO_2 is produced. Iron can be used, but unless it is very pure, hydrogen sulfide, which is smelly and quite toxic, may be evolved. Remember that the hydrogen gas evolved is very flammable.

Lab B2 - Properties of Ionic and Molecular Substances

Note the comments in the Chemistry 2202 Curriculum Guide, p. 45 as some substitutions are recommended. Check the hazardous properties of the substances used in this activity in Appendix A before carrying out the lab.

Lab C1 - Evidence for Chemical Reactions

Read the comments in the Curriculum Guide and in the Alchem text and Teacher's Guide. As in all chemistry lab activities, make sure students wear eye protection (safety glasses or goggles).

Procedure 3. If drain cleaner is spilled, wash it off with COLD water, not hot.

Procedure 6. The lighting of gunpowder should be demonstrated by the teacher using very small quantities of gunpowder, rather than performed by students. The demonstration should be carried out behind a safety shield.

Procedure 7. Provide a dump for lead compounds and dispose of them appropriately (see the section of this manual on Disposal of Chemicals).

Procedure 10. Barium nitrate is quite toxic - caution students to be careful.

Procedure 11. Use 3% hydrogen peroxide obtainable from a drugstore.

Procedure 15. Use tincture of iodine obtainable from a drugstore.

Demo C1 - Types of Chemical Reactions

Read the comments in the Curriculum Guide and in the Alchem text.

Procedure 1. The reaction of zinc and sulfur should be performed in a fume hood. If this is not practical, replace this reaction by the burning of magnesium, as described in the Curriculum Guide.

Procedure 2. Avoid using mercury compounds. As mentioned in the Curriculum Guide, an alternative is the decomposition of hydrogen peroxide. Even though the products of this decomposition are not both elements (O_2 and H_2O), the principle of decomposition is illustrated and the oxygen gas formed can be tested. If electrolysis equipment is available and the teacher knows how to use it safely, the electrolytic decomposition of water to H_2 and O_2 may be demonstrated.

Procedure 3b. When preparing the aqueous chlorine solution as described in the Curriculum Guide, do so in the fume hood as chlorine gas is evolved. Once the reaction is complete and no more chlorine is released, the solution may be taken out of the hood for use. Also note that dichloromethane is MORE dense than water but is quite volatile.

Procedure 3c. Potassium metal reacts explosively with water and should be replaced by lithium or sodium. This demonstration should be performed behind a safety shield, with wire gauze over the mouth of the beaker as described in the Curriculum Guide.

Lab C3 - Chemical Reactions

Read the comments in the Curriculum Guide and in the Alchem text and Teacher's Manual.

Procedure 1. The light from burning magnesium is bright enough to be harmful to eyes. As mentioned in the Curriculum Guide, teachers may prefer to demonstrate this reaction.

Procedure 3. Students should hold the beaker of water over the flame with tongs, not their hand, to minimize the risk of burns.

Procedure 6. See the Curriculum guide and the comment above on Procedure 3b of Demo C1.

Lab D1 - The Operation of a Balance

Read the comments in the Curriculum Guide and the Alchem text and Teacher's Guide. As stated in the Curriculum Guide, do not substitute water for other colorless liquids. Deliberate mislabeling of containers is dangerous and students will not appreciate what they may interpret as fraud on the part of the teacher. It is better to omit these substances than to mislabel water. Give the students sealed containers containing the substances and prevent students from opening them.

Lab D2 - Mass to Moles

Read the comments in the Curriculum Guide and the Alchem text and Teacher's Guide. Make sure the containers are sealed and do not allow students to open them as some of the substances used are hazardous (see Appendix A).

Station 16. It will be difficult to obtain pure $(NH_4)_3PO_4$ as the acidic NH_4^+ ion reacts with the basic PO_4^{3-} ion, making the compound unstable. Possible substitutes are ammonium hydrogen phosphate (dibasic ammonium phosphate, $(NH_4)_2HPO_4$) or ammonium sulfate ($(NH_4)_2SO_4$). The Teacher's Guide suggests ammonium nitrate (NH_4NO_3).

Lab D3 - Moles to Mass

The advice to "return the substance to the original container" after weighing is bad laboratory practice and can cause contamination of stocks of chemicals. While this may not matter for this particular lab, students who think that this is acceptable practice may ruin bottles of expensive chemicals in later experiments, or worse, inadvertantly mix incompatible chemicals, leading to a potentially dangerous reaction.

Lab E1 - Gravimetric Stoichiometry - A Precipitation Reaction

If potassium chloride is substituted for potassium iodide in this activity, the precipitate formed ($PbCl_2$) is about 15 times more soluble (on a mass basis) than PbI_2. This does not necessarily introduce further hazard (except that the filtrate left after filtration of the precipitate will contain a higher concentration of lead(II) ions) but the yield of the precipitate will be lower. To avoid handling lead compounds which are toxic and difficult to dispose of, the teacher may consider substituting a similar activity wherein sodium carbonate and calcium chloride solutions are mixed and the resulting precipitate of calcium carbonate is collected by filtration. The residual solutions from such a procedure may safely be disposed of in the sink.

For the remaining unit of Chemistry 2202, teachers can choose between two units - Chemistry and the Environment and Chemistry of Selected Elements and Groups. Hazards associated with the activities of these units are described below.

Chemistry and the Environment

Activity D1

Tell students to avoid contact with the actual pesticides when gathering their information - they only need to read the container label. Many pesticides are very toxic.

Chemistry of Selected Elements and Groups

Read the Teacher's Guide to this unit before doing any lab activities or demonstrations. Unfamiliar activities should be tried out before they are done in class and if resources are limited, some student experiments may be carried out as demonstrations. Teachers who feel that a particular experiment or demonstration can not be carried out safely in their lab should omit that activity.

Supplementary Experiment A - Heating Oxygen-Containing Compounds

Teachers may prefer to do this as a demonstration or omit it. Potassium chlorate is a strong oxidizing agent and should be treated with care. Be careful when testing the gas evolved from the potassium chlorate with a wooden splint - if the splint contacts the hot potassium chlorate, a violent reaction can occur. The lead(II) nitrate and copper(II) nitrate should be heated in a fume hood as toxic NO_2 gas is evolved.

Experiment 2 - The Laboratory Preparation of Oxygen

Note that 6% hydrogen peroxide is required for this activity. This is commercially available (eg. from BDH) and requires a little more care than the 3% solution available at drugstores.

Experiment 3 - Chemical Properties of Oxygen

As mentioned in the Teacher's Guide, the combustion of sulfur and of red phosphorus should be done in a fume hood and may be better demonstrated. Warn students that the burning magnesium gives off a bright light, especially in oxygen - teachers may want to demonstrate this. When burning the magnesium and the steel wool, avoid touching the side of the bottle with the burning metal - the heat may cause the bottle to break.

Experiment 4 - Reactions Between Metals and Acids

The reaction between iron and dilute sulfuric or hydrochloric acids may produce some hydrogen sulfide, if the iron is not highly pure. Carry out the reactions with nitric acid in a fume hood as toxic NO_2 is produced.

Experiment 5 - Preparation and Properties of Hydrogen

This experiment should be omitted or demonstrated by the teacher. It should be tested ahead of time by teachers unfamiliar with the experiment. Read the Teacher's Guide carefully. Hydrogen -

air mixtures are explosive so great care should be taken. Even though the water produced from the burning hydrogen may be safe to drink, it is a dangerous practice to taste anything in the lab and this should be omitted.

Experiment 6 - The Reaction of Sodium, Potassium, Magnesium and Calcium with Water

Read the Teacher's Guide carefully before carrying out this demonstration. Potassium metal reacts quite violently with water and should be replaced with the less reactive lithium. The use of both a piece of wire gauze over the mouth of the beaker and a safety shield between the demonstration and the students is advised. For the reaction between magnesium metal and steam, make sure that all of the air is swept out of the reaction vessel by the steam before heating the magnesium, since any air left in the apparatus will form an explosive mixture with the hydrogen gas produced.

Demonstration - Properties of Aluminum and its Compounds

If aluminum powder is blown into a flame, make sure that there is nothing combustible nearby for the burning aluminum particles to land on and ignite. Read the precaution about the toxicity of mercury(II) chloride in the Teacher's Guide and the information in Appendix A. The Thermite reaction is quite dangerous to demonstrate but may be available as a demonstration on videotape.

Demonstration - Properties of Calcium and its Compounds

If students blow into limewater, make sure they do not inhale. When adding water to calcium oxide, place a safety screen between the reaction and the students - the heat released may cause spattering.

Experiment 7 - Some Reactions of Copper and its Compounds

Read the comments in the Teacher's Guide. The reaction between copper metal and nitric acid should be done in a fume hood as toxic NO_2 is evolved. If a fume hood is not available for students, this step may be demonstrated and the students provided with copper(II) nitrate for the next step. Caution students to be careful when heating the copper(II) hydroxide mixture as it may "bump" if heated too strongly, splattering the hot mixture.

Experiment 8 - The Rusting of Iron

Avoid inhaling silica gel - prolonged exposure can cause lung disease. Do not use a finely powdered silica gel (like that used for chromatography) as this increases the chance of inhaling the dust. Instead, use a silica gel desiccant or drying agent such as self-indicating silica gel, which is available with a moisture indicator (a blue indicator that becomes pink as the silica gel becomes saturated with water).

Experiment 9 - The Chemistry of Chlorine

This demonstration involves many potentially very dangerous chemicals and reactions. Chlorine is a very toxic gas and its preparation must be done in an efficient fume hood to prevent inhalation of the gas. Chlorine is also very reactive and the reactions with phosphorus and sodium are quite vigorous. The phosphorus pentachloride produced from reaction with phosphorus reacts violently with water to produce acids (HCl and H_3PO_4) and is corrosive. Unless a teacher is a very experienced chemist, he or she should omit this activity. If a teacher chooses to do this demonstration, he or she should try it beforehand to be sure he or she can do it safely. Be sure all students are protected from possible explosions or violent reactions by carrying out reactions in a fume hood behind a safety shield. Be prepared to evacuate the lab if substantial amounts of chlorine gas leak into it.

Demonstration - Properties of Phosphorus and its Compounds

White phosphorus spontaneously ignites in air and is very toxic, producing severe burns. This activity should be omitted.

Experiment 10 - The Allotropy of Sulfur

Teachers may prefer to demonstrate this experiment. Read carefully the comments in the Teacher's Guide. Carbon disulfide is very flammable and should be handled with extreme care in a fume hood. Hydrogen sulfide is extremely toxic and should only be prepared by teachers very experienced in chemistry and handled in an efficient fume hood. One or two inspirations of hydrogen sulfide may cause death from respiratory failure in a few seconds. The reaction of sodium sulfite with acidic potassium permanganate should also be done in the fume hood as some SO_2 may be evolved. If the reaction between sulfuric acid and sugar is carried out, be sure to wash the mass of carbon well with water before disposing of it as concentrated sulfuric acid, which is corrosive, will be trapped inside it.

CHEMISTRY 3202

Preparation of Soap

Caution students that the hot lye (sodium hydroxide) solution is very corrosive. Read the sections of this manual on First Aid, Chemical Hazards and Chemical Spills and know what to do if any lye solution is spilled or splashed on anyone.

Mini-demonstration, Page I22, Alchem 20

Tetrachloroethene is a suspected carcinogen - handle with gloves in a fume hood. 1,1,1-Trichloroethane may be a suitable replacement.

Effect of Concentration and Temperature on the Rate of Reaction

A small amount of sulfur dioxide is produced in this reaction. To avoid the buildup in the air of SO_2, which is smelly and toxic in higher concentrations, teachers may prefer students to dispose of reaction mixtures in the sink in the fume hood.

Demo N1 - Classification of Solutions

Remember that acids and bases are corrosive, although they pose little hazard at concentrations of 0.1 mol/L if they are treated with respect.

Demo N2 - pH of Common substances

If bleach is used in this demonstration, be careful as it is corrosive. Do not mix acid and bleach - they react to produce chlorine gas which is quite toxic.

Concentration of an Acid

Use HCl and NaOH at concentrations of approximately 0.1 mol/L. Make sure students report any spills and, if they splash any acid or base on themselves, they should wash it off right away and inform the teacher. Read the sections of this manual on Chemical Spills and First Aid.

For the remaining units of Chemistry 3202, teachers can choose among three units - Carbon chemistry, Electrochemistry and Nuclear Chemistry. Hazards associated with the activities of these units are described below.

Carbon Chemistry

Fractional Distillation

The alcohols used in this activity are flammable and should be kept well away from the flame or heat source used in the distillation. Make sure boiling chips are used - these will promote smooth boiling and prevent superheating and "bumping" of the liquid. Heat the mixture slowly to prevent vigorous boiling of the liquid mixture, with the possible danger of the liquid boiling out of the flask and igniting. Be prepared for a possible fire (read the section of this manual on Fire Hazards).

Electrochemistry

Lab M1 - An Introduction to Redox

It is suggested in the Chemistry 3202 Curriculum Guide that only Cu and Zn and their salts be studied. This avoids some expense and the problem of dealing with the Pb and Ag waste although only two metals would be available to be ranked in order of reducing ability.

Lab M3 - Electrochemical Cells

Cadmium and its compounds are extremely toxic and suspected carcinogens and should be omitted from this activity. Caution students to be careful with potassium dichromate as it is a strong oxidizing agent.

Simple Cell Operation

Make sure students wash their hands after this activity - they may be contaminated with the solutions on the paper towels.

Demo M1 - Qualitative Aspects of Electrolysis

Replace carbon tetrachloride (a suspected carcinogen) with 1,1,1-trichloroethane. Note that chlorine is produced in the electrolysis of aqueous sodium chloride - the Alchem 30 Teacher's Manual suggests using a fresh solution of NaCl each time the electrolysis is carried out to prevent the buildup of hazardous levels of chlorine gas.

Nuclear Chemistry

Demonstration U1 - Detecting Radioactivity

Read the section of this manual on Radiation Hazards.

SPECIFIC HAZARDS ASSOCIATED WITH CORE ACTIVITIES FOR HIGH SCHOOL PHYSICS COURSES

Many of the general hazards which may be encountered in Physics lab activities are described in the sections of this manual on Electrical Hazards, Mechanical Hazards, Fire Hazards and Radiation Hazards. Listed below are specific laboratory activities containing dangers deserving special mention.

Teachers should read the entire manual and, when preparing for a specific laboratory activity, should refer to appropriate sections of the manual again. Teachers should also refer to safety information in the Teacher's Edition of the textbook they are using. Textbooks referred to are *Fundamentals of Physics* by D.G. Martindale, R.W. Heath, W.W. Konrad and R.R. Macnaughton and *Physics for a Modern World*.

PHYSICS 2204

Experiment 3 - Work and Kinetic Energy

In this experiment, and in following experiments where dynamics carts are used, caution students to avoid letting the cart run off the bench onto their feet - the carts are heavy enough to cause injury.

Experiment 7 - Speed of Sound in Air

Students should wear safety glasses or goggles where there is danger of the glass tube shattering when touched by the vibrating tuning fork.

Experiment 12 - Dispersion by a Prism

If the light source is very bright, students should be cautioned not to look directly at it.

PHYSICS 3204

Experiment 10 - Current-Voltage Relationship for Diodes

Students should wear safety glasses or goggles if working with light-emitting diodes whose housings might explode.

Experiment 11 - Magnetic Fields Due to Currents

Caution students not to connect both wires to the battery terminals for too long - as mentioned in the text, the wire can get very hot quite quickly.

HAZARDS ASSOCIATED WITH CORE ACTIVITIES FOR HIGH SCHOOL EARTH SCIENCE/GEOLOGY COURSES

Because of the upcoming revision of the high school Earth Science/Geology courses, hazards pertaining to specific laboratory activities in these courses will not be discussed. Teachers of Earth Science/Geology courses should read this manual keeping in mind possible hazards in laboratory activities. Especially useful may be the sections on Mechanical Hazards and Radiation Hazards and, for activities involving the use of chemicals, the section on Chemical Hazards and the appropriate entries in Appendix A.

REFERENCES

The references consulted in the preparation of this safety manual are listed below. To make finding desired information a little easier, the references are listed either as general references or as being relevant to a specific topic in the manual. This is not an exhaustive list, but can provide a starting point for further reading.

General References

The references listed here contain information on several topics related to safety in high school science laboratories. They may be consulted for information on specific topics.

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The Merck Index, An Encyclopedia of Chemicals, Drugs and Biologicals, M. Windholtz, Ed., Tenth Edition, Merck and Co., Inc., 1983.

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Hollbach Consultants Ltd., August, 1990.

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Occupational Health and Safety Act, The Workplace Hazardous Materials Information System Regulations (WHMIS), Occupational Health and Safety Division, Department of Labour, St. John's, Newfoundland, A1C 5T7, October 31, 1988.

Introducing the Workplace Hazardous Materials Information System (WHMIS), Minister of Labour and Minister of Consumer and Corporate Affairs, Government of Canada, 1987.

Chemical Storage

Safe Storage of Laboratory Chemicals, D.A. Pipitone, Ed., John Wiley and Sons, Inc., 1984.

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SECTION III

APPENDICES

APPENDIX A: CHEMICALS USED IN CORE HIGH SCHOOL SCIENCE ACTIVITIES

The following table contains a list of the chemicals used in science activities in high schools in Newfoundland and Labrador and the hazards and handling precautions associated with their use. The codes used in the table to indicate toxicity, flammability and reactivity are assigned in accordance with the *Guidelines on Toxic and Hazardous Chemicals used in Educational Institutions*, published by Health and Welfare Canada, 1980, with some modification. These codes are explained below.

TOXICITY (T)

This section of the table gives information about the acute toxic hazards[1] of each chemical. If a particular chemical shows chronic toxicity, this is indicated in the Comments section of the appropriate entry. The codes used are:

4 - Extremely Dangerous

Materials with an oral LD_{50} value no higher than 50 mg/kg; a dermal (skin exposure) LD_{50} value no higher than 40 mg/kg or an inhalation LC_{50} value of less than 50 ppm over four hours.[2] Also includes highly corrosive materials causing tissue damage after only brief exposures to minimal amounts.

3 - Dangerous

Materials with an oral LD_{50} value between 50 and 500 mg/kg; a dermal LD_{50} value between 40 and 200 mg/kg or an inhalation LC_{50} value between 50 and 200 ppm over four hours. Also includes corrosive materials causing tissue damage on splash contact.

2 - Caution

Materials with an oral LD_{50} value between 500 and 2500 mg/kg; a dermal LD_{50} value between 200 and 1000 mg/kg or an inhalation LC_{50} value between 200 and 1000 ppm over four hours. Also includes corrosive substances causing tissue damage on extended contact (one hour).

1 - Low Hazard

Materials with an oral LD_{50} value greater than 2500 mg/kg; a dermal LD_{50} value greater than 1000 mg/kg or an inhalation LC_{50} value greater than 1000 ppm over four hours or which are non-corrosive.

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[1]For more information on toxicity, see the section of this manual on Chemical Hazards.

[2]For definitions of LD_{50} and LC_{50}, see the section of this manual on Chemical Hazards.

FLAMMABILITY (F)

This section of the table gives information about the fire hazards[3] of each chemical. The codes used are:

4 - Extremely Dangerous

Flammable gases in air.
Liquids or solids with a flashpoint[4] less than 0EC or with a boiling point less than 35EC.
Solids that can ignite spontaneously in contact with air or moisture.

3 - Dangerous

Liquids or solids with a flashpoint between 0EC and 20EC.

2 - Caution

Liquids or solids with a flashpoint between 20EC and 50EC.
Solids which may be ignited readily by heat or flame.

1 - Low Hazard

Liquids or solids with flashpoints greater than 100EC.

REACTIVITY (R)

This section of the table gives information on the reactive hazards[5] of each chemical. The codes used are:

4 - Extremely Dangerous

Materials that explode spontaneously or that react vigorously with water; very strong oxidizing or reducing agents or monomers that may polymerize violently.

3 - Dangerous

Materials that may explode if heated or detonated or that react with water to produce heat or hazardous gases; strong oxidizing or reducing agents; materials that deteriorate during storage.

[3]For more information on flammability, see the section of this manual on Fire Hazards.

[4]For a definition of flashpoint, see the section of this manual on Fire Hazards.

[5]For more information on reactivity, see the section of this manual on Chemical Hazards.

2 - Caution

Oxidizing agents that react with combustible materials to produce explosive mixtures; materials that undergo rapid, exothermic reactions.

1 - Low Hazard

Materials with low reactivity.

STORAGE

This section of the table gives information about the storage hazard class[6] to which each chemical belongs. The codes used are:

A	acids (non-oxidizing)
B	aqueous solutions of bases
D	Do not store - prepare or obtain as required.
F	flammable and combustible materials
G	gases
GI	general storage (inorganic chemicals)
GO	general storage (organic chemicals)
O	oxidizing agents
PD	permanently-sealed samples for display purposes
R	reducing agents
S	special storage

[6]For more information on storage hazard classes, see the section of this manual on Chemical Storage.

DISPOSAL

This section of the table gives information about the disposal[7] of each chemical. The codes used are:

A - Dilute aqueous solutions may be flushed down the drain with large amounts of water.

B - Solids in their original containers may be placed with garbage for disposal.

C - Package separately for disposal in a labelled container. Contact a disposal company or the nearest regional office[8] of the Environmental Investigations Division of the Government of Newfoundland and Labrador Department of Environment and Lands for advice.

D - Place with non-halogenated organic solvents in a labelled container for disposal.

E - Place with halogenated organic solvents in a labelled container for disposal.

F - Permanently-sealed samples for display purposes should be reused.

G - Return gas cylinders to supplier.

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[7]For more information on disposal, see the section of this manual on Disposal of Chemical Wastes.

[8]For information on the locations and telephone numbers of these regional offices, see the section of this manual on Disposal of Chemical Wastes.

Chemical	T	F	R	Storage	Disposal	Comments
Acacia						See gum arabic.
Acetic acid (concentrated, glacial), CH_3COOH		2	3	F	A,C	Corrosive, flammable. Dilute solutions (such as vinegar) are less hazardous. Keep away from bases and oxidizing agents.

T - Toxicity
F - Flammability
R - Reactivity
See beginning of table for key to entry codes.

Chemical	T	F	R	Storage	Disposal	Comments

T - Toxicity
F - Flammability
R - Reactivity
See beginning of table for key to entry codes.

Chemical	T	F	R	Storage	Disposal	Comments
	4					
Acetone, C_3H_6O	1	4	1	F	D	Highly flammable, irritant. Keep away from oxidizing agents.
Aluminum, Al (forms other than powder)	1	1	1	R	C,F	The powdered form is highly reactive and flammable. Keep away from oxidizing agents, acids and halogens.
Aluminum chloride, $AlCl_3$	2	1	2	GI	A,C	The anhydrous compound is corrosive and reacts vigorously with water to produce corrosive and toxic acidic vapours. The hydrated compound is less hazardous.
Aluminum sulfate, $Al_2(SO_4)_3$	.1	1	1	GI	C	Low hazard.
Ammonia (ammonium hydr-oxide), concentrated, $NH_3(aq)$	3	1	3	B	C	Corrosive, releases toxic ammonia gas. Keep away from acids, metals, halogens (reacts with halogens to produce highly explosive products).
Ammonium acetate, NH_4CH_3COO	1	1	1	GI	A,B	Low hazard.Keep away from strong oxidizing agents and acids.
Ammonium chloride, NH_4Cl	2	1	1	GI	A,B	Also called sal ammoniac. Causes skin and eye irritation. Keep away from acids, bases, silver and lead salts.
Ammonium dihydrogen phosphate, $NH_4H_2PO_4$	1	1	1	GI	A,B	Also called monobasic ammonium phosphate. Low hazard.
Ammonium hydrogen phosphate, $(NH_4)_2HPO_4$	1	1	1	GI	A,B	Also called dibasic ammonium phosphate. Low hazard.

T - Toxicity
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R - Reactivity
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Chemical	T	F	R	Storage	Disposal	Comments
Ammonium hydroxide						See ammonia.
Ammonium nitrate, NH_4NO_3	1	1	3	S	A,C	Highly reactive and explosive if heated. Can explode at lower temperatures if contaminated. Keep away from oxidizing agents, reducing agents, metals and organic materials.
Ammonium sulfate, $(NH_4)_2SO_4$	1	1	1	GI	C	Low hazard.
Antifreeze						See ethylene glycol.
Antimony, Sb (forms other than powder)	2	1	1	PD	C,F	Toxic, flammable in powdered form. Keep away from oxidizing agents, acids. Keep only as a permanently sealed sample for display purposes.
Arsenic, As (forms other than powder)	3	1	1	PD	C,F	Highly toxic, powdered form is flammable. Keep away from acids, oxidizing agents. Keep only as a permanently sealed sample for display purposes.
Baking soda						See sodium hydrogen carbonate.
Barium chloride, $BaCl_2$	3	1	1	GI	C	Highly toxic. Keep away from acids, oxidizing agents.
Barium nitrate, $Ba(NO_3)_2$	3	1	2	O	C	Highly toxic, oxidizing agent. Keep away from reducing agents and organic and combustible materials.
Basic copper(II) carbonate						See copper(II) carbonate, basic.
Benedict's solution	2	1	1	GI	C	A mixture of copper(II) sulfate, sodium carbonate and sodium citrate in water solution. The solution is basic and corrosive.

T - Toxicity
F - Flammability
R - Reactivity
See beginning of table for key to entry codes.

Chemical	T	F	R	Storage	Disposal	Comments
Benzoic acid, C_6H_5COOH	2	1	1	GO	C	Low hazard. Keep away from bases, oxidizing agents and reducing agents.
Bismuth, Bi (forms other than powder)	2	1	1	PD	C,F	Toxic, flammable in powdered form. Keep away from acids, oxidizing agents. Keep only as a permanently sealed sample for display purposes.
Biuret reagent	2	1	1	GI	C	A mixture of copper(II) sulfate and sodium hydroxide in water solution. The solution is basic and corrosive.
Bluestone						See copper(II) sulfate.
Bromine, Br_2	4	1	4	S,PD	C	Highly corrosive, irritating vapour. Keep away from ammonia, metals, reducing agents, organic materials. Keep only as a permanently sealed sample for display purposes.
Bromothymol blue, $C_{27}H_{28}Br_2O_5S$	1	1	1	GO	A	Low hazard if dilute solutions are used.
1-Butanol, C_4H_9OH	2	2	1	F	D	Flammable, irritant. Keep away from oxidizing agents, reactive metals.
Cadmium, Cd (forms other than powder)	3	1	1	GI	C	Highly toxic, carcinogenic, can cause allergic reaction. Powder is flammable. Keep away from oxidizing agents, acids and potassium metal.
Cadmium sulfate, $CdSO_4$	3	.1	1	GI	C	Highly toxic, carcinogenic.
Calcium, Ca	3	2	3	R	C	Flammable solid, reacts vigorously with water to produce flammable hydrogen gas. Keep away from water, acids, oxidizing agents.

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Chemical	T	F	R	Storage	Disposal	Comments
Calcium carbonate, $CaCO_3$	1	1	1	GI	B	Also called limestone, chalk, marble chips. Reacts with acids to generate carbon dioxide gas.
Calcium chloride, $CaCl_2$	2	1	1	GI	A,B	Irritant, low hazard.
Calcium hydroxide, $Ca(OH)_2$	1	1	1	GI,B	A,C	Also called slaked lime. The saturated aqueous solution of calcium hydroxide is called limewater. Irritant.
Calcium nitrate, $Ca(NO_3)_2$	1	1	3	O	A,C	Oxidizing agent. Keep away from reducing agents, organic material and acids.
Calcium oxide, CaO	3	1	3	GI	C	Also called lime. Corrosive, reacts vigorously with water. Keep away from water, acids.
Calcium sulfate, $CaSO_4$	1	1	1	GI	B	Also called gypsum, plaster. Low hazard. Keep away from aluminum powder.
Carbon, C (forms other than powder)	1	1	1	GI	B	Also called graphite, charcoal. The powdered form is more reactive and is a fire hazard. Keep away from oxidizing agents.
Carbon dioxide, CO_2	1	1	1	G	G	The solid form is known as dry ice. This is very cold and will cause frostbite - handle with tongs or gloves.
Carbon disulfide, CS_2	2	4	1	F	D	Highly flammable, toxic to nervous system. Keep away from oxidizing agents and metals.
Carbon tetrachloride, CCl_4	2	1	1	GO	E	Suspected carcinogen, toxic. Keep away from oxidizing agents and metals.
Chalk						See calcium carbonate.

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Chemical	T	F	R	Storage	Disposal	Comments
Charcoal						See carbon.
Chlorine, Cl_2 (gas) (aqueous solution)	4 2	1 1	4 2	D O	C C	Gas is a highly toxic, corrosive and reactive oxidizing agent. The aqueous solution is less hazardous but should be handled with care. Keep away from reducing agents, metals, acids and bases.
Chromium, Cr (forms other than powder)	1	1	1	PD	C,F	Powdered form is a fire hazard. Keep away from acids and oxidizing agents. Keep only as a permanently sealed sample for display purposes.
Citric acid, $C_6H_8O_7$	1	1	1	GO	A,B	Low hazard. Keep away from acids and oxidizing and reducing agents.
Cobalt(II) chloride, $CoCl_2$	2	1	1	GI	C	The hexahydrate is less toxic than the anhydrous form.
Cobalt(II) nitrate, $Co(NO_3)_2$	2	1	3	O	C	Oxidizing agent. Keep away from reducing agents and organic material.
Copper, Cu (forms other than powder)	1	1	1	GI	C,F	Powdered form is a fire hazard.
Copper(II) carbonate, basic, $CuCO_3.Cu(OH)_2$	3	1	1	GI	C	Also called cupric carbonate, basic copper(II) carbonate. Toxic. Reacts with acids to produce carbon dioxide gas.
Copper(II) chloride, $CuCl_2$	3	1	1	GI	C	Also called cupric chloride. Toxic.
Copper(II) nitrate, $Cu(NO_3)_2$	2	1	3	O	C	Also called cupric nitrate. Oxidizing agent. Keep away from reducing agents and organic material.
Copper(II) oxide, CuO	2	1	1	GI	C	Also called cupric oxide. Keep away from reducing

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Chemical	T	F	R	Storage	Disposal	Comments
						agents, metals.
Copper(II) sulfate, $CuSO_4$	2	1	1	GI	C	Also called bluestone, cupric sulfate. Toxic, irritant. Available as the pentahydrate or the anhydrous compound.
Cream of tartar						See potassium hydrogen tartrate.
Cupric carbonate						See copper(II) carbonate.
Cupric chloride						See copper(II) chloride.
Cupric nitrate						See copper(II) nitrate.
Cupric oxide						See copper(II) oxide.
Cupric sulfate						See copper(II) sulfate.
Dextrose						See glucose.
Dichloromethane, CH_2Cl_2	2	1	1	GO	E	Also called methylene chloride. Possible carcinogen. Keep away from metals.
Dry ice						See carbon dioxide.
Epsom salts						See magnesium sulfate.
Ethanol, C_2H_5OH	1	3	1	F	D	Also called ethyl alcohol. Flammable, denatured ethanol is poisonous. Keep away from oxidizing agents, metals, acids.
Ethyl acetate, $CH_3COOC_2H_5$	1	4	1	F	D	Highly flammable. Keep away from oxidizing agents.
Ethyl alcohol						See ethanol.

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Chemical	T	F	R	Storage	Disposal	Comments
Ethylene glycol, $C_2H_6O_2$	2	1	1	GO	D	Also called antifreeze. Toxic if ingested. Keep away from oxidizing agents.
Ferric chloride						See iron(III) chloride.
Ferric nitrate						See iron(III) nitrate.
Ferric oxide						See iron(III) oxide.
Ferrous sulfate						See iron(II) sulfate.
Formaldehyde, HCHO	3	2	3	F	C	The 37% aqueous solution containing 15% methanol is called formalin. Carcinogen, flammable, toxic. Keep away from oxidizing agents, hydrochloric acid (reacts with HCl to form carcinogenic products).
Formalin						See formaldehyde.
Gelatin	1	1	1	GO	A,B	Low hazard.
Germanium, Ge	1	1	1	PD	C,F	Powdered form is flammable. Keep away from oxidizing agents. Keep only as a permanently sealed sample for display purposes.
Glucose, $C_6H_{12}O_6$	1	1	1	GO	A,B	Also called dextrose. Low hazard.
Glycerin						See glycerol.
Glycerol, $C_3H_8O_3$	1	1	1	GO	A	Also called glycerin. Low hazard. Keep away from oxidizing agents as violent reactions can occur.
Graphite						See carbon.

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Chemical	T	F	R	Storage	Disposal	Comments
Gum arabic	1	1	1	GO	C	Also called acacia. Low hazard. Keep away from oxidizing agents.
Gypsum						See calcium sulfate.
Hydrochloric acid, concentrated, HCl(aq)	3	1	3	A	A,C	Also called muriatic acid. Corrosive. Keep away from bases, metals. Dilute solutions are less hazardous.
Hydrogen peroxide, H_2O_2 (3%)	1	1	1	O	A	Oxidizing agent. Do not store 30% solutions in schools. Keep away from reducing agents, organic material, metals.
(30%)	4	1	4	O	C	
Iodine, I_2	2	1	2	GI	C	Corrosive, irritating vapour. Keep away from metals, ammonia.
Iron, Fe (forms other than powder)	1	1	1	GI	C	Often in form of steel wool. Powdered form is a fire hazard. Keep away from oxidizing agents, acids, non-metals.
Iron(III) chloride, $FeCl_3$	2	1	1	GI	A,B	Also called ferric chloride. Corrosive. Anhydrous compound reacts vigorously with water, producing acidic vapours. Keep away from oxidizing agents, alkali metals.
Iron(III) nitrate, $Fe(NO_3)_3$	2	1	2	O	A,C	Also called ferric nitrate. Oxidizing agent, irritant. Keep away from reducing agents, organic material.
Iron(III) oxide, Fe_2O_3	1	1	1	GI	B	Also called ferric oxide. Low hazard.
Iron(II) sulfate, $FeSO_4$	2	1	1	GI	C	Also called ferrous sulfate. Low hazard.
Isopropanol						See 2-propanol.

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Chemical	T	F	R	Storage	Disposal	Comments
Lead, Pb (forms other than powder)	2	1	1	GI	C	Powdered form is a fire hazard. Chronic exposure can cause poisoning.
Lead(II) nitrate, $Pb(NO_3)_2$	2	1	3	O	C	Oxidizing agent. Chronic exposure can cause poisoning.
Lead(II) oxide, PbO	2	1	1	GI	C	Chronic exposure can cause poisoning.
Lime						See calcium oxide.
Limestone						See calcium carbonate.
Limewater						See calcium hydroxide.
Lithium, Li	.4	4	4	R	C	Flammable solid. Reacts with water to form flammable H_2 gas. Store under mineral oil. Keep away from air, water, oxidizing agents, acids.
Lithium chloride, LiCl	2	1	1	GI	C	Low hazard.
Litmus	1	1	1	GO	A,B	Low hazard.
Lugol's Iodine Stain	2	1	1	GI	C	This is a solution of KI and I_2 in water. Irritant. Keep away from metals, ammonia.
Lye						See sodium hydroxide.
Magnesium, Mg (forms other than powder)	1	2	2	R	C	Powdered form is highly reactive and flammable. Reacts with water to form flammable H_2 gas. Keep away from water, oxidizing agents, acids.
Magnesium sulfate, $MgSO_4$	1	1	1	GI	C	The heptahydrate also called epsom salts. Low hazard.
Manganese dioxide						See manganese(IV) oxide.

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Chemical	T	F	R	Storage	Disposal	Comments
Manganese(IV) oxide, MnO_2	2	1	2	S	C	Also called manganese dioxide. Oxidizing agent. Keep away from other oxidizing agents, reducing agents, organic material.
Marble chips						See calcium carbonate.
Mercuric chloride						See mercury(II) chloride.
Mercuric oxide						See mercury(II) oxide.
Mercury, Hg	3	1	1	PD	C,F	Vapour highly toxic. Keep away from oxidizing agents, metals, ammonia. Keep only as a permanently sealed sample for display purposes.
Mercury(II) chloride, $HgCl_2$	4	1	1	GI	C	Also called mercuric chloride. Highly toxic, can be absorbed through the skin.
Mercury(II) oxide, HgO	4	1	2	O	C	Also called mercuric oxide. Highly toxic, oxidizing agent. Can be absorbed through the skin. Keep away from reducing agents, metals.
Methane, CH_4	1	4	1	G	G	Flammable gas, simple asphyxiant. Keep away from oxidizing agents.
Methanol, CH_3OH	2	3	1	F	D	Also called methyl alcohol, wood alcohol. Flammable, toxic. Ingestion can cause blindness. Keep away from oxidizing agents, metals.
Methyl alcohol						See methanol.
Methylene blue, $C_{16}H_{18}ClN_3S$	2	1	1	GO	A	Dilute solutions are low hazard.

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Chemical	T	F	R	Storage	Disposal	Comments
Methylene chloride						See dichloromethane.
Mineral oil	1	1	1	GO	D	Also called paraffin oil. Possibly carcinogenic if inhaled. Combustible. Keep away from oxidizing agents.
Muriatic acid						See hydrochloric acid.
Nickel, Ni (forms other than powder)	2	1	1	GI	C,F	Powdered form is a fire hazard and possible carcinogen. Keep away from oxidizing agents.
Nickel(II) chloride, $NiCl_2$	2	1	1	GI	C	Toxic, irritant.
Nickel(II) nitrate, $Ni(NO_3)_2$	2	1	3	O	C	Oxidizing agent, toxic. Keep away from reducing agents, organic material.
Nitric acid, concentrated, HNO_3	4	1	4	O	A,C	Corrosive, oxidizing agent. Dilute solutions are less hazardous, but still require care. Keep away from reducing agents, organic materials and metals.
Nitrogen, N_2	1	1	1	G	G	Simple asphyxiant. The liquid form is extremely cold. Handle with insulated gloves.
Oil of cloves	1	1	1	GO	D	Low hazard.
Paraffin oil						See mineral oil.
Paraffin wax, $C_{25}H_{52}$	1	1	1	GO	B	Combustible solid.
Perchloroethylene						See tetrachloroethene.
Phenolphthalein, $C_{20}H_{14}O_4$	2	1	1	GO	A,B	Dilute solutions are low hazard.
Phenyl 2-hydroxy-benzoate,	2	1	1	GO	C	Also called salol, phenyl salicylate. Low hazard.

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Chemical	T	F	R	Storage	Disposal	Comments
$C_{13}H_{10}O_3$						
Phenyl salicylate						See phenyl 2-hydroxybenzoate.
Phosphoric acid, concentrated, H_3PO_4	3	1	4	A	A,C	Corrosive. Keep away from metals, bases.
Phosphorus, red, P_4	2	2	2	GI	C	Flammable solid, toxic. Keep away from oxidizing agents, metals, organic material, bases.
Phosphorus, white, P_4	4	4	4	S	C	Highly toxic, ignites spontaneously when exposed to air. Must be stored under water. Do not store this material in schools.
Plaster						See calcium sulfate.
Potassium, K	4	4	4	R	C	Flammable solid, reacts vigor-ously with water to produce flammable H_2. Can ignite spontan-eously in moist air. Must be stored under mineral oil. Oxide coating can be explosive. Do not store this material in schools.
Potassium bitartrate						See potassium hydrogen tartrate.
Potassium bromide, KBr	1	1	1	GI	A,B	Low hazard.
Potassium chlorate, $KClO_3$	2	1	4	O	C	Oxidizing agent. May form explosive mixtures with combustible material. Keep away from reducing agents, organic material, metals, non-metals.
Potassium chloride, KCl	2	1	1	GI	A,B	Low hazard.
Potassium chromate, K_2CrO_4	2	1	4	O	C	Oxidizing agent, carcinogen. Keep away from reducing

T - Toxicity
F - Flammability
R - Reactivity
See beginning of table for key to entry codes.

Chemical	T	F	R	Storage	Disposal	Comments
						agents, organic material.
Potassium dichromate, $K_2Cr_2O_7$	3	1	2	O	C	Oxidizing agent, carcinogen. Keep away from reducing agents, organic material.
Potassium hydrogen tartrate, $KHC_4H_4O_6$	1	1	1	GO	A,B	Also called potassium bitartrate, cream of tartar. Low hazard.
Potassium iodide, KI	2	1	1	GI	C	Low hazard. Keep away from oxidizing agents.
Potassium nitrate, KNO_3	2	1	3	O	A,C	Oxidizing agent. Can form explosive mixtures with combustible material. Keep away from reducing agents and organic material.
Potassium permanganate, $KMnO_4$	2	1	3	O	C	Oxidizing agent. Keep away from reducing agents, organic material, acids.
Potassium thiocyanate, KSCN	2	1	2	GI	C	Toxic. Keep away from acids.
Propane, C_3H_8	1	4	1	G	G	Flammable gas, simple asphyxiant. Keep away from oxidizing agents.
2-Propanol, $(CH_3)_2CHOH$	2	3	1	F	D	Also called isopropanol, rubbing alcohol. Flammable, toxic if ingested. Keep away from oxidizing agents.
Sal ammoniac						See ammonium chloride.
Salol						See phenyl 2-hydroxybenzoate.
Sand						See silicon dioxide.
Scarlet Red						See Sudan IV.

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Chemical	T	F	R	Storage	Disposal	Comments
Silica gel						See silicon dioxide.
Silicon, Si (forms other than powder)	1	2	2	PD	C,F	Powdered form is flammable. Keep away from oxidizing agents. Keep only as a permanently sealed sample for display purposes.
Silicon dioxide, SiO_2	1	1	1	GI	B	Also called silicon(IV) oxide, silica gel, sand. Finely powdered form can cause lung damage if inhaled.
Silicon(IV) oxide						See silicon dioxide.
Silver, Ag (forms other than powder)	1	1	1	GI	C,F	Powdered form is a fire hazard and toxic by inhalation.
Silver nitrate, $AgNO_3$	3	1	3	O	C	Oxidizing agent, toxic, corrosive. Keep away from reducing agents, organic material, ammonia.
Slaked lime						See calcium hydroxide.
Sodium, Na	4	4	4	R	C	Flammable solid, reacts vigorously with water to produce flammable H_2 gas. Can spontaneously ignite in moist air. Store under mineral oil, away from air, water, acids, oxidizing agents.
Sodium acetate, CH_3COONa	1	1	1	GI	A,B	Low hazard. Keep away from oxidizing agents.
Sodium bicarbonate						See sodium hydrogen carbonate.
Sodium bisulfate						See sodium hydrogen sulfate.
Sodium bromide, NaBr	1	1	1	GI	A,B	Low hazard.
Sodium carbonate, Na_2CO_3	2	1	2	GI	A,C	Also called washing soda. Corrosive and basic. Reacts

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Chemical	T	F	R	Storage	Disposal	Comments
						vigorously with acids to produce CO_2 gas.
Sodium chloride, NaCl	1	1	1	GI	A,B	Low hazard.
Sodium chromate, Na_2CrO_4	2	1	2	O	C	Oxidizing agent, carcinogen. Keep away from reducing agents, organic material.
Sodium dihydrogen phosphate, NaH_2PO_4	1	1	1	GI	A,B	Also called sodium phosphate, monobasic. Low hazard.
Sodium hydrogen carbonate, $NaHCO_3$	1	1	1	GI	A,B	Also called sodium bicarbonate, baking soda. Low hazard. Reacts vigorously with acids to produce CO_2 gas.
Sodium hydrogen phosphate, Na_2HPO_4	1	1	1	GI	A,B	Also called sodium phosphate, dibasic. Low hazard.
Sodium hydrogen sulfate, $NaHSO_4$	2	1	2	GI	A,C	Also called sodium bisulfate. Acidic, corrosive.
Sodium hydroxide, NaOH	4	1	4	GI,B	A,C	Also called lye. Highly corrosive. Keep away from acids, metals.
Sodium iodide, NaI	1	1	1	GI	C	Low hazard. Keep away from oxidizing agents.
Sodium nitrate, $NaNO_3$	1	1	3	O	A,C	Oxidizing agent. Can form explosive mixtures with combustible material. Keep away from reducing agents, organic materials, metals.
Sodium phosphate, Na_3PO_4	2	1	1	GI	A,B	Also called sodium phosphate, tribasic, trisodium phosphate, TSP. Basic, corrosive.
Sodium phosphate, monobasic						See sodium dihydrogen phosphate.

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See beginning of table for key to entry codes.

Chemical	T	F	R	Storage	Disposal	Comments
Sodium phosphate, dibasic						See sodium hydrogen phosphate.
Sodium phosphate, tribasic						See sodium phosphate.
Sodium sulfate, Na_2SO_4	1	1	1	GI	A,B	Low hazard.
Sodium sulfite, Na_2SO_3	2	1	2	GI	C	Reducing agent, reacts with acids to produce toxic SO_2 gas. Keep away from oxidizing agents, acids.
Sodium thiosulfate, $Na_2S_2O_3$	1	1	1	GI	A,B	Low hazard. Reacts with acids to produce toxic SO_2 gas.
Span 40 (sorbitan mono-palmitate)	1	1	1	GO	A,B	Low hazard.
Stannous chloride						See tin(II) chloride.
Starch	1	1	1	GO	A,B	Low hazard.
Steel wool						See iron.
Strontium chloride, $SrCl_2$	2	1	1	GI	C	Low hazard.
Sucrose, $C_{12}H_{22}O_{11}$	1	1	1	GO	A,B	Also called table sugar. Low hazard.
Sudan III, $C_{22}H_{16}N_4O$	2	1	1	GO	B	Low hazard.
Sudan IV, $C_{24}H_{20}N_4O$	2	1	1	GO	B	Also called Scarlet Red. Low hazard.
Sulfur, S_8, S	1	2	1	GI	C	Combustible solid. Keep away from oxidizing agents, reducing agents and metals.
Sulfuric acid, concentrated, H_2SO_4						Highly corrosive and reactive. Dilute solutions are less hazardous. Keep away from bases, reducing agents,

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H_2SO_4	4	1	4	A	A,C	organic material, metals, oxidizing agents.
Table sugar						See sucrose.
Tartaric acid, $C_4H_6O_6$	1	1	1	GO	A,B	Low hazard.
Tetrachloroethene, C_2Cl_4	2	1	1	GO	E	Also called perchloroethylene, tetrachloroethylene. Carcinogen. Keep away from metals and bases.
Tetrachloroethylene						See tetrachloroethene.
Tin, Sn (forms other than powder)	1	1	1	GI	C	Powdered form is a fire hazard.
Tin(II) chloride, $SnCl_2$	2	1	2	GI	C	Also called stannous chloride. Irritant. Keep away from reducing agents, oxidizing agents, metals.
Toluidine blue, $C_{15}H_{16}ClN_3S$	2	1	1	GO	A	Also called toluidine blue O. Dilute solutions are low hazard.
1,1,1-Trichloroethane, $C_2H_3Cl_3$	1	1	1	GO	E	Irritant. Keep away from metals, bases.
1,1,2-Trichlorotrifluoroethane, $C_2Cl_3F_3$	1	1	1	GO	E	Keep away from metals.
Tween 40 (polyoxyethylene-(20)sorbitan monopalmitate)	1	1	1	GO	A,B	Low hazard.
Washing soda						See sodium carbonate.
Wood alcohol						See methanol.
						Reducing agent. Powdered form is reactive. Mixtures

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Chemical	T	F	R	Storage	Disposal	Comments
Zinc, Zn (forms other than powder)	1	2	2	R	C	with combustible materials may ignite in contact with moist air. Keep away from non-metals, oxidizing agents, acids, organic material.
Zinc nitrate, $Zn(NO_3)_2$	1	2	3	O	A,C	Oxidizing agent. Keep away from reducing agents, organic material, non-metals.
Zinc sulfate, $ZnSO_4$	2	1	1	GI	A,C	Low hazard.

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