Science Safety

RESOURCE MANUAL

BRITISH COLUMBIA | Ministry of Education

Disclaimer

It is intended that this manual will be used by schools and school districts to examine science safety in schools and initiate actions to improve science safety for all students and teachers.

This manual is located in PDF format at: https://curriculum.gov.bc.ca/tools

A Note on the 2016 Update of this Manual:

The British Columbia (BC) *Science Safety Resource Manual* is a resource support for teachers to use with the BC Science curriculum. This manual provides guidance for school districts and safety considerations for teachers and students as students increase their understanding of science through inquiry and hands-on experiences.

The BC science curriculum is rooted in inquiry and designed to allow students to pursue their own inquiries using scientific methods. Inquiry is the tool with which students gain scientific knowledge, learn the habits of mind and skills and processes associated with the doing of science, and develop as scientifically educated citizens.

Goals of the BC science curriculum (K–12)

The BC Science curriculum contributes to students' development as educated citizens through the achievement of the following goals. Students are expected to develop:

- an understanding and appreciation of the **nature of science** as an evidence-based way of knowing the natural world that yields descriptions and explanations that are continually being improved within the context of our cultural values and ethics
- **place-based knowledge** and experiences about the natural world in the area in which they live by accessing and building on existing understandings, including those of local First Peoples
- a solid foundation of **conceptual and procedural knowledge** in biology, chemistry, physics, and earth and space sciences that they can use to interpret the natural world and apply to new problems, issues, and events, to further learning, and to their lives
- the **habits of mind** associated with science — a sustained curiosity; a valuing of questions; an openness to new ideas and consideration of alternatives; an appreciation of evidence; an awareness of assumptions and a questioning of given information; a healthy, informed skepticism; a seeking of patterns, connections, and understanding; and a consideration of social, ethical, and environmental implications
- a lifelong interest in science and the attitudes that will make them **scientifically literate citizens** who bring a scientific perspective, as appropriate, to social, moral, and ethical decisions and actions in their own lives, culture, and the environment.

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1 Introduction to Science Safety

Developing scientific literacy is a key goal of the BC Science curriculum. Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity (Programme for International Student Assessment). The development of scientific literacy is supported by instructional environments that encourage students to ask questions and to seek answers to their questions by conducting their own scientific inquiries.

With active inquiry comes a need for caution and safety. The safety consciousness of society in general and science educators in particular has been raised substantially over the past few years.

This manual was developed and has been revised to address the need for an increased safety consciousness. The teaching of science requires the active involvement of students in scientific inquiries that take place in classrooms used for hands-on science activities. Any safety guidelines should support and encourage inquiry and include instruction on safe procedures in classrooms used for science activities, while at the same time assisting in the development of a safe teaching environment.

The information in this manual is intended to help educators provide a complete science safety program that supports an exciting and meaningful science curriculum and reduces the risk of injury to staff and students.

Teachers and school districts are not expected to guarantee 100% safety. Risk is always present in a school science setting. With each science investigation the teacher should weigh the total benefits against potential hazards. In the final analysis, it is the classroom teacher who is in the best position to decide which activities should be performed by the students, performed by the teacher as a demonstration, or omitted entirely. The materials included in this manual have been compiled to assist those involved in the education system, and in particular the classroom teacher, in making sound decisions regarding science safety.

Some Legal Aspects of Science Safety

Any teacher will be held to the standard of care shown by a reasonably prudent science teacher in the province of British Columbia. Following the suggestions in this manual will help to ensure that legal standards are met. If an accident and injury occurs during a science class, a science teacher‘s legal liability for that injury will be judged by considering some of the following criteria:

1. Did he/she use appropriate activities for the grade level?
2. Did he/she give careful instruction of all aspects of the activity?
3. Did he/she teach safety rules, and satisfy himself/herself that the students understood the activity and safety requirements ?
4. Did he/she carefully supervise the activity?
5. Did he/she strictly enforce safety rules?

Responsibilities

Responsibility for ensuring a safe environment in the science classroom is shared by four main groups:

- school district/trustees and superintendent
- school administration
- science teacher
- science student

The co-operation of all these groups helps to develop a strong safety consciousness both inside and outside the school.

School district/trustees and superintendent

The school district/trustees and superintendent should endeavour to:

- plan for the necessary improvements and procedures outlined in this manual
- set up a school district science safety committee, with representatives from the school district administration, school administration, and teachers, and consult with this committee on matters of science safety
- ensure that school administrators carry out the safety responsibilities outlined in this manual
- provide in-service training and encouragement to ensure that professional staff have the necessary expertise to develop and maintain a safe working/learning environment (e.g., every employee should have Workplace Hazardous Material Information System (WHMIS) training)
- make provisions for staffing alternatives to permit safe operation and maintenance of science facilities on a day-to-day basis
- provide any special safety facilities/provisions needed for special needs students and students for whom English is a second language
- establish fire drills and emergency procedures
- maintain school buildings, furniture, and equipment in proper repair

School administration

The school administration should endeavour to:

- work with the science teachers in the school to provide support in maintaining a safe working/learning environment in the school
- ensure that safety concerns that can be dealt with at the school level are resolved promptly
- direct any safety concerns that cannot be resolved at the school level to the appropriate district personnel
- ensure regular (annual, monthly, and special) safety inspections of science facilities, and report findings to the school district, the school safety representative/committee, and the district safety committee (the checklist provided on pages 91–97 of this manual is a useful instrument for use in safety inspections)
- ensure that the school has effective policies and procedures to follow in case of accidents and emergencies
- conduct fire drills and emergency training during the school year
- ensure that all teachers and teachers teaching on call required to teach science have the expertise to teach the science assigned to them in a safe and effective manner
- ensure that the size of science classes allows for a safe learning environment that can be reasonably supervised
- support teachers in providing a safe working environment, by:
  - providing necessary safety equipment
  - enabling teachers to obtain in-service training in science safety (e.g., WHMIS, First Aid, CPR)
  - providing necessary guidance to ensure safety in science classes
  - ensuring that the safety procedures identified in this manual are effectively carried out
  - making provisions for the safety of students with special needs
  - being sensitive to culture and language difficulties
  - ensuring that teachers have the necessary resources to carry out their safety responsibilities
- co-operate with outside personnel and agencies in encouraging science safety (e.g., Fire Commissioner's office, BC Hydro, WorkSafeBC) (see pages 87–88)
- ensure that teachers teaching on call do not undertake activities that endanger the safety of students (i.e., ensure that they have the necessary expertise to carry out the activities outlined in the lesson plans; otherwise alternative activities should be arranged)
- maintain safety equipment and supplies
- ensure that science equipment and facilities conform to safety standards
- provide proper security to prevent theft

Science teacher

Safety in the classroom is paramount. Other components of education — resources, teaching strategies, and facilities — are effective only in a safe classroom or lab. Safety is not just a matter of common sense.

A teacher should:

- be informed, by:
  - being familiar with the content of this manual
  - exchanging information with colleagues
  - being aware of school district and provincial policies related to scientific inquiries
  - where applicable, reading safety articles in teachers' journals
  - where applicable, attending safety sessions at in-services or conferences
- be aware, by:
  - having safety equipment prominently displayed
  - having safety posters on the wall
  - placing regular emphasis on safety precautions prior to an activity
- be proactive, by:
  - protecting the health, welfare, and safety of the students
  - providing students with the necessary personal protective equipment
  - being aware of students' health or allergy problems
  - planning carefully for all activities
  - modelling safe procedures at all times
  - instructing students about safe procedures regularly
  - supervising students
  - reporting all hazardous or potentially hazardous conditions to supervisory personnel immediately
  - maintaining adequate records of all aspects of laboratory operations
  - implementing and maintaining safe storage and waste disposal systems for potentially dangerous substances used or produced in the course of laboratory work
  - displaying commercial, teacher-made, or student-made safety posters
  - taking First Aid, CPR, and WHMIS courses

The following questions can be used to guide planning for a particular unit or activity:

- What are the hazards?
- What are the "worst case" scenarios?
- How can I prepare for and avoid the "worst case" scenarios?
- What practices, safety equipment, and protective facilities are prudent and appropriate?

Science student

A science student should:

- give undivided attention to science activities and behave in a safe and careful manner in the science room
- follow all safety procedures and instructions
- not carry out any science activity without the teacher's permission and appropriate supervision
- report any unsafe situations or accidents to the teacher immediately

2 Elementary Science

Safety awareness should start at the earliest possible age. Science can be taught safely in an elementary classroom as long as both the teacher and the students are aware of all potential hazards relating to the planned activity, and appropriate safety measures have been taken. If students can learn how to do lab activities in a safe manner at the elementary level, they will be better prepared for science when they reach secondary school.

The teacher is responsible for setting the safety rules, but should also explain to the students why the safety rules are necessary. Students must also understand that if they cannot follow the safety rules, they may lose out on the opportunity to participate in fun, hands-on scientific activities.

It is the teacher's responsibility to ensure that any planned activity, whether for use as a class activity or a demonstration, is both safe and appropriate for the age of the students involved. The teacher must perform the activity prior to assigning it to students. This way, the teacher will be familiar with the activity, the materials needed, and potential hazards that the activity may present. The teacher should be aware of any safety concerns with any of the materials to be used and the appropriate response should an incident occur. If there is even the slightest question in the teacher's mind about the safety of the activity, the activity should be abandoned and a safer and more appropriate one selected.

There are more risks when an activity has been sourced from the Internet. Depending on the source, the activity may contain inaccurate, misleading, or dangerous information. Consider the source when determining the suitability of the activity, and if there is any question, consult with an experienced science teacher or find an alternate activity from a more reliable source.

As part of the activity planning process, extra consideration should be given to students who are on Individual Education Plans (IEPs) and who may need adaptations or modifications to the planned activity to ensure the safety of themselves and others in the classroom. Adaptations could include giving directions visually or orally, providing a more appropriate workspace for a student in a wheelchair, or providing individual help and supervision.

Teachers also need to be aware of any student allergies. These need to be taken into consideration when planning the activity. Students may have allergies to certain foods, latex (often found in gloves and other rubber items), and other chemicals.

When planning a hands-on activity for students, consider the following questions:

- Do I understand the risks associated with equipment and materials to be used in this activity?
- Do I know how to safely use the equipment and materials, and am I able to clearly share this knowledge with my students?
- Is the location where I plan to carry out the activity suitable and safe for the planned activity?
- Is all the appropriate safety equipment available in the space and in working order?
- Have I considered the needs of students on IEPs, ESL students, and those with medical conditions and allergies?
- Is there a plan for clean-up after the activity?
- Do I know how to safely dispose of excess or used materials/chemicals after the activity?
- Is there a safer alternative to the planned activity that will have the same educational outcomes?

General Elementary Science Safety Tips

- Know the safety hazards before starting the activity.
- Inspect all equipment before starting the activity to make sure it is safe and in good working order. Students should be taught how to use all equipment in a safe manner.
- Never use mercury thermometers in a school situation.
- Prevent contamination by never returning excess chemicals to the original container. Dispose of them safely.
- Ensure that all chemicals are properly labelled.
- Check for potential toxicity of any plants to be used in the classroom.
- Students should tie back long hair and secure loose clothing or jewelry before doing a lab activity.
- Open-toed shoes should not be worn during a lab activity.
- No food or drink should be consumed in any area where lab activities are carried out.
- Students should always wear appropriate personal protection for a lab activity (e.g., safety goggles, apron, gloves)
- Students should always wash their hands thoroughly, with soap, after completing a lab activity.
- Use student safety contracts, with clear safety expectations. Have both students and parents read and sign the contracts.
- Have students check the classroom daily for any safety concerns.
- Ensure that any hazardous chemicals or equipment are kept locked up when not in use or unsupervised.
- Discuss any safety concerns with the class prior to starting the lab activity and monitor students to make sure they work in a safe manner.
- Do not allow elementary students to dispense chemicals or handle containers of hot liquids.
- Avoid using glass containers in an elementary lab situation.
- Ensure that there are no tripping hazards in the work area (e.g., bags).

Post a simple set of grade-appropriate rules for students to follow. Make sure that all students in the class understand the rules and know how to follow them.

Here is a suggested set of rules for Grades K–4:

- I will listen carefully to my teacher's directions.
- I will make sure I know what to do before I begin the lab.
- I will handle all science materials and tools carefully and safely.
- I will wait for permission before I touch any of the science materials.
- I will behave safely and appropriately.

Chemicals

The following chemicals can be used safely with elementary students:

Aluminum foil

Antacid preparations (e.g., Alka-Selzer)

Baking powder (sodium bicarbonate and tartaric acid)

Baking soda (sodium bicarbonate)

Bath salts/Epsom salts (magnesium sulfate)

Borax (sodium borate)

Carbonated (fizzy) drinks

Chalk (calcium carbonate)

Charcoal (carbon)

Citric acid crystals

Clay (moist)

Cobalt chloride paper (only the paper)

Copper foil or powder

Cream of tartar (tartaric acid and potassium hydrogen tartrate)

Detergents – hand-washing types (but not dishwashing)

Food colouring

Glycerine (glycerol)

Iron filings

Lemon juice (contains citric acid)

Litmus paper or solution

Marble chips (calcium carbonate)

Milk

Oils – vegetable and mineral (but not motor oil)

Petroleum jelly ("Vaseline")

Plaster of Paris or cellulose fillers ("Polyfilla")

Salt (sodium chloride)

Sand

Soap

Starch

Steel wool

Sugar

Tea (contains tannic acid)

Universal (pH) indicator paper or solution

Vinegar (dilute acetic acid)

Vitamin C (ascorbic acid)

Washing powder – hand-washing types

Water glass (sodium silicate)

Zinc foil

Remember: Any substance, even salt, can be harmful if ingested in sufficient quantity, and any substance in a fine powder or dust form can be inhaled and be harmful.

Use of Plants in the Elementary Classroom or School Garden

Teachers need to take precautions when managing plants both inside and outside the classroom. Several common indoor and outdoor plants contain toxins, including daffodil, English ivy, ficus, peace lily, lilies, amaryllis, rhododendron, and aloe vera. Some plants are highly toxic or produce toxic seeds or fruits. Others may cause allergic reactions in some students.

Teachers may want to keep any indoor plants out of reach of very small children or determine if the plants contain any toxins. On field trips, teachers should point out toxic or poisonous plants to students to prevent or reduce the students' exposure to the plants.

Students should be instructed never to place any part of an unknown plant in their mouth, and to avoid rubbing plant sap or juice from a plant's fruit onto the skin. Students should never touch mushrooms growing outside, as many varieties are highly poisonous.

Students should also be discouraged from picking wildflowers or unknown plants, to both prevent any possible risk and protect the environment. Picking of most types of wild flowers is prohibited.

Plant-related lab activities often involve the study of seeds sprouting (germination). It is recommended that teachers purchase seeds for this purpose from a grocery store, rather than seeds marketed for garden planting, as these may be coated with chemicals that are toxic or irritating to the skin.

The following are some guidelines to follow when working with plants:

- Wash hands thoroughly or wear non-allergenic gloves when working with plants. Avoid using plants that have thorns.
- Use sterilized potting soil instead of soil directly sourced from the ground, which may contain mould and other fungi.
- Take care if studying aquatic plants from ponds or marshes, as pond or marsh water may contain substances and micro-organisms that can cause illness.
- Students should wash their hands thoroughly after the plant activities, and all surfaces where the plants were handled should be cleaned thoroughly.

On field trips or when students are working outside in a school garden, an unpleasant, painful encounter with animals such as snakes, spiders, or ticks and other insects is always possible. Check for these animals both while working outdoors and before heading back into the school (so they are not brought indoors accidentally). Students should learn to respect wildlife of all kinds and to observe with their eyes, not with their hands.

When working in woodpiles, sheds, or dark, undisturbed areas, where spiders may live, look before you touch. Gloves that fit properly will help to keep students' hands safe from unwanted encounters.

Although ants, bees, and caterpillars have a useful role in the environment, some species may also be dangerous. Wasps and yellow jackets can sting. Some caterpillars also have stinging hairs. Some people are allergic to fire ants. Children may not be able to distinguish good from bad, so good advice for them is to "look but don't touch" insects in the garden and to tell an adult if they see a nest, hive, or mound where insects live.

Animals in the Classroom and on Field Trips

Using live animals in the classroom can help students understand and appreciate life cycles and processes. Before bringing animals into the classroom, teachers should check school district policy on the use of animals in the classroom. It is important to select animals that are both appropriate to instructional needs and practical to maintain in a school setting. Good safety procedures should be established for protecting students from the hazards of classroom animals and ensuring the humane treatment of animals.

Teachers are also responsible for familiarizing themselves with any local, provincial, or federal regulations pertaining to the care of animals. If in doubt, inquire. Pet shops may have useful information. Remember that there are regulations preventing the captive use of migratory birds or endangered species.

The following are some guidelines for the care of animals in the classroom:

- Be wary of any possible signs of allergic reactions among students to any animals.
- Inform the administration before bringing any animals into the school, including student pets.
- Inquire about specific feeding and facility requirements for classroom pets.
- Be wary of possible diseases that may be spread to people by animals, or by people to animals.
- Poisonous animals, or other potentially dangerous animals such as venomous snakes and spiders, should not be brought into the school.
- Wear gloves when handling animals in the classroom. All handling of animals by students should be done voluntarily and only under immediate teacher supervision. Students should not be allowed to mishandle or mistreat animals. Excessive handling can cause animals severe stress.
- Involve students in helping to care for animals. Students should be taught how to safely care for and treat an animal, ideally before the animal is brought into the classroom.
- Make arrangements to have classroom animals looked after on weekends and during vacations.
- Animals caught or found dead in the wild should not be brought into the classroom. They may carry diseases such as salmonella, and many wild animals are subject to rabies.
- On field trips or during other outdoor activities, be aware of the danger of rabies exposure from wild animals. Also be aware of the potential hazards of insect bites, such as allergic reactions to insect stings or diseases spread by ticks or fleas.
- Animal dissections should only be performed on specimens purchased from a reliable supplier specifically for that purpose. Any animal that has been preserved in formaldehyde should not be used in a school.

3 Secondary Science

No matter what grade the students are in, safety is a primary concern in the science classroom. Secondary students may already have some experience handling chemicals and science equipment. As they progress through secondary school, they are given more opportunities to work with more sophisticated apparatus and chemicals, which requires more in-depth safety knowledge.

It is a teacher's responsibility to weigh the risks and benefits inherent in every science activity. Teachers should not pass off part of that responsibility by involving students in decision-making processes.

Teachers must instruct students in the process of evaluating the risks and benefits of any laboratory activity, and can ask for students' creativity by seeking their ideas on ways to minimize any risks.

To have a safe laboratory environment, it is essential to properly inform the students of the hazards and precautions involved in the assigned lab work. It is good practice to involve students in a discussion of these matters, encouraging their participation and guiding their discussion toward the correct conclusions for safe work in the laboratory activity. They will be better able to learn to work safely and develop an individual sense of safety and responsibility, and they might have some useful ideas or suggestions about how to make the activity even safer.

Preparing for Laboratory Activities

When planning a laboratory activity for students, consider the following points:

- Before each activity in the laboratory, weigh the potential risk factors against the educational value. Try to plan an activity with the least possible amount of risk.
- Have an understanding of all the potential hazards of the materials, the process, and the equipment involved in every laboratory activity.
- Inspect all equipment/apparatus in the laboratory before use. Know the location of and how to use all safety and emergency equipment (e.g., safety shower, eyewash, first-aid kit, fire blanket, fire extinguishers, and mercury spill kits).
- Know the location of and how to use the cut-off switches and valves for water, gas, and electricity in the laboratory.

- Clearly instruct students on and check their understanding of all laboratory procedures that will be conducted.
- Discuss all safety concerns and potential hazards related to the laboratory work that students will be performing before starting the work.

Ensuring Appropriate Laboratory Conduct

When running a lab activity for students, consider the following points to ensure appropriate conduct in the lab:

- Be a role model of good safety conduct.
- Make sure students are wearing the appropriate personal protective equipment (e.g., chemical splash goggles, laboratory aprons or coats, and gloves).
- Ensure that all safety rules and procedures are enforced at all times.
- Never leave students unsupervised in the laboratory, and do not allow unauthorized visitors to enter the laboratory.
- Never allow students to take chemicals out of the laboratory.
- Never permit the consumption of food, beverages, or gum in the laboratory.

Science Safety Rules and Procedures for a Secondary Science Class

The following are guidelines, cautions, and recommendations for students that form the basis of a set of safety rules appropriate for a secondary-level science course. Please note that this list is not exhaustive.

- The safety of everyone in the laboratory requires you to behave responsibly at all times. Do not engage in practical jokes or boisterous conduct in the laboratory.
- Never run in the laboratory.
- Never work in the laboratory without teacher supervision.
- Never conduct unauthorized experiments.
- Inform your teacher of any known sensitivities to chemicals.
- Know the location of all safety equipment and how to use it.
- Never eat, drink, smoke, apply cosmetics, or chew gum in a science laboratory or storage area. Do not store or consume food or beverages in a laboratory environment.
- Never taste anything in the laboratory unless you are specifically instructed to do so by your teacher.
- Restrain loose clothing (e.g., sleeves, full-cut blouses, neckties) and long hair and remove dangling jewellery.
- Always wear closed shoes during laboratory activities.
- Wear safety goggles and other protective clothing as instructed by your teacher.
- If you wear contact lenses, notify the teacher. Some activities may require you to remove contact lenses.
- Ensure that your workspace is clear of anything that is not required for completion of the lab.
- Read all directions before starting an experiment. If in doubt about anything, ask your teacher before proceeding.

- Always alert your teacher about any accident or spill.
- If a chemical reagent comes in contact with your skin, rinse it off immediately with large amounts of cold water and continue for at least 5 minutes. Please note that a concentrated acid spill should be wiped off first and then the area can be flushed thoroughly with water.
- If any foreign substance enters your eye, rinse the eye immediately and continue for 15 minutes.
- Never leave heat sources unattended (e.g., gas burners, hot plates, heating mantles, sand baths).
- Do not use cracked or chipped laboratory glassware, as it may cause cuts or break when heated.
- Be careful when handling hot glassware and other apparatus in the laboratory. Hot glassware looks just like cold glassware.
- Never point the open end of a test tube containing a substance at yourself or others.
- Never hold bottles by the neck.
- Chemicals and equipment are to be used only in the lab unless otherwise instructed.
- Always keep containers of chemicals closed when not in use.
- Take only as much of a chemical as needed, and never return excess chemicals to the original container.
- Never place a chemical, not even water, near the edge of a lab bench or workspace.
- Always dispose of chemicals as directed by your teacher. If you are unsure, ask.
- Never enter the chemical storeroom without specific teacher permission and supervision.
- Always thoroughly clean your work area and any equipment used after completion of an experiment, ensuring that any waste is disposed of as instructed by your teacher.
- At the end of the laboratory session, wash your hands thoroughly with warm water and soap.

Safety Equipment for Science Classrooms

Teachers and students should be familiar with the location of and use of the following equipment:

- The safety equipment should be located for easy access.
- Safety equipment should be checked at least twice a year.
- Frequently used safety items should be provided on a separate, centrally located cart for easy access and availability.
- It is recommended that science rooms have both windows and extractor fans.
- Science safety posters should be displayed.
- Emergency lighting should be available.
- A hand-held drench hose may be installed to supplement the safety shower and eye wash units.

Safety Equipment for Science Classrooms	
Equipment	**Comments**
Free-standing clear plastic screen, minimum size 60 cm high x 1 m wide	Polycarbonate is less easily scratched and therefore preferable. Use for teacher demonstrations. Screen should be securely fastened.
One pair heat-resistant gloves	Gloves should be made of treated textured silica or woven fabric. Do not use asbestos gloves.
One eyewash station	A plumbed-in type of eyewash station is preferred, provided the water supply is free of grit and contaminants. The water supply should be tempered by mixing hot and cold water. Eyewash facilities must be tested at least once every month and be maintained in good working order. A maintenance and testing record should be kept.
One fire blanket with wall stand mounted low on wall	The only use for the blanket is to smother clothing fires. Replace any existing asbestos blankets with fire-proofed wool/rayon fabric.
One ULC-listed 2A10BC type dry chemical fire extinguisher	After use, the extinguisher will require service. Demonstrations should not be carried out with this extinguisher. A spare extinguisher should be reserved specifically for that purpose. Fire exits and routes out of science classroom must be clearly marked and kept clear of obstructions at all times.
Sand bucket (approximately 20 L of sand)	For small fires only.
One pair of safety glasses or goggles for each person in the room	Teachers and students must wear eye protection if there is any risk of eye injury. It is good practice to wear eye protection in laboratories at all times. Safety eyewear must meet the requirements of CSA Standard CAN/CSA-Z94.3-92 (8.14 OHSR).
One full face shield	Should be used by teacher when there is any risk of materials splashing or hitting the face during a demonstration.
Lab coats/aprons	Lab coats or aprons should be worn when there is a possibility of exposure to corrosive or other harmful chemicals. It is good practice to wear a lab coat or apron in laboratories at all times.
One pair safety/beaker tongs	Use with heat-resistant gloves when handling very hot equipment. Extreme care should be taken to avoid accidents with heated material.
One fume hood with working extractor fan, sink, and adequate lighting (controls must be placed outside the hood)	Required in each science classroom. The fume hood must provide average air velocities over the operational face of a hood of 0.5 metres/second but not less than 0.4 meters per second at any point across the face. This velocity is for substances that are not carcinogenic or radioactive. The face velocity must be measured and recorded at least once annually.
Simple hand-washing facilities	Should be in or near each science classroom.
Safety showers	Must be readily accessible from each science classroom. Should be installed well away from chemicals. Safety showers must be tested at least once every six months and be maintained in good working order. A maintenance and testing record should be kept.
Spill kits	Spill kits absorb spills or dilute solutions of chemicals. The spill kits should be specific to the chemicals being handled.
Pails containing 12 to 15 L of kitty litter or bentonite	Containers should be clearly labelled and contents disposed of safely.

Safety Equipment for Science Classrooms (continued)	
Equipment	**Comments**
Waste disposal: a) Glass b) Organic solvents and soluble chemicals c) Biological waste	a) Broken glass, metal, or similar waste that is sharp and can cut must be disposed of in separate and clearly identified waste containers. b) Organic solvents and flammable waste must be collected in separate, tightly covered containers and disposed of according to municipal, provincial, and federal regulations. c) Biological waste must be segregated and disposed of safely.
Fireproof metal container with lid	Materials soiled with combustible or flammable agents should be disposed of in a metal container with a lid.
Weak acid solution (acetic acid)	To neutralize small alkali spills.
Large container of dry Na_2HCO_3 (baking soda)	To neutralize strong acids before disposal.
One plastic hand dustpan, brush, pair of protective gloves, and scooping device	Used for brushing up used sand, vermiculite, broken glass, etc. As both pan and brush will be contaminated after use, wash and clean up thoroughly.
One pair chemically resistant rubber gloves, 45 cm long	Should always be worn when dealing with spills. Broken glassware is often involved, and the risk of toxic chemicals entering through open cuts is serious.
One pack heavy-duty garbage bags (also useful for biohazard bags)	For disposal of all solid waste, including used sand, vermiculite, and chemically contaminated broken glass. Double-bag if necessary. Dispose of each spill separately. Tie bags very securely and label. For disposal of specimens, cultures, etc., use designated biohazard bags or extra-thick garbage bags.
Goggle-sterilizing cabinet (using an ultraviolet [UV] source) with interlocking door (recommended for Grade 8–12 science classrooms)	For sterilizing goggles worn by students. The door cannot be opened when the UV light is on. One cabinet can serve a number of classrooms.

Personal Protective Equipment for Students

- Teachers should ensure that students are provided with personal protective equipment. If personal injuries to students result from the failure to have or use appropriate safety equipment, negligence may be claimed.
- The use of laboratory coats or safety aprons is recommended for protection of persons and clothing when working with chemicals, and as appropriate in other science activities (e.g., dissections).
- Non-latex gloves should be worn in all work involving hazardous chemicals or as appropriate in other science activities (e.g., dissections).
- Eye protection must be used in all situations where there is any risk of eye injury.
- The use of contact lenses is not recommended in a science laboratory. Dusts or chemicals can be trapped behind the lens and cause irritation or damage to the cornea or both; gases and vapours can cause irritation and excessive eye watering; and chemical splash may be more injurious when contact lenses are worn.

Potential Eye Injuries	
Foreign bodies	• Most common danger to the eye • Particles can lodge on the surface of the eye, where they become very irritating • Sharp objects may penetrate deeply into the eye, where they may cause no pain • Some chemicals have a toxic effect on eye tissue
Flying glass	• From an exploding test tube or flask
Chemical agents	• Acids – the eye will set up a protection barrier • Caustic materials – readily penetrate into the eye tissue
Radiation	• Ultraviolet, visible, and infrared radiation can all damage eye tissue if the intensity level is sufficiently high • Use of lasers requires special eye protection in addition to special facilities and proper techniques

First Aid

First aid kit — recommended content

WorkSafeBC recommends that a Level 1 first aid kit be available for a classroom where there are between 11 and 50 people. A Level 1 first aid kit contains the following:

3	blankets
24	14 cm x 19 cm antiseptic towelettes, individually packaged
60	hand-cleansing towelettes, individually packaged
100	sterile adhesive dressings, assorted sizes, individually packaged
12	10 cm x 10 cm sterile gauze dressings, individually packaged
4	10 cm x 16.5 cm sterile pressure dressings with crepe ties
2	7.5 cm x 4.5 m crepe roller bandage
1	2.5 cm x 4.5 m adhesive tape
4	20 cm x 25 cm sterile abdominal dressings, individually packaged
6	cotton triangular bandages, minimum length of base 1.25 m
4	safety pins
1	14 cm stainless steel bandage scissors
1	11.5 cm stainless steel sliver forceps
12	cotton tip applicators
1	pocket mask with a one-way valve
6	pairs of latex gloves
1	first aid record book, and pencil or pen

Except for blankets, these items must be kept in a container that can readily be taken to the scene of an injury. Blankets must be readily available to the first aid attendant.

First aid procedures

In the event of a serious accident involving personal injury, the teacher should:

1. Report immediately to the school office via the school phone system or by sending a student to the office.

2. Explain where the accident occurred, how many students were injured, and how serious the injuries appear to be.
3. Request that the school first aid attendant be summoned to the site of the accident.
4. If needed, request that emergency services be called to the school.
5. While waiting for first aid attendant and/or emergency services personnel to arrive, remove everyone from the vicinity of the accident and administer emergency first aid as required.

Basic first aid in the science classroom

Note: First aid should be provided by a trained first aid attendant where possible. These guidelines should be followed while the first aid attendant is getting to the location of the incident.

First Aid in the Science Classroom	
Injury	**Response**
Burns and scalds	• For minor burns and scalds, immerse the wound in cold water. Where immersion is not possible, apply towels or cloths soaked in clean cool water to the affected area and change frequently. • Do NOT apply any lotions or ointments. • Do NOT remove clothing if stuck to the burned area. • Arrange for immediate medical attention.
Bruises	• Apply cold compresses.
Fainting	• Leave the person lying down and place in the recovery position. • Loosen any tight clothing. • Keep crowds away.
Inhalation of toxic fumes or gases	• Summon trained emergency personnel who can administer oxygen and other medical procedures.
Poisoning	• Note the suspected poisoning agent. • Call Poison Control Centre – 1-800-567-8911 or 604-682-5050. • Call an ambulance. Send container and contents with the injured person to the hospital.
Cuts	**Teachers must use disposable gloves when in potential contact with blood.** • For **minor cuts**, clean and cover the wound. Minor cuts and scrapes usually stop bleeding on their own. • Control **severe bleeding** by: – Compressing the wound with a cloth or whatever is available. – If blood is spurting, placing a pad directly on the cut and applying firm pressure. – Elevating the injury above the level of the heart. – Wrapping the injured person (to avoid shock). – Getting immediate medical attention.

First Aid in the Science Classroom (continued)	
Injury	**Response**
Less severe bleeding:	• Wash the cut. • Apply a pressure pad firmly on the wound. • If bleeding continues or if any pieces of glass have to be removed, seek medical attention.
Chemical spills and splashes *On the skin*	• Flush affected area with cold water for at least 5 minutes. • Wash affected area with a mild detergent, preferably soap and water. • Do NOT neutralize chemicals on the skin. • Remove any clothing contaminated with chemicals. Use caution when removing pullover shirts or sweaters to prevent contamination of the eyes. • Depending on the nature of the chemical, seek medical help.
In the eyes:	• Check for and remove contact lenses before irrigation. If contact lenses are difficult to remove, begin irrigation with lenses in place. • Irrigate both eyes immediately with steady gentle stream of tap water, from the eyewash station, for at least 15 minutes. • Arrange for medical help and continue irrigation while victim is transported to emergency care facility. **Notes** • Alkali splash in the eyes is more dangerous than acid at the same concentration, because of its rapid penetration into tissues of the skin and eye. • Fresh tap water is preferable to stored saline solution, which may become contaminated. • DO NOT USE HOT WATER. • Protective goggles or preferably face shields must be worn when handling caustic solutions.
Ingestion of hazardous chemicals	• Encourage the victim to drink large amounts of water while waiting for professional medical assistance. • Never give anything by mouth to an unconscious person.
Electrical accident	• DISCONNECT POWER FIRST. Do not touch a person in contact with live electrical current. • Give artificial respiration if necessary and treat burns.

Planned Accident Response

Accidents do not just happen – they are caused. Accidents in laboratories can be prevented by:

- an educational safety program
- proper supervision of students
- instruction in appropriate laboratory techniques
- good laboratory housekeeping

Science teachers who have been alerted to the hazards in laboratories, who have taught students how to work safely in laboratories, and who promote sound laboratory techniques are in a better position to ensure a safe and successful science program.

The purpose of any action taken at an accident is to minimize the effect of the accident. Especially if action must be taken quickly, this can be achieved by having and knowing how to follow a Planned Accident Response.

A Planned Accident Response requires the following:

- Everyone, including teachers and students, should:
  - be familiar with the resources (knowledge, human resources, and material) available for reducing the effects of an accident
  - understand the steps necessary for a rapid, organized response to an accident
- The resources available for reducing the effects of an accident must be maintained on a regular basis.
- One person must have absolute control of the actions taken by all people at the site. If necessary, this will include sending for qualified help, and making sure that the person who goes for help will report back the person in control.
- Parents of injured students should be contacted.
- Life-threatening conditions must be recognized and reduced immediately. This may just mean clearing everyone from the area.
- The injury must be assessed and appropriate action initiated quickly. People should do only the things they have been trained to do, leaving extensive treatment to medical professionals.
- The accident environment must be made safe. Fire, electrical, and toxic material hazards can be reduced by shutting off gas and power, ventilating the area, and using protective gear. A safe approach to the accident area must be well thought out.
- Every accident must have a thorough investigation that results in written recommendations for the prevention of more accidents of the same type.
- The preliminary investigation of an accident must be assigned to one person and initial notes and photographs taken before clean-up starts.
- For all minor accidents, an accident investigation report should be completed. The report should include:
  - an objective description of the accident event
  - a description of the accident result
  - a description of the action taken at the accident
  - a description of the root cause(s) of the accident
  - recommendations for action that will prevent recurrence of the accident
- All accidents with significant personal injury should be referred to the school district, and all district accident and safety policies should be followed. Ensure that the accident is reported before beginning an investigation.
- For any accident that occurs, follow-up action should include a thorough discussion with students.

To reduce accident frequency, students as well as teachers must be aware, be alert, and be willing to act. Student safety awareness and attitudes should be addressed frequently.

4 Chemicals

Chemicals Likely to Be Found in School Science Departments

The following list provides recommendations and comments on hazardous or potentially hazardous chemicals. The information on chemicals contained on pages 22 through 43 has been compiled from sources believed to be reliable, accurate, and representative of the best opinions on the subject as of 2016. While every reasonable effort has been made to provide dependable information, neither the authors nor the Ministry of Education can assume responsibility for the validity or completeness of all chemical references given or for the consequences of their use.

The purpose of listing a substance here is not to discourage its proper use, but rather to make information available relative to its hazardous properties. It should be noted that the Health (H), Fire (F), and Reactivity (R) columns are keyed to concerns in a fire situation; they do not provide a complete picture of hazards such as carcinogenicity. Additional hazards appear in the Comments column and should be carefully noted. If there is doubt as to the potential hazard of a substance, additional sources or authorities, such as the material safety data sheets (MSDS), should be consulted.

The decision to use certain substances in school laboratories should be based on the best available knowledge of each chemical's particular hazard, the availability of proper handling facilities, and district policy. When the risk outweighs the benefits and no substitute is available, the experiment/demonstration should not be conducted.

For safety's sake, remember:

- Limit the quantities of chemicals.
- Only trained educators should use dangerous chemicals.
- Use proper storage techniques.

NFPA chemical hazard labels

The National Fire Protection Association (NFPA; http://www.nfpa.org/) has developed a system for indicating the health, flammability and reactivity hazards of chemicals. In addition, a special notice symbol may be used where necessary.

This system is used in the list of chemicals that begins on the next page.

Rating Summary		
Health (Blue) H		
4	Danger	May be fatal on short exposure; specialized protective equipment required
3	Warning	Corrosive or toxic; avoid skin contact or inhalation
2	Warning	May be harmful if inhaled or absorbed
1	Caution	May be irritating
0		No unusual hazard
Flammability (Red) F		
4	Danger	Flammable gas or extremely flammable liquid
3	Warning	Flammable liquid flash point below 100°F
2	Caution	Combustible liquid flash point of 100° to 200°F
1		Combustible if heated
0		Not combustible
Reactivity (Yellow) R		
4	Danger	Explosive material at room temperature
3	Danger	May be explosive if shocked, heated under confinement or mixed with water
2	Warning	Unstable or may react violently if mixed with water
1	Caution	May react if heated or mixed with water but not violently
0	Stable	Not reactive when mixed with water
Special Notice Key (White)		
	~~W~~	Water reactive
	OX	Oxidizing agent

The chemicals

The table below contains information on common chemicals that may be found in secondary school laboratories and science classrooms. The chemical names and formulae are listed in the first column, followed by the chemical hazard ratings (detailed above) and additional comments. Some chemical listings may have additional chemical names, which are noted in parentheses. Capitalized names in parentheses indicate cross-listings (i.e., another listing for the same substance with another name). The information provided in cross-listings is identical. **Note**: If there is nothing listed under H, F, or R (see NFPA Chemical Hazard Labels), this does **not** imply that there is no hazard for the material.

Chemical Name and Formula	H	F	R	Comments
**Acetaldehyde CH_3CHO	3	4	2	Moderately toxic (narcotic). Possible carcinogen. Highly flammable. Fire and explosion risk. May form explosive levels of peroxides on concentration.
Acetamide CH_3CONH_2				Possible carcinogen; otherwise low toxicity. Practise strict hygiene when using this material.
Acetic acid (7.4M, 99.8%) CH_3COOH	3	2	0	Moderately toxic by ingestion and inhalation. Corrosive to skin and tissue. Moderate fire risk.
**Acetic anhydride (oxide) $C_4H_6O_3$	3	2	1	Moderately toxic by ingestion. Strongly irritating and corrosive. Causes severe eye damage. Wear eye protection; have access to eyewash. Vapours are strongly irritating; open and dispense in a hood. Reacts violently with water (reaction sometimes delayed). Moderate fire risk.
Acetone CH_3COCH_3	1	3	0	Slightly toxic by ingestion and inhalation. Fire risk; flammable.
Aceto-carmine stain				
Aceto-orcein 2% solution				Moderately toxic by ingestion. Slightly corrosive to eyes and skin.
**Acetyl chloride CH_3COCl	3	3	2	Corrosive. Reacts with water and alcohol.
**Acrolein C_3H_4O	4	3	3	Strong irritant. Flammable.
**Acrylamide C_3H_5NO	3	2	2	Toxic by absorption. Suspected carcinogen.
**Acrylic acid $C_3H_4O_2$	3	2	2	Irritant. Causes eye damage. Flammable.
Adipic acid $C_6H_{10}O_4$		1	0	Eye irritant. Combustible.
**Adrenaline (Epinephrine) $C_9H_{13}NO_3$	2			Toxic by ingestion. Increases blood pressure.
L-alanine $C_3H_7NO_3$				
Alizarin $C_{14}H_8O_4$				Low toxicity. Combustible.
Alum (Aluminum potassium sulfate) $KAl(SO_4)_2$				Low toxicity. Non-combustible.
Aluminon $C_{22}H_{23}N_3O_9$				Low acute toxicity. Mutagen.
Aluminum Al	0	3	1	Fine metal powders form an explosive mixture with air.
Aluminum ammonium sulfate (Ammonium alum) $AlNH_4(SO_4)_2$				Absorbs moisture on exposure to air.
**Aluminum carbide Al_4C_3				Dangerous fire risk.
Aluminum carbonate $Al_2(CO_3)_3$				Do not store near combustible materials.
Aluminum chloride, anhydrous $AlCl_3$				Slightly toxic by ingestion. Body tissue irritant.
Aluminum hydroxide $Al(OH)_3$				Non-combustible.
Aluminum nitrate $Al(NO_3)_3$				Slightly toxic by ingestion. Strong oxidizer.
Aluminum oxide Al_2O_3				Body tissue irritant. Avoid inhalation of dust.
Aluminum phosphate $AlPO_4$				Solutions are corrosive to body tissue.
Aluminum potassium sulfate (Alum) $KAl(SO_4)_2$				Low toxicity. Non-combustible.
Aluminum sodium sulfate $NaAl(SO_4)_2$				Low toxicity. Non-combustible.
Aluminum sulfate $Al_2(SO_4)_3$				Low toxicity. Non-combustible.

*** Should not be used in secondary school laboratories.*

Chemical Name and Formula	H	F	R	Comments
Aluminum sulfide Al_2S_3				
**Ammonia, anhydrous gas NH_3	3	1	0	Moderately toxic by inhalation and ingestion. Corrosive to eyes, respiratory tract, and skin. Use only under fume hood. Stainless steel control valve required for use with ammonia gas.
Ammonia solution NH_4OH				Slightly toxic by ingestion and inhalation. Both liquid and vapour extremely irritating, especially to eyes.
Ammonium acetate CH_3COONH_4				
Ammonium alum (Aluminum ammonium sulfate) $AlNH_4(SO_4)_2$				Absorbs moisture on exposure to air.
Ammonium bicarbonate NH_4HCO_3				Creates irritating fumes when heated.
Ammonium bromide NH_4Br	2	0	0	Moderately toxic by ingestion and inhalation.
**Ammonium chlorate NH_4ClO_3				Explosive. Very dangerous.
Ammonium chloride NH_4Cl	2	0	0	
**Ammonium chromate $(NH_4)_2CrO_4$				Moderately toxic by ingestion. Strong irritant. Very strong oxidizing agent.
Ammonium citrate $(NH_4)_2HC_6H_5O_7$				
**Ammonium dichromate $(NH_4)_2Cr_2O_7$	2	1	1 OX	Dusts and solutions are toxic. Eye and skin irritant. Known carcinogen. Dangerous fire risk. Very strong oxidizing agent.
Ammonium ferrous sulfate (Mohr's salt) $FeH_8N_2O_8S_2$				
**Ammonium fluoride NH_4F	3	0	0	Corrosive to tissue. Toxic by ingestion and inhalation.
Ammonium hydroxide (7.4M; 28%) NH_4OH				Moderately toxic by ingestion and inhalation. Serious respiratory hazard. Both liquid and vapour are extremely irritating, especially to eyes. Dispense in a hood and be sure an eyewash is accessible.
Ammonium molybdate $(NH_4)_6Mo_7O_{24}$				Moderately toxic by ingestion. Skin and eye irritant.
**Ammonium nitrate NH_4NO_3	0	0	3 OX	Slightly toxic by ingestion. Body tissue irritant. May explode if heated under confinement; will explode at temperatures of 210°C; explodes more readily if contaminated with combustible material. Strong oxidizer.
Ammonium oxalate $(NH_4)_2C_2O_4$				Moderately toxic by ingestion and inhalation. Corrosive to body tissue.
Ammonium phosphate, monobasic $(NH_4)H_2PO_4$				
Ammonium phosphate, dibasic $(NH_4)_2HPO_4$				
Ammonium sulfate $(NH_4)_2SO_4$				Slightly toxic by ingestion.
Ammonium sulfide $(NH_4)_2S$				Toxic by skin absorption. Strong skin and mucous membrane irritant. Vapour harmful. Even low concentrations may cause headache and general discomfort. Contact with acids or acid fumes may liberate flammable and poisonous hydrogen sulfide gas.
Ammonium sulfite $(NH_4)_2SO_3$				
Ammonium thiocyanate NH_4SCN				Moderately toxic by ingestion.
Ammonium thiosulfate $(NH_4)_2S_2O_3$				
n-Amyl acetate $CH_3COOC_5H_{11}$	1	3	0	Dangerous fire risk.
n-Amyl alcohol (1-pentanol; pentyl alcohol) $C_5H_{11}OH$	1	3	0	Slightly toxic by ingestion and inhalation. Severe body tissue irritant. Moderate fire risk.

*** Should not be used in secondary school laboratories.*

Chemical Name and Formula	H	F	R	Comments
Aniline (amino benzene) C_6H_7N	3	2	0	Highly toxic by ingestion, inhalation, and skin absorption. Severe eye irritant and mild sensitizer. Mutagen. Combustible. Limited access suggested.
**Antimony Sb				
**Antimony pentachloride $SbCl_5$	4	0	1	
**Antimony sulfate $Sb_2(SO_4)_3$				
**Antimony trichloride $SbCl_3$				Moderately toxic. Corrosive as solid or liquid. Strong skin and eye irritant.
**Antimony trioxide Sb_2O_3				
**Antimony trisulfide Sb_2S_3				
L. Arabinose $C_5H_{10}O_5$				
Arginine $C_6H_{14}N_4O_2$				
Argon Ar				
**Arsenic As				
**Arsenic pentoxide As_2O_5	3	0	0	
**Arsenic (tri)chloride $AsCl_3$	3	0	0	
**Arsenic trioxide As_2O_3	3	0	0	Highly toxic by ingestion and inhalation. Known carcinogen. Use only under a fume hood.
**Asbestos (Magnesium silicate minerals)				
Ascorbic acid (Vitamin C) $C_6H_8O_6$				
Asparagin $C_4H_8O_6$				
Aspartic acid $C_4H_7NO_4$				
Baking soda (Sodium bicarbonate, Sodium hydrogen carbonate) $NaHCO_3$				
**Barium Ba				
Barium carbonate $BaCO_3$				Moderately toxic by ingestion. Strong body tissue irritant.
Barium chloride $BaCl_2$				Highly toxic by ingestion.
**Barium chromate $BaCrO_4$	3	0	3	Toxic. Carcinogen. Oxidizer.
**Barium dioxide BaO_2				
Barium hydroxide $Ba(OH)_2$				Toxic by ingestion.
Barium nitrate $Ba(NO_3)_2$	1	0	0 OX	Moderately toxic by ingestion. Potentially serious fire risk.
**Barium sulfide BaS				
Benedict's qualitative solution (water solution of sodium carbonate, copper sulfate, sodium citrate)				
Benzaldehyde green (Malachite green) $C_{23}H_{25}ClN_2$				Carcinogen. Can make a huge mess!

*** Should not be used in secondary school laboratories.*

Chemical Name and Formula	H	F	R	Comments
**Benzene C_6H_6	2	3	0	Moderately toxic by ingestion, inhalation, and skin absorption. Known carcinogen. Strict observance of safety precautions must be practised (i.e., use a hood, wear gloves, use eye or face protection). Flammable; dangerous fire risk. Use toluene as a substitute.
**Benzene sulfonic acid $C_6H_5SO_3H$				
Benzoic acid $C_7H_6O_2$	2	1	–	Slightly toxic by ingestion. Body tissue irritant. Combustible.
**Benzoyl peroxide $C_4H_{10}O_4$				Explodes when heated. Radical initiator.
**Beryllium Be	3	1	0	Very toxic. All beryllium compounds should be removed.
**Beryllium compounds (Be salts)				Very toxic. All beryllium compounds should be removed.
Bismuth Bi				Slightly toxic by inhalation or ingestion. Flammable in finely divided form such as dust.
Bismuth chloride (trichloride) $BiCl_3$				
Bismuth nitrate $Bi(NO_3)_3$				Slightly toxic. Fire risk near organic material. Oxidizer.
Bismuth oxide Bi_2O_3				
Biuret (reagent) $C_2H_5N_3O_2$				Corrosive liquid; corrosive to body tissue. Eye protection essential when working with this solution.
Bleach (Sodium hypochlorite) (dilute) NaOCl				Moderately toxic by ingestion and inhalation. Corrosive liquid; causes skin burns. Reacts with acid to evolve chlorine gas. Evolves chlorine when heated. Avoid contact with organic material.
Bleaching powder (Calcium hypochlorite) $Ca(OCl)_2$				Moderately toxic by ingestion and inhalation. Body tissue irritant. Fire risk in contact with organic substances. Oxidizer.
Borax (Sodium borate, Sodium tetra borate) Na_2B4O_7				Slightly toxic by inhalation and ingestion.
Boric acid crystal H_3BO_3				Slightly toxic by ingestion. Skin irritant in dry form.
**Boron B				
Brass (copper-zinc alloys)				
**Bromine (reagent) Br_2				Highly toxic by inhalation and ingestion. Severe skin irritant. Very strong oxidizer; reacts violently with many organic compounds. Very hazardous substance even in small amounts.
**Bromobenzene C_6H_5Br	2	2	0	Toxic. Flammable. Bioaccumulative pollutant.
Brom(o)cresol green $C_{21}H_{14}Br_4O_5S$				
Brom(o)cresol purple $C_{21}H_{16}Br_2O_5S$				
Bromoethane (Ethyl bromide) C_2H_5Br	2	1	0	Tumorigen. Mutagen. Limit exposure to vapour.
Bromophenol blue C_6H_5BrO				
Bromothymol blue $C_{27}H_{28}Br_2O_5S$				
1-Butanol (n-butyl alcohol) $C_4H_{10}O$	1	3	0	Moderately toxic by inhalation and ingestion. Eye irritant. Absorbed by skin. Moderate fire risk.
2-Butanone (Methyl ethyl ketone) C_4H_8O	1	3	0	Narcotic by inhalation. Flammable; dangerous fire risk.
iso-butyl alcohol $C_4H_{10}O$				Slightly toxic. Skin, eye, and respiratory irritant. Flammable.
Tert-butyl alcohol $C_4H_{10}O$ (2-methyl-2-propanol)	1	3	0	Slightly toxic by ingestion and inhalation. Eye irritant. Absorbed by skin. Moderate fire risk.
Butyric acid $C_4H_8O_2$	3	2	0	Moderately toxic by ingestion and skin absorption. Strong irritant to skin and eyes. Flammable liquid. Obnoxious odour; stench agent.

*** Should not be used in secondary school laboratories.*

Chemical Name and Formula	H	F	R	Comments
**Cadmium Cd				Dust or fume inhalation especially toxic. Known carcinogen.
**Cadmium carbonate $CdCO_3$				All cadmium salts are highly toxic.
**Cadmium chloride $CdCl_2$	3	1	0	Toxic heavy metal. Carcinogen.
**Cadmium iodide CdI_2				
**Cadmium nitrate $Cd(NO_3)_2$				Known carcinogen. Moderately toxic by inhalation and ingestion. Fire and explosion risk. Strong oxidizer.
Caffeine $C_8H_{10}N_4O_2$				Very toxic; ingestion of as little as 65 mg can be life-threatening.
Calcium Ca	3	1	2 ~~W~~	Skin irritant. Contact with water or moisture evolves flammable hydrogen. Flammable in finely divided form. Avoid contact with oxidizers.
Calcium acetate $CaC_2H_6O_4$				
**Calcium carbide CaC_2	3	3	2 ~~W~~	Exposure to water or moisture evolves flammable acetylene gas; corrosive to eyes and skin. 500 grams of calcium carbide will yield approximately 150 litres of flammable acetylene.
Calcium carbonate (powder) $CaCO_3$				
Calcium chloride $CaCl_2$				Slightly toxic.
Calcium fluoride CaF_2				Slightly toxic. Skin irritant.
**Calcium hydride CaH_2			3 ~~W~~	Fire hazard. Water reactive.
Calcium hydroxide $Ca(OH)_2$				Skin irritant. Avoid dust inhalation.
Calcium hypochlorite (Bleaching powder) $Ca(OCl)_2$				Moderately toxic by ingestion and inhalation. Body tissue irritant. Fire risk in contact with organic substances. Oxidizer.
Calcium nitrate $Ca(NO_3)_2$				Slightly toxic. Potential fire risk in contact with organic material. May explode if shocked or heated. Strong oxidizer.
Calcium oxide CaO	3	0	1	Corrosive. Dangerous in contact with organic material. Exposure to water or moisture evolves heat. A lump of calcium oxide my disintegrate violently when water is added. Wear eye protection when handling this substance.
Calcium oxalate CaC_2O_4				
**Calcium phosphide Ca_3P_2				Emits poisonous, flammable phosphine gas when wet.
Calcium phosphate (monobasic) $Ca(H_2PO_4)_2$				
Calcium phosphate (tribasic) $Ca_3(PO_4)_2$				Body tissue irritant.
Calcium propionate $C_6H_{10}CaO_4$				
Calcium sulfate $CaSO_4$				
Calcium sulfide CaS				
Camphor $C_{10}H_{16}O$	0	2	0	Flammable and explosive vapours on heating.
Caprylic alcohol (n-octanol) $C_8H_{18}O$				
Carbamide (Urea) CH_4N_2O				

*** Should not be used in secondary school laboratories.*

Chemical Name and Formula	H	F	R	Comments
**Carbolic acid (Phenol) C_6H_6O	4	2	0	Toxic by ingestion, inhalation and skin absorption. Strong skin irritant. ****Special hazard alert:** Phenol in contact with more than approximately 100 inches square of skin is absorbed so quickly through intact skin as to be fatal in 90 seconds—unless promptly and completely washed off by scrubbing with a cloth under a copious quantity of flowing water. Drench affected area quickly and thoroughly.
Carbon C				
Carbon dioxide (gas) CO_2				Very damaging to skin and eyes in solid form (dry ice).
**Carbon disulfide CS_2	3	4	0	Moderately toxic by ingestion and inhalation. Dangerous fire and explosion risk (flash point 30°C). Can be ignited by friction. Vapour heavier than air and may travel at floor level—thus distant ignition is possible.
**Carbon tetrachloride CCl_4				Mutagen. Carcinogen.
Carmine				
Carnoy's fluid (alcohol + acetic acid)				Moderately toxic. Flammable liquid. Store in a dedicated flammables cabinet.
Caustic potash (Potassium hydroxide) KOH	3	0	1	Strongly corrosive as a solid and as a solution. Skin contact causes severe blisters. Extremely harmful to eyes. Very harmful if swallowed. Use gloves when handling.
Caustic soda (pellets) (Sodium hydroxide) NaOH				Corrosive solid. Skin burns are possible. Very harmful to eyes. Much heat evolves when added to water. Wear face and eye protection and gloves.
Cellulose methyl ether (Methyl cellulose)				
**Cesium Cs				
Cesium chloride CsCl				Slightly toxic by ingestion.
Cetyle alcohol				Slightly toxic by ingestion. Body tissue irritant.
Charcoal, wood (amorphous carbon) C				Flammable solid.
**Chlorine (gas) Cl_2	4	0	0 OX	
Chlorobenzene C_6H_5Cl				Emits poisonous, flammable phosphine gas when wet.
**Chloroethanol C_2H_5ClO	4	2	0	Toxic by skin absorption. Can produce acid gas. Flammable.
**Chloroform $CHCl_3$	2	0	0	Toxic and narcotic by inhalation. Prolonged inhalation may be fatal. Ingestion may be fatal. Suspected carcinogen.
**m-Chlorophenol C_6H_5ClO				Toxic by skin absorption.
**Chromic acetate $C_6H_9CrO_6$				Oxidizer.
**Chromic acid (Chromium trioxide) CrO_3	3	0	1 OX	Corrosive to skin. Highly toxic. Carcinogen as fume or dust. Practise strict hygiene when using this substance. Powerful oxidizing agent. Avoid contact with reducing agents and organic material.
Chromic chloride $CrCl_3$	3	3	0	
**Chromic nitrate $Cr(NO_3)_3$				
Chromium metal Cr				Known carcinogen as fume or dust.
Chromic potassium sulfate $CrK(SO_4)_2$				Body tissue irritant.
**Chromium trioxide (Chromic acid) CrO_3				Highly toxic. Corrosive to skin. Carcinogen as fume or dust. Practise strict hygiene when using this substance. Powerful oxidizing agent. Avoid contact with reducing agents and organic material.
**Chromous salts				Toxic.
Citric acid $C_6H_8O_7$				Extreme eye irritant.
Cobalt Co				Possible carcinogen as fume or dust.

*** Should not be used in secondary school laboratories.*

Chemical Name and Formula	H	F	R	Comments
Cobaltous carbonate $CoCO_3$				Moderately toxic. Cobalt compounds are possible carcinogens.
Cobaltous chloride $CoCl_2$				Moderately toxic by ingestion; causes blood damage. Possible carcinogen as fume or dust. Practise strict hygiene when using this substance.
Cobaltous nitrate $Co(NO_3)_2$				Moderately toxic. Possible carcinogen. Oxidizer. Fire risk in contact with organic material.
Cobaltous sulfate $CoSO_4$				Moderately toxic. Eye, skin, and respiratory irritant. Possible carcinogen.
**Colchicine $C_{22}H_{25}NO_6$				Highly toxic; ingestion of as little as 0.02 grams could be fatal.
**Collodion (solution of pyroxylin in alcohol and ether)				Body tissue irritant. Dangerous fire risk.
Congo red $C_{32}H_{22}N_6Na_2O_6S_2$				Mutagen. Moderate toxicity. Negative reproductive effects.
Copper Cu				
**Copper cyanide CuCN	4	0	0	Extremely poisonous. Releases poisonous gas when acidified even slightly.
Cream of tartar (Potassium bitartrate, Potassium hydrogen tartrate) $KHC_4H_4O_6$				
**Creosote				Carcinogen. Combustible.
Crystal violet (Gentian violet, Methyl violent) $C_{25}H_{30}N_3Cl$				Moderately toxic by ingestion. Body tissue irritant. Mutagen.
Cupric acetate $CuC_4H_6O_4$				Moderately toxic.
Cupric bromide $CuBr_2$				
Cupric carbonate (basic) $Cu_2(OH)_2CO_3$				Slightly toxic by ingestion and inhalation.
Cupric chloride $CuCl_2$				
Cupricnitrate $Cu(NO_3)_2$	1	0	0 OX	Moderately toxic. Oxidizing material. Dangerous in contact with organic material.
Cupricoxide CuO				
Cupric sulfate $CuSO_4$				
Cupric sulfide CuS				
Cuprous chloride CuCl				Toxic. Eye, skin, and respiratory tract irritant.
Cyclohexane C_6H_{12}	1	3	0	Slightly toxic by ingestion, inhalation, and skin contact. Dangerous fire risk; flammable liquid. Store in a dedicated flammables cabinet.
Cyclohexanol $C_6H_{12}O$	1	2	0	Slightly toxic by ingestion, inhalation, and skin absorption. Combustible. May form explosive peroxides; do not distill to dryness.
Cyclohexene C_6H_{10}	1	3	0	Slightly toxic by ingestion and inhalation. Flammable liquid; dangerous fire risk. May form explosive peroxides; do not distill to dryness. Store in a dedicated flammables cabinet. Strong, offensive odour.
Cysteine $C_3H_7NO_2S$				
Cystine $C_6H_{12}N_2O_4S_2$				
Dextrose (Glucose) $C_6H_{12}O_6$				
Diastase (amylolytic enzymes)				
p-Dibromo benzene $C_6H_4Br_2$	2	2	0	
p-Dichloro benzene $C_6H_4Cl_2$				Moderately toxic by ingestion. Severe eye, skin, and respiratory tract irritant. Possible carcinogen.

*** Should not be used in secondary school laboratories.*

Chemical Name and Formula	H	F	R	Comments
**Dichloro methane (Methylene chloride) CH_2Cl_2	2	1	0	Carcinogen. Mutagen. Readily absorbed through skin.
2,4 Dichloro phenoxy acetic acid (2,4D) $C_8H_6Cl_2O_3$				Toxic by ingestion. Severe eye irritant.
Dichloro tetra fluoroethane $CClF_2CClF_2$				
**Diethyl ether (Ethyl ether) $C_4H_{10}O$				Slightly toxic by inhalation. Absorbed by skin. Vapour harmful; use only under a hood or in a well-ventilated area. Possible carcinogen. Severe fire and explosion hazard. May form explosive peroxides upon concentration.
Dimethyl glyoxime $C_4H_8N_2O_2$				
**Dimethyl sulfate $(CH_3)_2SO_4$	4	2	0	
**3, 4 Dinitrophenol $C_6H_4N_2O_5$				
**1,4 Dioxane $C_4H_8O_2$	2	3	1	Slightly toxic by inhalation. Absorbed by skin. Possible carcinogen. Dangerous fire risk. May form explosive peroxides upon concentration.
Diphenylamine $C_{12}H_{11}N$	3	1	0	Moderately toxic by ingestion.
EDTA (ethylenedinitrilotetra acetic acid) $C_{10}H_{12}N_2Na_4O_8$ (Ethylene diamine tetra acetic acid, sodium salt)				
Eosin B $C_{20}H_6Br_2N_2Na_2O_9$				
Eosin Y $C_{20}H_6Br_4Na_2O_5$				
**Epinephrine (Adrenalin) $C_9H_{13}NO_3$				Toxic by ingestion. Increases blood pressure.
Eriochrome black T $C_{20}H_{12}N_3NaO_7S$				
Ethanol (Ethyl alcohol) C_2H_5OH	0	3	0	Dangerous fire risk; flammable. Addition of denaturant makes it poisonous – it cannot be made non-poisonous. Store in a dedicated flammables cabinet or safety cans.
Ethyl acetate $C_4H_8O_2$	1	3	0	Slightly toxic by inhalation, ingestion, and skin absorption. Skin and eye irritant. Dangerous fire hazard and explosion risk.
Ethyl alcohol (Ethanol) C_2H_5OH	0	3	0	Dangerous fire risk; flammable. Addition of denaturant makes it poisonous – it cannot be made non-poisonous. Store in a dedicated flammables cabinet or safety cans.
**Ethylamine C_2H_7N	3	4	0	
Ethyl bromide (Bromoethane) C_2H_5Br	2	1	0	Tumorigen. Mutagen. Limit exposure to vapour.
Ethyl butyrate $C_6H_{12}O_2$	0	3	0	
**Ethyl chloride C_2H_5Cl	2	4	2	Extremely flammable. Contact with water produces corrosive, toxic fumes.
**Ethyl ether (Diethyl ether) $C_4H_{10}O$	1	4	1	Slightly toxic by inhalation. Absorbed by skin. Possible carcinogen. Vapour harmful; use only under a hood or in a well-ventilated area. Severe fire and explosion hazard; may form explosive peroxides upon concentration.
Ethyl iodide (iodoethane) C_2H_5I				Mutagen.
Ethylene diamine $C_2H_8N_2$	3	2	0	Toxic. Irritant. Mutagen. Negative reproductive effects. Limit exposure to vapour.
Ethylene dichloride $C_2H_4Cl_2$	2	3	0	Moderately toxic by ingestion, inhalation, and skin absorption. Strong skin and eye irritant. Possible carcinogen. Dangerous fire risk; flammable.
Ethylene dinitrilotetra acetic acid (EDTA) $C_{10}H_{12}N_2Na_4O_8$ (ethylene diamine tetra acetic acid, sodium salt)				
Ethylene glycol $C_2H_6O_2$	1	1	0	Moderately toxic by ingestion, inhalation and skin absorption; ingestion of even small quantities can be lethal to some people.

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Note: *For Iron II compounds, see listings under ferrous compounds; for Iron III compounds, see listings under ferric compounds.*

Chemical Name and Formula	H	F	R	Comments
Fehling alkaline No. 1 copper sulfate + Fehling alkaline No. 2 alkalkine tartrate				
Ferric ammonium citrate				
Ferric ammonium sulfate $FeNH_4(SO_4)_2$				
Ferric chloride $FeCl_3$				Skin and tissue irritant. Corrosive. Slightly toxic by ingestion.
Ferric nitrate $Fe(NO_3)_3$				Skin and tissue irritant. Strong oxidizer.
Ferric oxide Fe_2O_3				
Ferric sulfate $Fe_2(SO_4)_3$				
Ferrous ammonium sulfate (Mohr's salt) $FeH_8N_2O_8S_2$				
Ferrous chloride $FeCl_2$				Slightly toxic by ingestion. Body tissue irritant.
Ferrous sulfate $FeSO_4$				Slightly toxic by ingestion.
Ferrous sulfide (Iron sulfide) FeS				Contact with acid liberates poisonous hydrogen sulfide gas.
**Fluorine F_2	4	0	3 OX ~~W~~	Extremely corrosive gas.
Formaldehyde (37% formaldehyde, methanol free) HCHO	3	2	0	Highly toxic by ingestion, inhalation and skin absorption. Strong irritant; avoid breathing vapour and avoid skin contact. Possible carcinogen. Use a fume hood.
Formalin (37% formaldehyde with 15% methanol) HCHO	3	2	0	Formaldehyde is an possible carcinogen. Avoid skin contact. Provide lots of ventilation.
Formic acid HCOOH	3	2	0	Corrosive to skin and tissue through ingestion and inhalation. Reacts violently with bases. On aging, decomposes to carbon monoxide and water thus creating potential explosive danger.
Freon (fluorocarbon products)				
Fructose $C_6H_{12}O_6$				
Fuchsin (acid) $C_{20}H_{17}N_3Na_2O_9S_3$				
Fumaric acid $C_4H_4O_4$				
Galactose $C_6H_{12}O_6$				
Gallium Ga				
Gentian violet (Crystal violet, Methyl violet) $C_{25}H_{30}N_3Cl$				Moderately toxic by ingestion. Body tissue irritant. Mutagen.
Germanium Ge				
Gibberellic acid $C_{19}H_{22}O_6$				
Glucose (dextrose) $C_6H_{12}O_6$				
Glutamic acid $C_5H_9NO_4$				
Glycerol (glycerine) $C_3H_8O_3$	1	1	0	Some people are allergic to glycerin and may experience irritation to their skin and eyes. Contact with strong oxidants (chromium trioxide, potassium chlorate, potassium permanganate) may cause an explosion.
Glycine $C_2H_5NO_2$	1	1	0	

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Chemical Name and Formula	H	F	R	Comments
Gold Au				
Graphite (plumbago) C				
n-Heptane C_7H_{16}	1	3	0	Slightly toxic by inhalation. Dangerous fire risk; flammable liquid.
n-Hexane C_6H_{14}	1	3	0	
1,6,-hexanediamine $C_6H_{16}N_2$				
Histidine HCl $C_6H_9N_3O_2$				
**Hydriodic acid HI	3	0	1	Toxic by inhalation. Corrosive.
Hydrochloric acid (11.6M, 36%) HCl				Highly toxic by ingestion or inhalation. Severely corrosive to skin and eyes.
**Hydrocyanic acid (Prussic acid, hydrogen cyanide) HCN	4	4	2	Extremely poisonous.
**Hydrofluoric acid HF				Extremely poisonous. Extremely corrosive to skin, eyes, and all other body tissue. Users must wear appropriate body, hand and face protection. THIS SUBSTANCE SHOULD NEVER BE USED IN THE CLASSROOM LABORATORY BY TEACHERS OR STUDENTS.
**Hydrogen gas H_2	0	4	0	Highly flammable gas; severe fire hazard.
**Hydrogen peroxide (30%, 50% solution) H_2O_2	2	0	1 OX	Extremely corrosive to skin, eyes, and respiratory tract. Many substances will cause hydrogen peroxide to decompose into water and oxygen gas. Wear appropriate protective clothing. Very strong oxidant. Dangerous fire and explosion risk. Do not heat this substance. Requires special handling and storage attention. DO NOT FREEZE.
Hydrogen peroxide (3%, 6% or 10%) H_2O_2				Very weak but is still a skin irritant and an oxidizer.
**Hydrogen sulfide H_2S	4	4	0	Toxic by ingestion or inhalation. Eye and respiratory tract irritant. Use adequate ventilation. Offensive odour. Solution may react with oxidants.
Hydroquinone $C_6H_6O_2$	2	1	0	Toxic by ingestion and inhalation. Corrosive to skin, eyes, and respiratory tract.
Indigo carmine $C_{16}H_8N_2Na_2O_8S_2$				Slightly toxic by ingestion. Body tissue irritant.
**Indium In				Extremely toxic.
3-Indoleacetic acid $C_{10}H_9NO_2$				
Iodine I_2				Toxic by ingestion or inhalation. Corrosive to eyes and respiratory tract. Inhalation of vapours or ingestion may be fatal. Skin irritant. Reacts violently with reducing materials, sulfur, iron, alkali metals, metal powders, and phosphorus.
Iodoethane (Ethyl iodide) C_2H_5I				Mutagen.
Iron Fe				
Iron sulfide (Ferrous sulfide) FeS				Contact with acid liberates poisonous hydrogen sulfide gas.
Iso-butyl alcohol (2 methyl, 1 propanol) $C_4H_{10}O$	1	3	0	Slightly toxic. Skin, eye, and respiratory irritant. Flammable.
Iso propyl alcohol (sec-Propyl alcohol) C_3H_8O	1	3	0	Slightly toxic by ingestion and inhalation. Moderate fire risk; flammable liquid.
Kerosine (kerosene)	0	2	0	Moderately toxic by ingestion, inhalation, and skin absorption. Moderate fire risk.
Kinetin $C_{10}H_9N_5O$				Mutagen.
Lactic acid $C_3H_6O_3$				Corrosive liquid. Corrosive to eyes. Skin and respiratory tract irritant.
Lactose $C_{12}H_{22}O_{11}$				

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Chemical Name and Formula	H	F	R	Comments
Lauric acid $C_{12}H_{24}O_2$				
Lead Pb				As a powder is extremely toxic by inhalation and ingestion. Possible carcinogen as fume or dust. Take all precautions when working with lead powder.
**Lead acetate $Pb(CH_3COO)_2$				Moderately toxic. Eye, skin, and respiratory irritant. Possible carcinogen.
**Lead arsenate $Pb_3(AsO_4)_2$	2	0	0	
**Lead carbonate (basic) $Pb(CO_3)_2Pb(OH)_2$				Moderately toxic by inhalation and ingestion. Skin, eye and respiratory tract irritant. Possible carcinogen.
**Lead chloride $PbCl_2$				
**Lead chromate $PbCrO_4$				
**Lead dioxide PbO_2				Moderately toxic by inhalation and ingestion. Severe body tissue irritant; avoid all body contact. Possible carcinogen.
Lead nitrate $Pb(NO_3)_2$				Moderately toxic by inhalation and ingestion. Body tissue irritant. Possible carcinogen. Strong oxidant. Dangerous fire risk in contact with organic material.
**Lead oxide (red) PbO				
**Lead oxide (yellow) (Litharge) PbO				Moderately toxic by ingestion and inhalation. Possible carcinogen.
**Lead sulfide PbS				Moderately toxic by ingestion and inhalation. Possible carcinogen.
Lime water $Ca(OH)_2$				
**Litharge (yellow) (Lead oxide) PbO				Moderately toxic by ingestion and inhalation. Possible carcinogen.
Lithium Li	3	2	2 W	Corrosive to skin, eyes and respiratory tract. Risk of explosion; flammable solid. Water-reactive. Use a Class D fire extinguisher or have a generous supply of dry sand to use as a fire extinguisher.
Lithium acetate $C_2H_3LiO_2$				
Lithium carbonate Li_2CO_3				Moderately toxic. Strong base when dissolved in water; corrosive to eyes and respiratory tract.
Lithium chloride LiCl				Moderately toxic by ingestion.
Lithium fluoride LiF				
Lithium hydroxide LiOH				Strong basic substance. Water solutions are strong irritants; corrosive to eyes, skin, and respiratory tract.
Lithium nitrate $LiNO_3$				Body tissue irritant. Strong oxidant. Risk of explosion when shocked or heated. Do not grind or pulverize.
Litmus, granular blue				
Lycopodium powder (vegetable sulfur)				Possible allergen. Highly flammable powder.
Magnesium Mg	0	1	1 W	Flammable solid. Burns with an intense flame. Keep either Class D fire extinguisher or dry sand available.
Magnesium bromide $MgBr_2$				
Magnesium carbonate $MgCO_3$				
Magnesium chloride $MgCl_2$				Slightly toxic by ingestion.
Magnesium hydroxide $Mg(OH)_2$				
Magnesium nitrate $Mg(NO_3)_2$	1	0	0 OX	Skin, eye, and respiratory tract irritant. Strong oxidant; fire and explosion risk in contact with organic material.
Magnesium oxide MgO				

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Chemical Name and Formula	H	F	R	Comments
**Magnesium peroxide (Magnesium dioxide) MgO_2				
Magnesium sulfate $MgSO_4$				Eye and respiratory tract irritant.
Malachite green (Benzaldehyde green) $C_{23}H_{25}ClN_2$				Carcinogen. Can make a huge mess!
Maleic acid $C_4H_4O_4$				Moderately toxic by ingestion. Severe body tissue irritant.
**Maleic anhydride $C_4H_2O_3$	3	1	1	
Malic acid $C_4H_6O_5$				
Maltose $C_{12}H_{22}O_{11}$				
Manganese Mn				Irritant as fume or dust. Dust is flammable.
Manganese carbonate $MnCO_3$				
Manganese dioxide MnO_2				Body tissue irritant. Strong oxidant. Avoid contact with organic material.
Manganese sulfate $MnSO_4$				
D-Mannose $C_6H_{12}O_6$				Body tissue irritant.
Marble chips (Calcium carbonate) $CaCO_3$				
Menthol $C_{10}H_{20}O$				Slightly toxic by ingestion and inhalation. Body tissue irritant. Severe eye irritant.
**Mercuric chloride $HgCl_2$				Highly toxic by ingestion, inhalation, and skin absorption. Exposure may be fatal! Use all precautions in handling this substance.
**Mercuric iodide HgI_2				Highly toxic by ingestion, inhalation, and skin absorption. Exposure may be fatal! Use all precautions in handling this substance.
**Mercuric nitrate $Hg(NO_3)_2$				Highly toxic by ingestion, inhalation, and skin absorption. Exposure may be fatal. Use all precautions in handling this substance. Fire risk in contact with organic materials. Strong oxidizer.
**Mercuric oxide (red, yellow) HgO				Highly toxic. Skin irritant. Avoid contact with organic material.
**Mercuric sulfate $HgSO_4$				Highly toxic. Skin, eye, and respiratory irritant.
**Mercuric sulfide (black, red) HgS				
**Mercurous chloride Hg_2Cl_2				
**Mercurous iodide Hg_2I_2				
**Mercurous nitrate $Hg_2(NO_3)_2$				
**Mercurous oxide Hg_2O				
Mercury Hg				Metallic mercury is highly toxic by skin absorption and by inhalation of vapour. Metallic mercury has a relatively low vapour pressure and vapourizes readily when heated. Continuous exposure to small concentrations of vapour is harmful. Frequent skin contact is harmful. Dispense and use mercury only under a hood or in a well-ventilated area. Dispense mercury in a plastic or glass tray so that any spillage can easily be recovered. KEEP ONLY SMALL QUANTITIES IN SCHOOLS AND STORE IN PLASTIC BOTTLES. **WARNING**: Students should not be permitted to amalgamate coins or jewellery with mercury.
Methanol (Methyl alcohol) CH_3OH	1	3	0	Toxic by ingestion (ingestion may cause blindness). Flammable; dangerous fire risk.
Methionine $C_5H_{11}NO_2S$				

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Chemical Name and Formula	H	F	R	Comments
Methyl alcohol (Methanol) CH_3OH	1	3	0	Toxic by ingestion (ingestion may cause blindness). Flammable; dangerous fire risk.
Methyl benzene (Toluene) C_7H_8	2	3	0	Hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation. Slightly hazardous in case of skin contact (permeator).
Methyl cellulose (Cellulose methyl ether)				
Methylene blue $C_{16}H_{18}ClN_3S$				Slightly toxic.
**Methylene chloride (Dichloro methane) CH_2Cl_2	2	1	0	Carcinogen. Mutagen. Readily absorbed through skin.
Methyl ethyl ketone (2-Butanone) C_4H_8O	1	3	0	Narcotic by inhalation. Flammable; dangerous fire risk.
Methyl glycol (1, 2 Propylene glycol) $C_3H_8O_2$				
Methyl orange (tropaeolin D) $C_{14}H_{14}N_3NaO_3S$				Highly toxic by ingestion.
2-methyl 1-propanol (Iso-butyl alcohol) $C_4H_{10}O$	1	3	0	Slightly toxic. Skin, eye, and respiratory irritant. Flammable.
Methyl red $C_{15}H_{15}N_3O_2$				Mutagen.
Methyl salicylate (Wintergreen oil) $C_8H_8O_3$	1	1	0	Moderately toxic by ingestion. Severe body tissue irritant.
Methyl violet (Crystal violet, Gentian violet) $C_{25}H_{30}N_3Cl$				Moderately toxic by ingestion. Body tissue irritant. Mutagen.
Methylene blue $C_{16}H_{18}ClN_3S$				Slightly toxic.
**Million reagent (solution of mercury – nitric acid – water)				A solution of mercury (II) nitrate in concentrated nitric acid. The combination of toxic mercury (II) nitrate and a corrosive acid and the fact that the solution is frequently boiled makes its use extremely hazardous.
Mohr's salt (Ammonium ferrous sulfate) $FeH_8N_2O_8S_2$				
Molybdenum Mo				
Naphthalene $C_{10}H_8$	2	2	0	Moderately toxic by ingestion, inhalation, and skin contact. Moderate fire hazard.
Nichrome				
Nickel Ni				
Nickel acetate $Ni(CH_3CO_2)_2$				
Nickel chloride $NiCl_2$				Highly toxic by ingestion and inhalation. Nickel compounds inhaled as dust are known carcinogens. Avoid dispersing this substance; dispense with care.
Nickel nitrate $Ni(NO_3)_2$				Slightly toxic. Nickel compounds inhaled as dust are known carcinogens. Avoid dispersing this substance; dispense with care. Strong oxidant.
**Nickel oxide NiO	2	0	0	Expected carcinogen, mutagen.
Nickel sulfate $NiSO_4$				Moderately toxic by ingestion and inhalation. Extreme body tissue irritant. Nickel compounds inhaled as dust are known carcinogens. Avoid dispersing this substance; dispense with care.
**Nicotine $C_{10}H_{14}N_2$	4	1	0	Poisonous. Extremely hazardous.
Ninhydrin $C_9H_6O_4$				Body tissue irritant. Common indicator.
Nitric acid (15.4 M, 69%) HNO_3	3	3	0 OX	Corrosive. Toxic by inhalation. Strong oxidant. Avoid contact with acetic acid and readily oxidized substances.
**Nitrobenzene $C_6H_5NO_2$	3	2	1	
Nitrogen, gas (liquified) N_2				

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Chemical Name and Formula	H	F	R	Comments
**Nitrogen dioxide (liquefied) NO_2	3	0	0 OX	
Octyl acetate $C_{10}H_{20}O_2$	2	2	0	
n-Octyl alcohol (1-octanol) (Caprylic alcohol) $C_8H_{18}O$	1	2	0	
Oleic acid $C_{18}H_{34}O_2$	0	1	0	
Orange IV (Troparolin OO) $C_{18}H_{14}N_3NaO_3S$				Hazardous in case of ingestion. Slightly hazardous in case of skin contact (irritant), of eye contact (irritant), of inhalation.
Oxalic acid $C_2H_2O_4$	3	1	0	Moderately toxic by ingestion. Skin and eye irritant. Avoid condensing.
Oxygen, gas O_2				
Palmitic acid $C_{16}H_{32}O_2$				
Paraffin (oil, wax) (solid hydrocarbons) C_nH_{2n+2}	0	1	0	
Paraformaldehyde	3	1	0	Severe skin and eye irritant.
**n-Pentane C_5H_{12}	1	4	0	Narcotic in high concentrations. Flammable liquid. Use hexane or heptane as a substitute.
Pentyl alcohol (n-Amyl alcohol) (1-2-3 pentanol) $C_5H_{11}OH$				Slightly toxic by ingestion and inhalation. Severe body tissue irritant. Moderate fire risk.
**Perchloric acid $HClO_4$	3	0	3 OX	Extreme explosion hazard. Requires special “wash-down” hoods. Reacts with metal duct work.
**Petroleum ether	1	4	0	Flammable liquid; extreme fire risk.
**Phenol (Carbolic acid) C_6H_6O	4	2	0	Toxic by ingestion, inhalation and skin absorption. Strong skin irritant. ****Special hazard alert:** Phenol in contact with more than approximately 100 inches square of skin is absorbed so quickly through intact skin as to be fatal in 90 seconds—unless promptly and completely washed off by scrubbing with a cloth under a copious quantity of flowing water. Drench affected area quickly and thoroughly.
Phenolphthalein $C_{20}H_{14}O_4$				
Phenol red (phenolsulfonephthalein) $C_{19}H_{14}O_5S$				
Phenylalanine $C_9H_{11}NO_2$				
Phenylhydrazine $C_6H_8N_2$	3	2	0	Mutagen. Negative reproductive effects. Limit exposure to vapour.
Phenyl salicylate $C_{13}H_{10}O_3$				Slightly toxic by ingestion.
**Phenylthiocarbamide (PTC paper)				Highly toxic by ingestion.
Phosphoric acid (14.6M, 85%) H_3PO_4	3	0	0	Slightly toxic by ingestion and inhalation. Corrosive to body tissue. Skin and eye irritant.
Phosphoric anhydride (Phosphorus pentoxide) P_2O_5			3 ~~W~~	Moderately toxic. Extremely corrosive. Reacts violently with water.
**Phosphorus, amorphous (red) P	1	1	1	Moderately toxic. Skin contact may cause burns. Flammable solid. Yields very toxic fumes on burning. Avoid contact with potassium chlorate or potassium permanganate or other strong oxidizing agents; explosions have been known to occur. Dangerous fire risk.
**Phosphorus, purified (yellow) P	4	4	2	
Phosphorus pentoxide (Phosphoric anhydride) P_2O_5			3 ~~W~~	Moderately toxic. Extremely corrosive. Reacts violently with water.
**Phosphorus trichloride PCl_3	4	0	2 ~~W~~	Reacts with water.

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Chemical Name and Formula	H	F	R	Comments
Phtalic acid $C_8H_6O_4$	0	1	1	
P-Hydrion paper (indicator paper)				
**Picric acid $C_6H_3N_3O_7$	3	4	4	Poisonous. Corrosive liquid possibly absorbed through the skin. If allowed to dry, the solid is a powerful explosive. Extremely dangerous.
Platinum Pt				
**Potassium K	3	1	2 ~~W~~	Extremely dangerous on contact with moisture and water; releases hydrogen with sufficient heat to cause ignition or explosion; may ignite spontaneously in air or oxygen; can cause severe skin or eye burns. Shipped under dry oil (no water) and must be stored that way. Keep away from water and handle with dry utensils. ****Special hazard alert:** Exterior surface of potassium metal is extremely prone to formation of peroxides, which will burn and melt when exposed to air. When the metal is cut into small pieces, it has been known to react explosively with the light oil (kerosene) in which the metal is stored. Be sure to provide personal protection when dealing with this very reactive metal. SUBSTITUTE WITH LITHIUM OR SODIUM, which do not develop peroxides on aging.
Potassium acetate CH_3COOK				
Potassium bicarbonate (Potassium hydrogen carbonate) $KHCO_3$				
**Potassium bichromate (Potassium dichromate) K_2Cr_2O7				Toxic by ingestion and inhalation. Corrosive to body tissue. Known carcinogen. Strong oxidant. Fire risk when in contact with organic material.
Potassium bisulfate (Potassium hydrogen sulfate) $KHSO_4$				Slightly toxic by ingestion. Extreme body tissue irritant.
Potassium bisulfide (Potassium hydrogen sulfide) KHS				
Potassium bitartrate (Potassium hydrogen tartrate, Cream of tartar) $KHC_4H_4O_6$				
Potassium binoxalate (Potassium hydrogen oxalate) KHC_2O_4				
Potassium bromate $KBrO_3$	1	0	0 OX	Moderately toxic. Strong irritant. Fire risk in contact with organic material. Oxidizer.
Potassium bromide KBr				Slightly toxic by ingestion. Severe body tissue irritant.
Potassium carbonate K_2CO_3				Slightly toxic by ingestion. Body tissue irritant.
**Potassium chlorate $KClO_3$	2	0	0 OX	Slightly toxic. Irritant. Strong oxidizer. Extremely dangerous: if only slightly contaminated, will explode when exposed to moderate shock or when heated. Frequently a source of accidents on school premises. Incompatible substances that should be avoided: ammonium salts, carbon, combustible material, finely divided materials, sulfur, phosphorus, sulfuric acid, metal powders, sugar.
Potassium chloride KCl				Slightly toxic by ingestion.
**Potassium chromate K_2CrO_4				Highly toxic. Harmful to skin, eyes and respiratory tract. Corrosive to skin and mucous membranes. Known carcinogen. Chromates as a chemical family require special safety attention.
**Potassium cyanide KCN	4	0	0	Extremely toxic. Releases poisonous gas when acidified even slightly.
**Potassium dichromate (Potassium bichromate) $K_2Cr_2O_7$				Toxic by ingestion and inhalation. Corrosive to body tissue. Known carcinogen. Strong oxidant. Fire risk when in contact with organic material.
Potassium ferricyanide $K_3Fe(CN)_6$				
Potassium ferrocyanide $K_4Fe(CN)_6$				Slightly toxic by ingestion. Dangerous if heated or if in contact with concentrated acids, since hydrogen cyanide gas may evolve.

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Chemical Name and Formula	H	F	R	Comments
Potassium hydrogen carbonate (Potassium bicarbonate) $KHCO_3$				
Potassium hydrogen oxalate (Potassium binoxalate) KHC_2O_4				Moderately toxic by ingestion.
Potassium hydrogen phthalate $KH_5C_8O_4$				
Potassium hydrogen sulfide (Potassium bisulfide) KHS				
Potassium hydrogen tartrate (Potassium bitartrate, Cream of tartar) $KHC_4H_4O_6$				
Potassium hydroxide, pellets (Caustic potash) KOH	3	0	1	Skin contact causes severe blisters. Strongly corrosive as a solid and as a solution. Very harmful if swallowed. Extremely harmful to eyes. Use gloves when handling.
Potassium iodate KIO_3				Moderately toxic. Body tissue irritant. Oxidizer.
Potassium iodide KI				
Potassium manganate K_2MnO_4				
Potassium nitrate KNO_3	1	0	0 OX	Skin irritant. Strong oxidant. Fire and explosion risk when heated or in contact with organic material.
Potassium nitrite KNO_2				Highly toxic. Skin irritant. Strong oxidant. Fire and explosion risk when heated or in contact with organic material.
Potassium oxalate $K_2C_2O_4$				
**Potassium perchlorate $ClKO_4$	1	0	1	Severe irritant. Powerful oxidizer. Reactivity hazard.
Potassium permanganate $KMnO_4$	1	0	0 OX	Slightly toxic by ingestion. Strong skin irritant. Common cause of eye accidents; wear face protection. Powerful oxidizing agent. Can explode on sudden heating. Use extreme care and store separately from organics.
**Potassium peroxide K_2O_2	3	0	1	Strong oxidizer. Water-reactive.
Potassium phosphate (monobasic) KH_2PO_4				
Potassium phosphate (tribasic) K_3PO_4				Slightly toxic. Severe body tissue irritant.
Potassium sodium tartrate (Rochelle salt) $KNaC_4H_4O_6$				
Potassium sulfate K_2SO_4				
Potassium sulfide K_2S	2	1	0	
Potassium sulfite K_2SO_3				
Potassium thiocyanate KSCN				Moderately toxic by ingestion. Emits toxic cyanide fumes if strongly heated or in contact with concentrated acids.
Proline $C_5H_9NO_3$				
n-Propanol (n-Propyl alcohol) C_3H_8O	2	3	2	Harmful to eyes and respiratory tract. Flammable liquid; high fire risk.
Propionic acid $C_3H_6O_2$	3	2	0	Liquid burns skin and eyes. Flammable liquid (flash point 54°C).
n-Propyl alcohol (n-Propanol) C_3H_8O	1	3	0	Harmful to eyes and respiratory tract. Flammable liquid; high fire risk.
sec-Propyl alcohol (Iso propyl alcohol) C_3H_8O	1	3	0	Slightly toxic by ingestion and inhalation. Moderate fire risk; flammable liquid.

*** Should not be used in secondary school laboratories.*

Chemical Name and Formula	H	F	R	Comments
1, 2 Propylene glycol (Methyl glycol) $C_3H_8O_2$	0	1	0	
**Prussic acid (Hydrocyanic acid or Hydrogen cyanide) HCN	4	4	2	Highly toxic.
**PTC paper (Phenylthiocarbamide, phenylthiourea) $C_7H_8N_2S$				PTC is highly toxic, but it has been calculated that each test strip contains less than 0.3 mg of PTC, far below the toxicity level.
**Pyridine C_5H_5N	3	3	0	Toxic by ingestion, inhalation, and skin absorption. Harmful to skin and eyes. Avoid prolonged exposure. Flammable liquid (flash point 20°C).
Pyrogallol $C_6H_6O_3$				Toxic. Readily absorbed through the skin. Harmful to eyes and lungs. Stains skin.
Quinaldine red $C_{21}H_{23}IN_2$				Mild irritant. Mutagen.
Quinine sulfate (quinine acid) $C_{40}H_{50}N_4O_8S$				Moderately toxic by ingestion. Skin irritant.
Resorcinol $C_6H_6O_2$	–	1	0	Toxic. Readily absorbed through skin. Skin and eye irritant.
Rhodanine $C_3H_3NOS_2$				Eye irritant.
Rochelle salt (Potassium sodium tartrate) $KNaC_4H_4O_6$				
Safranin (40% alcohol-based solution)				Mutagen. Vapours may be flammable.
Salicylic acid $C_7H_6O_3$	0	1	0	
Sand (Silicon dioxide, silica, quarz) SiO_2				
Selenium Se				Severe irritant.
Selenium + compounds Se (+ Se salts)				Toxic. Tumorigenic.
Serine $C_3H_7NO_3$				
Silicic acid (hydrated silica) H_2SiO_3				
Silicon Si				Flammable in powder form.
Silicon dioxide (silica, quartz, Sand) SiO_2				
Silver Ag				
Silver acetate $AgC_2H_3O_2$				
Silver bromide AgBr				
Silver chloride AgCl				
Silver nitrate $AgNO_3$	1	0	0 OX	Highly toxic. Corrosive solid; causes burns. Avoid contact with eyes and skin. Stains skin and clothing.
Silver oxide Ag_2O				Slightly toxic. Fire risk in contact with organic material or ammonia.
Silver sulfate Ag_2SO_4				
Soda lime CaO + NaOH				Corrosive solid; skin burns are possible. Very harmful to eyes. Much heat is evolved when added to water.

*** Should not be used in secondary school laboratories.*

Chemical Name and Formula	H	F	R	Comments
Sodium Na	3	3	2 ~~W~~	Flammable, corrosive solid. Spontaneously flammable when heated in air. Reacts violently with water, producing very dangerous hydrogen gas and a solution of corrosive sodium hydroxide. Dangerous when exposed to heat or flame. Dangerous when reacting with moist air, water, or any oxidizer. USE CAUTION WHEN HANDLING.
Sodium acetate $NaC_2H_3O_2$				Skin, eye, and respiratory irritant.
**Sodium arsenite $NaAsO_2$				Highly toxic by ingestion and inhalation. Possible carcinogen.
Sodium bicarbonate (Sodium hydrogen carbonate, Baking soda) $NaHCO_3$				
Sodium bisulfate (Sodium hydrogen sulfate) $NaHSO_4$				Moderately toxic. Body tissue irritant.
Sodium bisulfite (Sodium hydrogen sulfite) $NaHSO_3$				Slightly toxic. Severe irritant to skin and tissue as an aqueous solution.
Sodium borate (Borax, Sodium tetraborate) $Na_2B_4O_7$				Slightly toxic by inhalation and ingestion.
**Sodium bromate $NaBrO_3$				Toxic by ingestion. Skin irritant. Powerful oxidizing agent. Avoid contact with organic material.
Sodium bromide NaBr				Slightly toxic by ingestion or inhalation.
Sodium carbonate Na_2CO_3				May be skin irritant.
**Sodium chlorate $NaClO_3$				Slightly toxic. Dangerous fire risk. Strong oxidant; contact with organic material may cause fire.
Sodium chloride NaCl				
**Sodium chromate Na_2CrO_4				Highly toxic by ingestion, inhalation and skin absorption. Known carcinogen. Oxidizer.
Sodium citrate $Na_3C_6H_5O_7$				
**Sodium cyanide NaCN	4	0	0	Highly toxic. Releases poisonous gas when acidified even slightly.
**Sodium dichromate $Na_2Cr_2O_7$				Highly toxic. Corrosive to skin. Harmful to eyes and respiratory tract. Known carcinogen as dust. Strong oxidizer.
Sodium fluoride NaF	3	0	0	Highly toxic by ingestion and inhalation. Strong skin irritant.
Sodium hydrogen carbonate (Sodium bicarbonate, Baking soda) $NaHCO_3$				
Sodium hydrogen sulfate (Sodium bisulfate) Na_2HSO_4				Moderately toxic. Body tissue irritant.
Sodium hydrogen sulfite (Sodium bisulfite) $NaHSO_4$				Slightly toxic. Severe irritant to skin and tissue as an aqueous solution.
Sodium hydroxide, pellets (Caustic soda) NaOH	3	0	1	Corrosive solid; skin burns are possible. Very harmful to eyes. Much heat evolves when added to water. Wear face and eye protection and gloves.
Sodium hypochlorite (Bleach) NaOCl				Moderately toxic by ingestion and inhalation. Corrosive liquid; causes skin burns. Reacts with acid to evolve chlorine gas. Evolves chlorine when heated. Avoid contact with organic material.
Sodium iodate $NaIO_3$				Slightly toxic by ingestion. Oxidant. Fire risk on contact with organic material.
Sodium iodide NaI				Slightly toxic.
Sodium metabisulfite $Na_2S_2O_5$				Slightly toxic by ingestion. Skin and tissue irritant.
Sodium metasilicate Na_2SiO_3				Slightly toxic by ingestion. Body tissue irritant.
Sodium nitrate $NaNO_3$	1	0	0 OX	Moderately toxic by ingestion. Strong oxidizer. Avoid friction or shock – explosions have occurred.

*** Should not be used in secondary school laboratories.*

Chemical Name and Formula	H	F	R	Comments
Sodium nitrite $NaNO_2$				Highly toxic by ingestion and inhalation. Strong oxidizer. Fire and explosion risk if heated.
Sodium oxalate $Na_2C_2O_4$				Moderately toxic by ingestion. Body tissue irritant.
**Sodium perchlorate $NaClO_4$	2	0	1	Severe irritant. Powerful oxidizer. Reactivity hazard.
**Sodium peroxide Na_2O_2	3	0	1 OX	Moderately toxic. Corrosive to body tissue. Serious explosion/fire risk. Avoid contact with water, alcohol, acids, powdered metals, and all organic materials. Strong oxidizing agent. Keep dry.
Sodium phosphate (mono basic) NaH_2PO_4				
Sodium phosphate (tri basic) Na_3PO_4				Slightly toxic by ingestion. Severe body tissue irritant.
Sodium propionate $C_3H_5NaO_2$				
Sodium silicate (water glass) Na_2SiO_3				
Sodium sulfate Na_2SO_4				
Sodium sulfide Na_2S	3	1	1	Moderately toxic. Corrosive to body tissue. Dangerous fire and explosion risk. Flammable solid. Liberates toxic hydrogen sulfide on contact with acids.
Sodium sulphite Na_2SO_3				Moderately toxic. Possible body tissue irritant.
Sodium tetraborate (Sodium borate, Borax) $Na_2B_4O_7$				Slightly toxic by inhalation and ingestion.
**Sodium thiocyanide NaSCN	2	0	0	Highly toxic by ingestion. Contact with acid liberates toxic gas.
Sodium thiosulfate $Na_2S_2O_3$				Slightly toxic by ingestion. Body tissue irritant.
Stannic chloride $SnCl_4$	3	0	1	Moderately toxic by inhalation. Contact with warm, moist air produces hydrochloric acid. Fumes produced are severely irritating to eyes, skin, and respiratory tract.
Stannic oxide SnO_2				
Stannous chloride $SnCl_2$				Moderately toxic. Corrosive to body tissue.
Stannous oxide SnO				
Stannous sulfate $SnSO_4$				
Stearic acid $C_{18}H_{36}O_2$	1	1	0	
**Strontium Sr				Extremely reactive metal.
Strontium chloride $SrCl_2$				
Strontium nitrate $Sr(NO_3)_2$				Slightly toxic. Possible body tissue irritant. Strong oxidant. Fire risk in contact with organic material.
Styrene C_8H_8	2	3	2	
Succinic acid $C_4H_6O_4$				Slightly toxic by ingestion.
Sucrose $C_{12}H_{22}O_{11}$				
Sudan III $C_{22}H_{16}N_4O$				
**Sudan IV $C_{24}H_{20}N_4O$				Irritant. Suspected carcinogen and mutagen.
Sulfamic acid H_3NO_3S				Slightly toxic by ingestion. Corrosive to body tissues. Severe eye irritant.

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Chemical Name and Formula	H	F	R	Comments
Sulfur S	2	1	0	Low toxicity. May be skin irritant. Finely divided form of sulfur can be a moderate fire or explosion risk. When burned, toxic sulfur dioxide is produced.
Sulfuric acid (17.8M:95%) H_2SO_4	3	0	2 ~~W~~	Severely corrosive to eyes, skin, and other tissue. Even very dilute solutions are harmful to eyes and skin. Considerable heat produced from dilution with water; may cause spraying and spattering. Solutions best made by immersing the mixing vessel in an ice bath. Always add the acid to water, never the reverse. Extremely hazardous when coming into contact with finely divided materials, carbides, chlorates, nitrates, and other combustible materials.
Sulfur dioxide SO_2	3	0	0	Poisonous gas at high concentration levels. Corrosive to eyes and skin.
Tannic acid $C_{76}H_{52}O_6$	0	1	0	Slightly toxic by ingestion and inhalation. Possible allergen.
Tartaric acid $C_4H_6O_6$	0	1	0	
**Tetrabromoethane $C_2H_2Br_4$	3	1	1	Toxic by inhalation, ingestion, and skin absorption.
**Thallium Tl				Toxic metal.
Thioacetamide C_2H_5NS				Moderately toxic by ingestion and inhalation. Possible carcinogen.
**Thorium Th				Radioactive.
Thymol blue $C_{27}H_{30}O_5S$				Mutagen.
Thymolphthalein $C_{28}H_{30}O_4$				
Tin Sn				
Titanium Ti				
Titanium dioxide TiO_2				
**Titanium tetrachloride $TiCl_4$	3	0	2	Reacts with water.
Toluene (Methyl benzene) C_7H_8	2	3	0	Hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation. Slightly hazardous in case of skin contact (permeator).
Trichloroethane $C_2H_3Cl_3$				
Tryptophan $C_{11}H_{12}N_2O_2$				
Tungsten W				
Tungstic acid H_2WO_4				
Turpentine $C_{10}H_{16}$	1	3	0	Slightly toxic. Skin and mucous membrane irritant.
Tyrosine $C_9H_{11}NO_3$				
Universal indicator (alcohol-based solution)				Flammable liquid.
**Uranium compounds (soluble and insoluble) U + U salts				Radioactive.
Urea (Carbamide) CH_4N_2O				
Urethane $C_3H_7NO_2$				Slightly toxic by ingestion. Possible carcinogen. Combustible.
Valine $C_5H_{11}NO_2$				
Vanadium V				

*** Should not be used in secondary school laboratories.*

Chemical Name and Formula	H	F	R	Comments
Vitamin C (Ascorbic acid) $C_6H_8O_6$				
Water glass (Sodium silicate)				Body tissue irritant.
Wintergreen oil (Methyl salicylate) $C_8H_8O_3$	1	1	0	Moderately toxic by ingestion. Severe body tissue irritant.
Xylene C_8H_{10}	2	3	0	Slightly toxic by ingestion and inhalation. Avoid skin contact. Flammable liquid; moderate fire risk.
Zinc Zn	0	1	1	
Zinc acetate $ZnC_4H_6O_4$				Moderately toxic by ingestion. Possible body tissue irritant.
Zinc carbonate $ZnCO_3$				
Zinc chloride $ZnCl_2$				Moderately toxic. Both solid and solutions are severe skin irritants.
Zinc nitrate $Zn(NO_3)_2$	1	0	3	Slightly toxic by ingestion and inhalation. Corrosive to body tissues. Avoid all body tissue contact. Strong oxidizer. Fire risk when in contact with combustible materials.
Zinc oxide ZnO	1	0	0	If heated, fumes can be highly toxic. May react vigorously with some forms of rubber at elevated temperatures.
Zinc sulfate $ZnSO_4$				Slightly toxic. Skin and mucous membrane irritant.
Zinc sulfide ZnS				Contact with acid liberates toxic and flammable hydrogen sulfide gas.
Zirconium Zr				

*** Should not be used in secondary school laboratories.*

Chemical Labelling Requirements

Workplace Hazardous Materials Information System (WHMIS)

The Workplace Hazardous Materials Information System (WHMIS) was created in response to Canadian workers' right to know about the safety and health hazards that may be associated with the materials or chemicals they use at work. WHMIS is mandated under federal law. In British Columbia, the Workers' Compensation Act and Occupational Health and Safety Regulation, Part 5, apply to workers and employers.

Exposure to hazardous materials can cause or contribute to many serious health effects, such as damage to the nervous system, kidney or lung damage, sterility, cancer, burns, and rashes. Some hazardous materials are safety hazards and can cause fires or explosions. WHMIS was created to reduce the number of injuries, illnesses, and deaths, and the resulting medical costs, caused by hazardous materials. It is a comprehensive plan for providing information on the safe use of hazardous materials in Canadian workplaces.

Information is provided by means of:

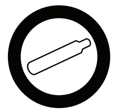
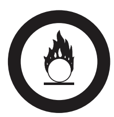
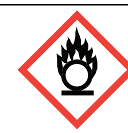
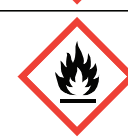
- bilingual product labels providing basic hazard information in a specific format
- material safety data sheets (MSDS) containing more detailed technical information, and
- worker education programs

WHMIS has incorporated the Globally Harmonized System of Classification and Labelling (GHS) for chemicals and aligned these with the classifications used by the United States and other Canadian trading partners. WHMIS is currently in a three-stage transition period between two hazard communication standards, WHMIS 1988 and WHMIS 2015. The table on pages 45–46 provides the WHMIS 1988 symbols and the new WHMIS 2015 symbols to support the transition to the new classification standard. School districts and teachers are encouraged to learn more about the WHMIS transition and how to remain compliant with new WHMIS requirements.

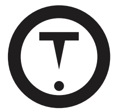
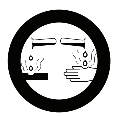
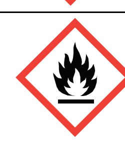
More information about this transition can be found on the Health Canada website: www.hc-sc.gc.ca/ewh-semt/occup-travail/whmis-simdut/index-eng.php

All teachers who teach science should be formally trained in WHMIS and have an official WHMIS certificate.

The WHMIS Symbols

WHMIS 1988			WHMIS 2015		
Class/ Division	**Description**	**Symbol**	**Class/ Division**	**Description**	**Symbol**
Class A – Compressed Gas	Contents under high pressure. Cylinder may explode or burst when heated, dropped or damaged.		**Compressed Gas**	Gases under pressure	
Class B – Flammable and Combustible Material	May catch fire when exposed to heat, spark or flame. May burst into flames.		**Flammable material**	Flammable gases, liquids, solids and aerosols	
				Pyrophoric gases, liquids and solids	
				Chemicals which, in contact with water, emit flammable gases	
				Self-heating liquids/solids (other than pyrophoric)	
Class C – Oxidizing Material	May cause fire or explosion when in contact with wood, fuels or other combustible material.		**Oxidizing liquids, solids and gases**		
			Organic Peroxide	Type A	
				Type B	 
				Types C–F	
				Type G	No labelling
Class D, Division 1 Poisonous and Infectious Material: Immediate and serious toxic effects	Poisonous substance. A single exposure may be fatal or cause serious or permanent damage to health.		**Acute Toxicity (oral/dermal/ inhalation**	Fatal or Toxic	
				Harmful	

The WHMIS Symbols (continued)

WHMIS 1988			WHMIS 2015		
Class/ Division	**Description**	**Symbol**	**Class/ Division**	**Description**	**Symbol**
Class D, Division 2 Poisonous and Infectious Material: Biohazardous infectious materials	Poisonous substance. May cause irritation. Repeated exposure may cause cancer, birth defects, or other permanent damage		**Other health effects (severe and/or chronic)**	Aspiration; carcinogens, mutagens, reproductive toxins; respiratory sensitizer; STOT SE/RE	
Class D, Division 3 Poisonous and Infectious Material: Biohazardous infectious materials	May cause disease or serious illness. Drastic exposures may result in death.		**Other health effects (less severe)**	Skin/eye/respiratory irritant; skin sensitizer; narcotic effects	
Class E – Corrosive Material	Can cause burns to eyes, skin or respiratory system.		**Corrosive material**	Corrosive to metals Skin corrosion/burns Eye damage	
Class F – Dangerously Reactive Material	May react violently causing explosion, fire or release of toxic gases, when exposed to light, heat, vibration or extreme temperatures.		**Self-reactive chemicals**	Type A	
				Type B	 
				Type C–F	
			Simple asphyxiants and combustible dusts		No symbol
			Health hazards not otherwise classified (HHNOC)		Any applicable WHMIS 2015 symbol

Materials not covered by WHMIS

When WHMIS was created, it was recognized that a lot of safety information was already being transmitted to workers for many of these products under other laws. To prevent delay in starting WHMIS, exclusions were made.

Nine basic categories of materials are *not* covered by WHMIS:

- consumer-restricted products (those products sold to people in regular stores that are already labelled following the rules of the Hazardous Products Act)
- explosives (as defined by the Explosives Act)
- cosmetics, drugs, food, or devices (as defined by the Food and Drug Act)
- pest control products (pesticides, herbicides, insecticides, etc., as defined by the Pest Control Products Act)
- radioactive materials (as defined by the Atomic Energy Control Act)
- wood and products made of wood
- manufactured articles
- tobacco or products made of tobacco
- hazardous wastes

The three major components of WHMIS

There are three major components of WHMIS:

1. Labels
2. Material safety data sheets (MSDS)
3. Education and training

1. Labels

Labels on chemicals from laboratory supply houses that are packaged in quantities of less than 10 kg must disclose the following information in both English and French:

- chemical name
- where a material safety data sheet (MSDS) is available
- any hazards of the chemical
- the supplier identification (including address and telephone number)
- precautionary measures to be followed for safe use
- where appropriate, first aid measures in case of exposure

If chemicals are removed and transferred to another container, the transfer container must be labelled clearly with enough information to enable the safe handling of the material. In the laboratory, samples in amounts of less than 100 mL in volume that are used in-house require only a product identifier.

A **supplier label** must:

- appear on all controlled products received at workplaces in Canada
- contain the following information:
  - product identifier (name of product)
  - supplier identifier (name of company that sold it)
  - a statement that an MSDS is available
  - hazard symbols (the pictures of the classification(s))
  - risk phrases (words that describe the main hazards of the product)
  - precautionary measures (how to work with the product safely)

  - first aid measures (what to do in an emergency)
  - text in English and French
  - the WHMIS hatched border

Supplier labels for materials from a laboratory supply house that are intended for use in a laboratory in amounts of less than 10 kg and any controlled product sold in a container of less than 100 mL may contain less information than listed above.

If the product is always used in the container with the supplier label, no other label is required (unless the supplier label falls off or becomes unreadable). However, if some of the material is placed in another container for use in the workplace, the new container requires a workplace label.

A **workplace label**:

- must appear on all controlled products produced in a workplace or transferred to other containers by the employer
- may appear in placard form on controlled products received in bulk from a supplier
- must have the following information:
  - product identifier (product name)
  - information for the safe handling of the product
  - statement that a MSDS is available
- may contain the WHMIS hazard symbols or other pictograms

These are the minimum requirements for workplace labels. The employer may wish to put more information on the labels, but it is not required under the law.

Laboratory chemicals from a recognized supply house may carry less information on the label (e.g., WHMIS symbols, distinctively marked border, and the supplier identifier).

All chemical containers, including the original container, must be labelled in such a way as to identify the contents clearly.

Inside the laboratory, small transfer containers and reaction vessels containing mixtures, solutions, or reaction products must have a clear identifier, usually the chemical name.

2. Material Safety Data Sheets (MSDS)

A material safety data sheet (MSDS) is a document that contains information on the potential health effects of exposure and how to work safely with the chemical product.

The MSDS is prepared by the supplier and contains much more information about the material than the label. It is intended to describe the hazards of the product, how to use the product safely, what to expect if the recommendations are not followed, what to do if accidents occur, how to recognize symptoms of overexposure, and what to do if such incidents occur.

Employers must make sure that all controlled products have an up-to-date (less than three years old) MSDS when it enters the workplace. The MSDS must be readily available to workers who are exposed to the controlled product and to the workplace health and safety committee or representative. If a controlled product is made in the workplace, the employer has a duty to make a MSDS for any of these products.

In Canada, every material that is controlled by WHMIS (Workplace Hazardous Materials Information System) must have an accompanying MSDS that is specific to each individual product or material (both the product name and supplier on the MSDS must match the material in use). Therefore, **all chemicals in stock in schools must have a MSDS**.

Teachers and students should be familiar with the type of information contained in a MSDS. WHMIS legislation does not require a standard format for the layout of a MSDS. MSDSs may look very different and information items may be located in different sections.

3. Education and training

WHMIS is a system of information delivery to workers.

- Employers must ensure that their employees are informed about the hazards of any controlled products they may work with.
- Employers are responsible for worker education and training within WHMIS.
- Schools are responsible for developing safe work procedures using knowledge of the job, information from the labels, and MSDSs.
- All science teachers should be properly trained to use the information to protect themselves and their students.
- It is the responsibility of all teachers to adhere to safe working procedures and the responsibility of principals to insist that they are followed.
- Science teachers have a responsibility to educate their students in aspects of WHMIS.
- Training programs must include all controlled products in use, including those which have been exempted from the federal WHMIS requirements of supplier label and MSDS.

A good basic introduction to WHMIS can be found in WorkSafeBC's *WHMIS: The Basics* (www.worksafebc.com/publications/health_and_safety/whmis/assets/pdf/whmis_basics.pdf).

Chemical Storage

A system to safely store and maintain an up-to-date inventory of all chemicals held in a school is essential for safety. An active inventory of biological, chemical, or physical agents stored and/or handled, as well as any tools, equipment, machines, or devices, must be maintained. Hazard information, or material safety data sheets (MSDS), must be readily available for any chemical or biological substance that could cause an adverse health effect.

Suggestions for chemical storage and organization

- Compile an inventory list with an MSDS for each chemical. The MSDS can be no more than three years old.
- All containers of chemicals should bear both a purchase date and an expiry date.
- Use a WHMIS-approved labelling system to segregate all chemicals into classes to make it easy to access and replace them in their proper storage position.
- Evaluate each chemical individually to determine where and how it should be stored.

- Organize chemicals into their compatible chemical families. The actual sequence of compatible families on the shelves is not critical. What is important is to keep the compatible families separate and to keep the organic and inorganic families as far apart as possible.
- As a general rule, segregate flammable/combustible liquids, toxic chemicals, explosive chemicals, oxidizing agents, corrosives, water-sensitive chemicals, and compressed gases.
- Avoid storing chemicals on the floor, even temporarily.
- Do not store chemicals above eye level (i.e., no top-shelf chemical storage).
- Store acids in an acid cabinet. Store nitric acid in the acid cabinet **only** if isolated from organic acids. Store "mineral" acids (HNO_3, H_3PO_4, H_2SO_4, HCl, HBr) in the same cabinet, but place each acid in a plastic tub to contain the liquid in case of bottle failure. Organic acids such as acetic acid, formic acid, and salicylic acid can be stored together and often with other organics, provided that ventilation is adequate. Never store organic acids with nitric and sulphuric acids. Perchloric acid should never be used.
- Store alkaline solutions in corrosion-resistant plastic trays as close to the floor as possible and away from acids.
- Store flammables in a dedicated flammables cabinet.
- Store extreme poisons in a dedicated poisons cabinet.
- **Never** store explosives in schools.
- Restrict the number of compressed gas cylinders stored in laboratories to those in daily use. Compressed gas cylinders of all sizes must be kept upright and fully secured against falling. Valve caps must be kept on all cylinders that are not being used.
- Before using compressed gas cylinders, check all fittings and regulators for defects, leaks, oil, and grease. Bulk storage of cylinders should be in a well-ventilated area, segregated from flammable and corrosive materials.
- Separate flammable gases from oxidizing gases using non-combustible partitions.
- Protect cylinders from excessive variations in temperature, sources of ignition, and direct contact with the ground.
- In laboratories, do not store chemicals other than dilute reagents on the open working bench or the shelving above it.

Suggestions for a chemical storage room

- A chemical storage room must be secure. This will prevent theft and unwarranted use of chemical stock. A key that is separate from those used to enter classrooms or preparation areas is essential. Only authorized, trained personnel should have access to the chemical storage room.
- An effective ventilation system is needed. The room itself must be adequately vented (5.0 $L/s/m^2$ floor area) with a fan that is allowed to run continuously.
- Explosion-proof lights, switches, and fan motor housing must be installed in order to prevent fires from electrical shorts or sparks in faulty switches. Ground fault interrupter (GFI) circuits should be installed, especially near sinks. The fan and the light switches should be outside the door.
- The ceiling and walls should be gyproc or some similar non-combustible material.
- Shelf assemblies should be firmly secured to walls. Avoid island shelf assemblies. Provide anti-roll-off lips on all shelves.

- Ideally, shelving assemblies should be of wood construction. Avoid metal adjustable shelf supports and clips; fixed wooden supports are a better option.

Alternatives to a separate chemical storage room

While a separate room is preferable for chemical storage, the principles of safe chemical storage can be maintained without a separate room. If a science preparation room is used as the chemical storage room:

- Prevent the accumulation of harmful vapours by adequately and continuously venting to the exterior with an exhaust fan.
- Equip the room with a properly vented flammables cabinet to house all solvents and flammable materials.
- Store acid and basic (alkaline) solutions separately in closed and vented cabinets.
- Keep toxic chemicals (poisons) in a separate locked cupboard.
- Keep oxidizers and reducers on separate shelves as far from each other as possible.
- Store hydrolyzing (water reactive) solids in a separate area.
- Store general miscellaneous chemicals alphabetically if they are compatible.

This is a challenging system to adequately maintain. Good housekeeping can be a problem when chemical storage is not housed in a separate room.

Note: When a science preparation room is used as a chemical storage room, it must not be used as a general teacher preparation area/working station (i.e., teachers should not be present in the room other than when dealing with chemicals).

Chemical stock and minimizing chemical waste

The quantities of chemical stock ordered from year to year and the cost of chemical disposal can be a major problem. The over-ordering of chemicals can waste limited science department budget money.

Before purchasing a chemical, ask:

1. What are the hazards and dangers associated with the chemical? How could this chemical cause injury to me or my students?
2. Is the chemical commonly used in a school setting?
3. What is the educational value of using the chemical? If it is only used for one lab per year, it may not be as valuable or as good a purchase as a chemical that can be used in multiple labs.
4. Is my lab space properly equipped for safe use and storage of the chemical?
5. Do I know how to use the chemical safely?
6. How will I dispose of the chemical after use or expiry? What will disposal cost?

Suggestions for reducing chemical quantities and disposal

- Do not order more chemical stock for your school than you will use in a 12-month period.
- Maintain an up-to-date inventory of your chemicals.
- Purchase chemicals carefully:
  - Purchase smaller-sized packages of chemicals – only what is needed for up to 12 months.

  - If you need only a dilute solution, buy the solution and not a large bottle of the solid.
  - Remember that buying chemicals in bulk to save a few dollars ends up costing more in disposal costs.
- Date and label your chemicals and buy only from chemical supply companies that date-label their chemicals.
- Date chemicals when the container is opened.
- Use older chemicals first, before they decompose.
- Provide good climate control for the chemical storeroom.
- Prepare only enough solution for immediate use, and always label.
- Never store chemicals or solutions in containers not designed for chemical storage.
- Store hygroscopic and deliquescent chemicals in proper containers.
- Use good laboratory practices.
- Never accept donations of chemicals.
- Purchase chemical demonstration kits or chemistry student kits that contain exact quantities of chemicals.
- Dispose of waste chemicals immediately after they are generated.
- Keep waste solutions separate.
- Consider doing micro-scale labs. Students can see the same results, but only a fraction of the amount of chemicals are used, saving money and reducing the amount of waste to be disposed of.

Incompatible Chemicals

There are many chemicals that should not be combined in a lab situation because of unpredictable or dangerous reactions that may occur.

Incompatible Chemicals	
Chemical	**Reagent**
Acetic acid	Chromic acid, ethylene glycol, hydroxyl-containing compounds, nitric acid, perchloric acid, permanganates, and peroxides.
Acetone	Bromine, chlorine, nitric acid, and sulfuric acid.
Acetylene	Bromine, chlorine, copper, mercury, and silver.
Alkaline and alkaline earth metals, such as calcium, cesium, lithium, magnesium, potassium, and sodium	Carbon dioxide, chlorinated hydrocarbons, and water.
Aluminum and its alloys (particularly powders)	Acid or alkaline solutions, ammonium persulphate and water, chlorates, chlorinated compounds, nitrates, and organic compounds in nitrate/nitrite salt baths.
Ammonia (anhydrous)	Bromine, calcium hypochlorite, chlorine, hydrofluoric acid, iodine, mercury, and silver.
Ammonium nitrate	Acids, chlorates, chlorides, lead, metallic nitrates, metal powders, finely divided organics or combustibles, sulfur, and zinc.
Ammonium perchlorate, permanganate, or persulfate	Combustible materials; oxidizing materials such as acid, chlorates, and nitrates.
Aniline	Hydrogen peroxide or nitric acid.
Barium peroxide	Combustible organics, oxidizable materials, and water.
Barium rhodanide	Sodium nitrate.
Bismuth and its alloys	Perchloric acid.
Bromine	Acetone, acetylene, ammonia, benzene, butadiene, butane and other petroleum gases, hydrogen, finely divided metals, sodium carbide, and turpentine.
Calcium or sodium carbide	Moisture (in air) or water.
Calcium hypochlorite	(Activated) ammonia or carbon.
Chlorates or perchlorates	Acids, aluminum, ammonium salts, cyanides, phosphorous, metal powders, oxidizable organics or other combustibles, sugar, sulfides, and sulfur.
Chlorine	Acetone, acetylene, ammonia, benzene, butadiene, butane and other petroleum gases, hydrogen, metal powders, sodium carbide, and turpentine.
Chlorine dioxide	Ammonia, hydrogen sulfide, methane, and phosphine.
Chromic acid	Acetic acid (glacial), acetic anhydride, alcohols, combustible materials, flammable liquids, glycerine, napthalene, nitric acid, sulphur, and turpentine.
Cumene hydroperoxide	Acids (mineral or organic).
Cyanides	Acids or alkalies.
Fluorine	Most materials.
Hydrocarbons, such as benzene, butane, gasoline, propane, and turpentine	Bromine, chlorine, chromic acid, fluorine, hydrogen peroxide, and sodium peroxide.
Hydrocyanic acid or hydrogen cyanide	Alkalies and nitric acid.
Hydrofluoric acid or anhydrous hydrogen fluoride	Ammonia (anhydrous or aqueous).
Hydrogen peroxide 3‰	Chromium, copper, iron, and most metals or their salts.
Hydrogen peroxide 30‰ or 90‰	Same as 3‰ hydrogen peroxide plus aniline, any flammable liquids, combustible materials, nitromethane, and all other organic matter.
Hydrogen sulfide	Fuming nitric acid or oxidizing gases.
Iodine	Acetylene, ammonia (anhydrous or aqueous), and hydrogen.
Lithium	Acids, moisture in air, and water.

Incompatible Chemicals (continued)	
Chemical	**Reagent**
Lithium aluminum hydride	Air, chlorinated hydrocarbons, carbon dioxide, ethyl acetate, and water.
Magnesium (particularly powder)	Carbonates, chlorates, heavy metal oxalates or oxides, nitrates, perchlorates, peroxides, phosphates, and sulfates.
Mercuric oxide	Sulfur.
Mercury	Acetylene, alkali metals, ammonia, nitric acid with ethanol, and oxalic acid.
Nitrates	Combustible materials, esters, phosphorous, sodium acetate, stannous chloride, water, and zinc powder.
Nitric acid (concentrate)	Acetic acid, aniline, chromic acid, flammable gases and liquids, hydrocyanic acid, hydrogen sulfide, and nitratable substances.
Nitric acid	Alcohols and other oxidizable organic material, hydriodic acid (hydrogen iodide), magnesium or other metals, phosphorous, and thiophene.
Nitrites	Potassium or sodium cyanide.
Nitro paraffins	Inorganic alkalies.
Oxalic acid	Mercury or silver.
Oxygen (liquid or enriched air)	Flammable gases, liquids, or solids, such as acetone, acetylene, grease, hydrogen, oils, and phosphorous.
Perchloric acid	Acetic anhydride, alcohols, bismuth and its alloys, grease, oils or any organic materials, and reducing agents.
Peroxides (organic)	Acids (mineral or organic).
Phosphorous	Chlorates and perchlorates, nitrates, and nitric acid.
Phosphorous pentoxide	Organic compounds or water.
Phosphorous (red)	Oxidizing materials.
Phosphorous (white)	Air (oxygen) or other oxidizing materials.
Potassium	Air (moisture and/or oxygen) or water.
Potassium chlorate or perchlorate	Acids or their vapours, combustible materials, especially organic solvents, phosphorous, and sulfur.
Potassium permanganate	Benzaldehyde, ethylene glycol, glycerin, and sulfuric acid.
Silver	Acetylene, ammonium compounds, nitric acid with ethanol, oxalic acid, and tartaric acid.
Sodium amide	Air (moisture and oxygen) or water.
Sodium chlorate	Acids, ammonium salts, oxidizable materials, and sulfur.
Sodium hydrosulfite	Air (moisture) or combustible materials.
Sodium nitrite	Ammonia compounds, ammonium nitrate, or other ammonium salts.
Sodium peroxide	Acetic acid (glacial), acetic anhydride, alcohols, benzaldehyde, carbon disulfide, ethyl acetate, ethylene glycol, furfural, glycerine, methyl acetate, and other oxidizable substances.
Sulfur	Any oxidizing materials.
Sulfuric acid	Chlorates, perchlorates, and perchlorates, and permanganates.
Water	Acetyl chloride, alkaline and alkaline earth metals and their hydrides and oxides, barium peroxide, carbides, chromic acid, phosphorous oxychloride, phosphorous pentachloride, phosphorous pentoxide, sulfuric acid, sulfur trioxide, etc.
Zinc (particular powder)	Acids or water.
Zinc chlorate	Acids or organic materials.
Zirconium (particularly in powder form)	Carbon tetrachloride and other halogenated hydrocarbons, peroxides, sodium bicarbonate, and water.

Chemical and Biological Lab Waste Disposal

Disposal of chemical waste

The disposal of waste chemicals and potentially hazardous materials is necessarily a common occurrence in school science laboratories. Management of chemical and biological wastes is everyone's responsibility. Failure to appropriately dispose of chemical and biological materials risks harm to people and the environment and could lead to prosecution if the appropriate procedures are not followed.

Disposal of these materials is subject to a number of federal, provincial, and municipal regulations. This manual cannot provide specific detailed information for the disposal of all materials. Science teachers must be fully acquainted with the properties and method of safe handling of all substances being used in the laboratory and must have access to the appropriate material safety data sheets (MSDS). The information can be accessed on the internet or by contacting the manufacturer of the material.

Please follow your school district policies and procedures when disposing of chemical waste. You may also consult reference books and the internet for the correct disposal practices for specific chemical and biological materials.

Disposal of biological materials
(animal tissues, tissue culture, and microbial waste)

Biological wastes may contain infectious agents and should be treated as biohazardous waste.

- **Autoclaving** – Autoclaving of potentially infectious waste is the preferred method of rendering tissue culture and microbiological waste non-infectious prior to disposal. Autoclave used petri dishes and cultures in autoclavable disposable bags before disposal in a landfill site. Autoclave liquid cultures and pour down a drain with large amounts of water.
- **Incineration** – If the waste contains dangerous materials that are likely to be evolved by heating in the autoclave, such as phenol, formaldehyde, or radio-iodine, it must not be autoclaved. Instead, the waste must be treated with a chemical such as bleach to render it non-infectious. Ideally, the materials should be incinerated in an appropriate incinerator.
- **Landfill** – If autoclaving and incineration are not possible, carcasses and animal remains should be placed in heavy opaque biohazard plastic bags, well sealed, and sent to the local landfill. Dispose of syringes, needles, scalpels, and razor blades in a labelled metal or thick plastic container.

Cleaning Up Spills

Spills are a frequent occurrence in science classrooms/labs. The teacher's first priority is to ensure that no students have been injured by the material spilled and then to clean up the spill immediately.

Students should be encouraged to report spills and breakages, so that they can be cleaned up immediately. Refer to material safety data sheets for directions.

Spill kits

The items suggested below will enable teachers to deal with the most common spills of acids, alkaline solutions, flammable solvents, and mercury. However, commercial spill kits are more convenient to use and are recommended.

Suggested spill kit items:

- Vermiculite (6 kg) and activated charcoal (1 kg) mixture
- Bentonite or kitty litter (10 kg)
- Sodium bicarbonate (baking soda) or sodium carbonate (soda ash) (3–4 kg of dry solid)
- Weak acid (boric or citric) (liquid or solid – 2 kg)
- Plastic aspirator bottle (250 mL capacity)
- Various sizes of freezer bags with ties
- Dustpan and whisk broom
- Labels and tape
- Metal containers for flammable wastes
- Large plastic scoop
- Plastic buckets
- Protective gloves
- Mask with organic cartridge to cover nose and mouth
- Heavy-duty apron
- Full eye protection
- Floor cloths (old rags)
- Paper towels
- Rubber boots
- Spill control pillows – Commercial spill control pillows can be used to absorb spills of hazardous chemicals. Applied directly, they will absorb and contain most spills within 30 seconds. The pillows contain an inert inorganic absorbent that is safe to use on flammable liquids, concentrated acids, and bases. Spill control pillows are available to handle spills of varying sizes (e.g., 250 mL; 1.0 L and 4.0 L).

Spill clean-up tips

Spill Clean-up Tips	
Spillage of	**Procedure**
Corrosive liquids (acids and bases)	• Neutralize acids. Test with indicator paper after bubbling has stopped. • Neutralize bases with boric or citric acid. Test with indicator paper. • Scrape or sweep up the residue that remains after all reaction has stopped. Discard down the sink drain with an excess of water. • Wash the spill area with water and wipe dry with paper towels.
Flammable liquids	• Shut off all sources of ignition. • Cover the spill with mineral absorbent (e.g., cat litter or vermiculite). • Scoop the contaminated absorbent into a heavy-gauge polythene bag or plastic bucket and arrange for disposal. • Mop the area of the spill or wipe with a damp disposable cloth. • Open windows to ventilate the room.
Other liquids (except mercury)	• For water-soluble liquids – dilute and mop up using paper towels or cloths. • For water immiscible liquids – cover the spill with mineral absorbent (e.g., cat litter) to prevent spreading. Then scrape and mop into a suitable container for disposal. (Only very small bench spills should be treated by swabbing into a sink, followed by flushing with large volumes of water.) • Wash down the spill area with water and wipe dry with paper towels. • Place any contaminated cloths and/or mops in a suitable container for disposal.
Large spills	• For large spills of poisonous, corrosive, or reactive materials, evacuate the lab, notify the administration, and seek immediate assistance from the Provincial Emergency Program (PEP) at 1-800-663-3456.
Mercury spills	• Immediate and thorough clean-up is imperative. • Provide maximum ventilation through doors and windows. • Never sweep with a broom or use a vacuum. • Wear gloves and cover shoes with plastic bags. • Push pools of mercury together. • Pick up pools with a dropper pipette. Transfer droplets to a seamless polyethylene or polypropylene bottle. Store mercury under a layer of water or oil and cover securely. • Good ventilation must be continued.
Solids	• Sweep up with a brush into a dustpan, taking care to avoid raising dust. If the substance is a highly reactive solid, such as an alkali metal, gathered using tongs. • Wipe the area with a damp disposable cloth. • Determine appropriate disposal procedures. • Place any clean broken glass in the glass disposal container.

5 Lab Hazards

There are many potential hazards in a school science lab. This section provides details on some of these hazards and how to avoid some of the associated risks. The hazards that will be examined are:

- corrosive chemicals
- reactive chemicals
- insidious hazards
- toxic hazards
- biological hazards
- radiation hazards
- carcinogens
- mechanical and electrical hazards
- fires

5.1 Corrosive Chemicals

The most familiar corrosive chemicals encountered in laboratories are the acids and bases. Corrosive chemicals are substances that are injurious to body tissues or corrosive to metals by direct chemical contact. A corrosive injury may be just a minor irritation or actual physical destruction of body tissue. Corrosive chemicals can be of any phase (gas, liquid, or solid).

How are corrosive chemicals hazardous?

The action of these substances on body tissues is through:

- direct contact with skin
- contact with eyes
- inhalation
- ingestion

The tissues of the body are affected by:

- direct chemical reaction
- dissolution of essential components
- destruction of protein
- disruption of cell membranes

Corrosive materials also pose a hazard through the dangerous gases produced when they react with other materials. For example, nitric acid will react with copper to produce nitrogen dioxide.

Corrosive liquids

Perhaps the most important category is the liquid corrosive. The most typical corrosive liquids encountered in school laboratories are the acids (hydrochloric, sulphuric, nitric, and acetic) and the bases (sodium hydroxide, potassium hydroxide, and ammonium hydroxide).

The acids act on body proteins, causing denaturation and destruction of the protein structure. The denatured protein produces a protein barrier that will limit the activity of the acid (although this is very painful). However, bases penetrate deeply with little or no pain and no protein barrier produced. Bases can cause greater skin or eye damage than acids because the protein barrier formed by acids is not formed by bases.

Corrosive solids

The effects of corrosive solids are related to their solubility in skin moisture and also the duration of contact. Examples of corrosive solids are:

- alkali metal hydroxides (e.g., NaOH)
- alkali metal carbonates (e.g., Na_2CO_3)
- alkali metal sulphides (e.g., Na_2S)
- alkaline earth hydroxides (e.g., $Ca(OH)_2$)
- elemental alkali metals (e.g., Na)
- trisodium phosphate
- chromium salts

Corrosive solids pose hazards by:

- being readily absorbed through the skin (solutions of corrosive solids)
- causing delayed injury (corrosive alkalis may not produce immediately painful reactions)
- being inhaled as dust
- being in a liquid and a molten solid form (e.g., phenols) that greatly increases the threat of exposure

It is a mistake to think of corrosive solids as being relatively harmless because they can be removed more easily than liquids. In fact, solid corrosives are usually rapidly dissolved by the moisture in the skin and even more rapidly dissolved by moisture in the respiratory and alimentary systems.

Corrosive gases

Perhaps the most serious hazard associated with corrosives is from substances in the gas phase. A common corrosive gas found in high school labs is ammonia. Corrosive gases enter the body by absorption through the skin and by inhalation. The corrosive gases are grouped by solubility and effect on the respiratory system.

The harmful effect of a corrosive gas is not directly related to the concentration and exposure duration. Furthermore, there are primary effects that can produce severe immediate damage, and even death, without causing systemic injuries.

Corrosive substances may react with another material to give off corrosive, toxic, and flammable gases, and may react to produce other hazardous substances. For example:

- **Halogens** will support combustion. They may ignite powdered metals (on contact) and react violently with organic substances.

- **Hydrochloric acid** can liberate gases such as hydrogen and hydrogen cyanide, and with formaldehyde produces chloromethoxychloromethane, a very potent carcinogen.
- Nitric acid can oxidize cellulose material, creating a self-igniting condition. Extremely exothermic when mixed with organic materials.
- Sulphuric acid is a powerful oxidizer. It can dehydrate organic material rapidly with the production of heat.

Personal precautionary measures with corrosive chemicals

It is important to:

- use adequate protective equipment (safety screen, lab coat, safety goggles/face shield, and gloves)
- use adequate respiratory protection (fume hood, gas mask)
- have adequate exhaust ventilation where corrosive hazards are present
- have plenty of water available for flushing, including eyewash
- have plenty of sodium bicarbonate available for neutralizing liquid corrosive spills
- obtain immediate medical attention on accidental contact
- store corrosive chemicals properly

Protection

In all cases where a procedure involves a corrosive chemical, wear protective goggles. If corrosive gases or solids are involved where dusting may occur, use the fume hood.

Note: The use of contact lenses in some laboratory environments can pose a danger to the eyes and/or the lenses. Contact lenses should not be worn where water-soluble gases, vapours, dusts, or other material may be released into the atmosphere.

Accident procedures

- In the event of contact with eyes, the first few seconds after contact are critical. Immediately flush eyes with water and continue to flush for 15 minutes. (If contact lenses are worn, remove them first.) Immediate flushing of the eyes may prevent permanent damage. An eyewash fountain is preferred; however, an eyewash hose or any other source of water should be used in an emergency. Remember, the one and only emergency treatment is to dilute the chemical immediately by complete flushing with water. The patient's eyelids may have to be forced open, so that the eyes may be flushed. Alkali (base) burns are usually more serious than acid burns.
- Strong chemicals burn the skin rapidly. There is no time to waste. Begin flushing the area with water immediately. Carefully remove and discard clothing, including socks and shoes. Continue to flood the area while clothing is being removed.
- Should corrosive chemicals come in contact with eyes or skin, seek medical attention.
- Consult the precautionary warning on the product label for full first aid information. Provide the label information to the attending physician.
- Neutralizers and solvents (alcohol, etc.) should not be used by the first aid attendant.

5.2 Reactive Chemicals

Frequently, accidents occur in laboratories simply because the effects of a particular chemical combination have not been anticipated. This is not uncommon, even among highly experienced chemists.

The mishandling of reactive chemicals is a well-known problem in all types of science laboratories. The literature contains many cases of explosions, fires, burns, and other bodily injuries that have been caused by improper and careless handling of reactive chemicals. Problems can occur not only while the reactive chemicals are being used, but also as a result of improper storage, record keeping, and labelling.

The frequency and severity of accidents involving reactive chemicals can be minimized through use of the information on chemical reactions and incompatible chemicals supplied in this manual or by reputable sources on the Internet.

Types of reactive chemicals

Reactive chemicals can be referred to as substances that will, under certain conditions, enter into violent reactions, with spontaneous generation of large quantities of heat, light, gas, or toxicants. The types of reactive chemicals can be classified as follows:

- **Explosives** are substances that will decompose with such speed as to cause rapid expansion of air, sometimes accompanied by burning gases and flying objects. Some substances can become unstable over time as they are oxidized by atmospheric oxygen. If there is any doubt about the stability of a substance, the container should not be moved; immediately clear the area and contact the local bomb squad.
- **Acid-sensitive chemicals** react with acids to release heat, hydrogen, explosive gases, and toxicants.
- **Water-sensitive chemicals** react with water to evolve heat and/or flammable or explosive gases.
- **Oxidation-reduction reactions** can occur in any phase. The reactions tend to generate heat and are often explosive.
- **Pyrophoric substances** burn when exposed to air.

Reactive Type	Examples	Specific Hazards	Precautionary Steps
Explosives – should not be stocked in schools	**Fulminates **Nitroglycerin **Peroxides (benzoyl, sodium) **Picric acid **Azides **Perchlorates (Na, K) **Hydrazines **Dioxane **Ether (not petroleum ether)	• Flying objects from explosion • Detonate easily • Can explode from shock, friction, or heat • Instability • Can form peroxides	Protect from shock, high temperature, sudden temperature changes, other reactive substances.
Acid-sensitive substances	Alkalai metals Alkaline hydroxides Carbonates **Carbides Nitrides Metals Sulphides **Cyanides	• Liberation of heat, flammable gases, and toxicants	Isolate from reactive substances. Wear and use adequate protection.
Water-sensitive substances	Strong acids and bases Acid anhydrides Alkalai metal hydrides **Carbides Aluminum chloride (anhydrous)	• Heat generation • Hydrogen generation • Ignition in moist air; can cause explosions • Can form acetylene or methane • Spontaneously decomposes on long storage and can explode on opening container	Isolate from other reactive substances. Store in cool, waterproof area. Wear protective gear.
Oxidation-reduction	Oxidizers Oxygen Mineral acid **Perchlorates **Peroxides (H_2O_2 excepted) Nitrites and nitrates Chromates and dichromates Permanganates Halogens **Chlorates Reducers **Hydrogen **Phosphorous Alkalai metals Metallic hydrides Formaldehyde	• All generate heat and can be explosive	Isolate from each other and other potentially reactive substances. Use adequate protection.
Special organic substances	** Acrolein ** Benzene	• Flammable and may also polymerize violently • Explodes with many oxidants	Store in an airtight container in a cool place. Isolate from oxidants.
Pyrophoric substances	**Phosphorous (white or yellow)	• Initiation of fire	Protect from air.

*** Should not be used in school chemistry labs.*

Examples of potentially explosive compounds

The following compounds are materials that may readily detonate or decompose or react explosively at normal temperatures and pressures, or that are sensitive to mechanical or localized thermal shock:

Acetyl peroxide (25% solution in dimethyl phathalate)
Ammonium perchlorate
3-bromopopane (propargyl bromide)
tert-Butyl hydroperoxide
tert-Butyl perbenzoate
tert-Butyl peroxyacetate (75% solution in benzene)
tert-Butyl peroxypivalate (75% solution in mineral spirits)
1-chloro-2,4 dinitrobenzene
Cumene hydroperoxide
Diacetyl peroxide
Dibenzoyl peroxide
tert-Dibutyl peroxide
Diethyl peroxide
Diisopropyl peroxydicarbonate
o-dinitrobenzene
Ethyl methyl ketone peroxide
Ethyl nitrate
Nitroglycerine
Nitromethane
2-nitro-p-toluidine
Peroxyacetic acid (diluted with 60% acetic acid solution)
Picric acid
Trinitrotoluene
Trinitrobenzene

All of these compounds and any other potentially explosive compounds must be treated with extreme caution, and adequate safety equipment must be used.

Examples of compounds that can form explosive conditions on peroxide formation

The following compounds can form explosive peroxides during storage and should be tested for peroxide formation before use and at least once every three months after opening:

Divinyl acetylene
Isopropyl ether
Potassium metal
Sodium amide
Vinylidene chloride

The following compounds can produce explosive peroxide conditions on concentration (e.g., during distillation or evaporation on storage). They should be tested for peroxide formation before use and at least once every 12 months after opening:

Acetal
Cyclohexene
Diacetylene
Dicyclopentadiene
Diethylene glycol dimethyl ether (diglyme)
Diethyl ether
Dioxane
Ethylene glycol dimethyl ether (glyme)
Methyl acetylene
Tetrahydrofuran
Tetrahydronaphthalene (tetralin)
Vinyl ethers

The following compounds can initiate explosive polymerization on peroxide formation. They should be tested for peroxide formation at least once every 12 months after opening, and a suitable peroxide inhibitor should be added before distillation:

Acrylic acid
Acrylonitrile
Butadiene
Chloroprene
Chlorotrifluoroethylene
Methyl methacrylate
Styrene
Tetrafluoroethylene
Vinyl acetate
Vinyl acetylene
Vinyl chloride
Vinylidene chloride
Vinyl pyridine

Specific precautionary measures

Note: Peroxide formation in laboratory solvents and reagents to explosive levels has caused many laboratory accidents. Peroxide inhibitors are usually included in compounds that readily form explosive peroxides, but may not be sufficient to control peroxide formation once the container has been opened.

- Inspect and test peroxide-forming compounds for peroxides regularly after the container is first opened, and maintain records of the tests.
- Dispose of compounds contaminated with peroxide materials using safe work procedures, or treat chemically to eliminate the peroxides.
- Store all peroxidizable compounds away from heat and light and protect from physical damage and ignition sources.
- There are several methods for the detection of peroxides. The simplest method is to dip a starch iodide paper strip into the solvent to be tested. If it turns purple, peroxides are present. If the solution to be tested has been stored past the expiry date, disposal is preferable to testing. **Never open a container containing peroxidizable liquid if visible solid is present**.

Cryogenic liquids

Cryogenic liquids are gases at normal temperatures; they are kept in their liquid state at very low temperatures.

Specific precautionary measures

- Containers used for storage, transport, and dispensing of cryogenic liquids must be designed for that purpose.
- Indoor dispensing stations and storage locations for cryogenic liquids must be adequately ventilated and monitored to prevent the development of harmful atmospheres.
- Dispensing stations and freezers with automatic filling cycles for cryogenic liquids must be posted with a sign identifying the materials, the hazards, and the precautions required.

General precautionary measures

Use the following guidelines when dealing with reactive substances:

- Isolate reactive substances.
- Have plenty of water available for flushing (where water-sensitive substances are not involved).
- Do not have water (extinguishers, sprinklers, etc.) in areas where water-sensitive chemicals are stored.
- Store substances in a well-ventilated, cool, dry area and protect from sunlight.
- Label substances properly, including the date they were received and opened.
- Protect substances from shock.
- Keep substances away from flammables.
- When handling substances, wear adequate protective equipment.
- Order only what you will use during the year. Do not overstock.
- Regularly discard old chemicals according to proper disposal procedures.
- Work on as small a scale as is practical. (Hazards are much less severe on a small scale.)

5.3 Insidious Hazards

Insidious hazards are conditions within the laboratory that present potential health hazards and, because they are not usually conspicuous (seen, tasted, smelled, or felt), are easily overlooked and ignored. However, they may cause local or systemic, acute, or chronic effects, depending on the nature of the substance and duration of exposure. In addition, insidious hazards represent a type of problem that one may never be aware of until chronic, systemic poisoning has occurred.

All too often, insidious or hidden hazards are overlooked during routine safety inspections. Substances such as mercury, present in small droplets on a floor, can emit toxic vapour over a long period of time. Explosive perchlorates can form in fume hoods and ventilation systems. Shock-sensitive azide salts form in copper drain pipes that are exposed to **sodium azide solutions. Improperly sealed containers of toxic liquids, such as carbon tetrachloride, and leaking cylinders of toxic gases can poison the air. In fact, defective safety devices represent a category of insidious hazards.

***** Should not be used in high school laboratories.***

The Mercury hazard

One of the most common insidious hazards – not only in laboratories but also in homes – is mercury. Mercury is widely used in such various items as electric switches, amalgams, boilers, barometers, thermometers, lamps, and cells. Mercury compounds are also common reagents found on laboratory stock shelves. Because of its widespread use, the hazardous nature of mercury may be overlooked or ignored, even when its hazards are understood. It may be common practice to aspirate or sweep up any visible drops after an accident involving mercury, but many small droplets may be hidden in small cracks and crevices where they are left to evaporate into the atmosphere.

- Mercury is capable of forming explosive compounds, such as mercury fulminate.
- Its maximum permissible concentration (PC) is 0.05 mg/m^3 averaged over an eight-hour exposure.
- Its accumulated effect works on the gastrointestinal and central nervous system.
- One mL of mercury can increase the mercury level in millions of cubic metres of air to above the permitted concentration.

Control of Mercury hazards

With proper controls and training, mercury can be safely used in a laboratory setting. In the school laboratory, specific consideration should be given to following:

- Store mercury in plastic bottles.
- Store mercury under a layer of water or oil.
- Keep containers sealed in a cool, well-ventilated area.
- Provide catch-trays beneath set-ups using mercury.
- Use care in handling mercury and instruments containing mercury.
- Use gloves when handling mercury.
- Clean up spills immediately and thoroughly.
- A commercial spill kit for mercury, properly used, is highly recommended. This includes the control of mercury vapours (aspirator, mercury absorbent, vapour absorbent).
- Organic-filled thermometers are recommended over mercury thermometers.

Mercury droplets (10–1000 micrometres in diameter) adhere to vertical surfaces and penetrate porous flooring. Large amounts of mercury can be left undiscovered after spills. Unless spills are promptly and thoroughly cleaned up and the area decontaminated, the contamination will continue.

Other insidious hazards

In the laboratory, one common source of insidious hazards is the sink drain. Disposing of aqueous solutions by flushing down the drain can lead to the buildup of toxic or other hazardous materials that may be released into the laboratory air on contact with a catalyst.

Other insidious hazards include:

- coal process products
- peroxide formed in old or improperly stored **ethers
- leaking toxic gas cylinders (**phosgene, **hydrogen, **cyanide, **chlorine)
- mixed chemicals that can slowly react to form toxic products or build pressure
- liquid chemicals in glass containers stored above eye level
- explosive **perchlorate in fume hoods
- unlabelled chemicals
- reactive chemicals stored on the same shelf
- faulty pressure-control equipment for compressed gases
- ignition sources in flammable solvent areas

***** Should not be used in high school laboratories.***

5.4 Toxic Hazards

A toxic substance has the potential to cause injury by direct chemical action with body systems. Almost any substance is toxic when taken in excess of "tolerable" limits.

Toxic substances include corrosive as well as poisonous materials.

Toxic materials can enter the body in four ways:

- **Inhalation** – breathing in poisonous or corrosive vapours and dust – by far the most common route by which toxic materials enter the body
- **Ingestion** – swallowing liquid or solid toxic materials
- **Direct entry to the bloodstream** – getting chemicals in open wounds (including direct injection through punctures) – may result in rapid distribution throughout the body
- **Contact** – absorption of toxic materials through skin, mucous membrane, and eyes

The effects of corrosive materials are usually rapid, but the effects of poison may not be immediately noticed. In fact, many substances (e.g., arsenic and mercury) are cumulative, and poisoning can be the result of several exposures over a period of time.

Poisoning may be suspected when any of the following are evident and access to poisons is possible:

- strange odour on the breath
- discolouration of lips and mouth
- unconsciousness, confusion, or sudden illness
- pain or burning sensation in the throat
- bottles or packages of drugs or poisonous chemicals found open in the presence of students

Toxic materials damage the body by interfering with the function of cells in body tissue. The damage can occur as the destruction of tissue by direct corrosive action (e.g., NaOH contact with skin), interference with chemical reactions of the body (e.g., CO replaces O_2 in hemoglobin), or disruption of biological processes (e.g., NO_2 causes pulmonary edema and allergic responses).

Toxic effects can be local or systemic as well as acute or chronic. Local effects are confined to the area of the body that has come in contact with toxic materials. Systemic effects occur throughout the body after absorption into the bloodstream. Acute effects are more or less immediate, while it may take years for chronic effects to become evident.

Toxic materials are rated in British Columbia by Permissible Concentrations (PC), the average airborne concentration of a substance to which a person can be exposed without likely adverse effect. Some people will be harmed by exposure to materials at or below the listed PC value. PCs are determined on the basis of adult body mass and metabolism; they may therefore be misleading when applied to small children. When using PC measures, the time of exposure to a substance and the concentration of airborne contaminant should be considered.

The potential for contact with toxic materials exists in many areas of the school curriculum. Chemistry experiments are the most obvious situation with potential hazards. However, a person may be exposed to toxic substances from unsuspected sources. Toxic materials may be involved incidentally as part of a laboratory or demonstration procedure. Careful consideration must be given to all materials used and produced in an activity. For example, the dust of heavy metal minerals may be inhaled during the breaking of rock samples. Inadequate cleanup can lead to exposure to toxic materials after a lab procedure is finished. Substances left on benches, beakers, and bottles may be contacted by the next person working with them. Students may ingest toxic materials that they have been in contact with if they do not wash very thoroughly before eating or smoking. Foods and beverages readily absorb many vapours and must not be brought into a lab. Chewing of gum should also not be allowed in a lab.

Hazardous situations

Hazardous situations include the following:

- **Handling toxic materials in open containers** – Vapours, dust, and liquids can easily escape during normal handling.
- **Heating toxic materials** – Smoke and vapours may be released in much greater quantity when material is hot.
- **Creating dusts of toxic materials** – Crushing and grinding solids and transferring powders may release dusts into the air.
- **Using toxic materials in areas without adequate ventilation** – Toxic vapours can rapidly accumulate to dangerous levels in a room, or part of a room, that does not have a constant replacement of contaminated air. Toxic vapours can be in high concentrations immediately above an open bottle, even in well ventilated rooms – do not lean over open bottles.
- **Storage of toxic materials without proper ventilation** – Dangerous levels of toxic substances accumulate in the air and on surfaces in closed, unventilated storage areas.
- **Storage of toxic materials without proper hazard identification** – Hazards must be clearly seen and understood every time a substance is used in order to avoid dangerous mistakes.
- **Use of toxic materials without proper protective gear** – Prevent skin contact with hazardous materials and inhalation of toxic vapours through the use of appropriate clothing, face protection, fume hoods, or respirators.
- **Storing or consuming food and beverages, or chewing gum in an area where toxic materials are used** – Food and beverages can readily absorb toxic vapours or become contaminated with unseen toxic dust. Poisons may be transferred from hands to food and cigarettes.

Special note: Odours and appearance are not reliable guides to the toxicity of substances. What looks like water could be a dangerous acid or base – or worse. Many toxic vapours have little or no odour, even in dangerous concentrations.

Toxic materials protection policy

Accident prevention depends on forethought, identification of hazards, and careful instruction of students. The onus is on the teacher to be aware of potential dangers and to convey this information to students. The teacher must instruct students in proper handling procedures and must insist that they be followed.

The acquisition, use, and storage of toxic materials must be related to real needs. If safe alternatives exist, they should be used. Toxic materials should be used only when there is adequate protection from exposure.

Protection guidelines

- Unless you know definitely that a substance is not toxic, treat it as though it were toxic.
- When using poisonous or corrosive material, cover all exposed areas with chemical-resistant clothing. Use appropriate protective gloves, aprons, lab coats, and face shields.
- Wash with soap and warm water after handling any chemicals. The glassware that was used and your hands should always be clean at the end of a lab period.
- Keep food, beverages, and cigarettes out of all laboratory rooms.
- Do not use lab glassware for eating or drinking.
- When using substances with toxic vapours or dusts, work in a fume hood.
- Clearly label all bottles. Read the label so you know the hazard.
- Do not store anything in unlabelled containers. Replace the bottle lid as soon as you have taken the materials you need.
- Be informed. Know what you are working with, its hazards, and how to handle it safely. Always be sure you know what to do in the event of an accident.

5.5 Biological Hazards

Micro-organisms, like toxic chemicals, present a potential hazard to people performing biological experiments. Working with them requires special handling, storage, and disposal techniques. Teachers must be aware of the hazards presented by infectious agents and their possible sources.

Common causes of accidental infection

Common causes of accidental infection include:

- oral aspiration through pipettes
- accidental syringe inoculation
- contact with an animal
- animal bites or scratches
- spray from syringes
- centrifuge accidents
- allergic reactions to plants
- cuts or scratches from contaminated glassware
- cuts from dissecting instruments
- spilled or dropped cultures
- airborne contaminants entering the body through the respiratory tract

Biological Precautions	
Activity or Item	**Precaution**
Handling micro-organisms	• Avoid bacteria, fungi, and so on that are known to be pathogenic. • Do not encourage growth of any micro-organisms other than those that occur naturally on mouldy bread, cheese, or mildewed objects. • Grow cultures at room temperature, in the range of 25°C to 32°C; incubation at 37°C encourages growth of micro-organisms that are capable of living in the human body. • Clean and disinfect all work surfaces before and after handling micro-organisms. All apparatus used in microbiology must be autoclaved. Liquid disinfectants and germicidal agents generally have limited effectiveness and should not be relied on for complete sterilization. • Do not culture anaerobic bacteria, soil bacteria, or swabs from any surface that may contain micro-organisms from a human source. • Sterilize (autoclave) petri dishes containing cultures before disposal. • Use transparent tape to seal petri dishes before they are passed around the class. • Avoid spattering cultures to prevent aerosol formation, which is a common means of infection. • Flame wire loops and needles before and immediately after transfer of cultures. • Do not move throughout the lab with a wire loop containing a culture.
Dissections	• Do not dissect wild or stray animals found dead outside, as they may be diseased or carry infectious agents. • Use organs that have been federally and provincially inspected. • Use dissecting instruments with care; make sure they are rust-free and clean. • When making incisions, cut down and away • Use a 70% solution of ethanol in water for preserving specimens. • If you are using specimens stored in formaldehyde, thoroughly rinse them in running water and soak in water overnight. • Vacuum-packed specimens are recommended. • Discard specimens in biohazard bags immediately after dissection, as some species of bacteria can begin to grow even on specimens that have been in preservatives. • Use disposable non-latex gloves. • Always wash hands before and after dissections • Use a wax or Styrofoam pan for dissections; never dissect in your hands.
Plants	• Handle with care. • If you are unsure, treat a plant as though it were poisonous. • Do not allow students to put any part of a plant in or near their mouths. • Avoid skin contact with the juice or sap of plants. • Wash hands after handling plants and before eating.
Food	• Do not store food in refrigerators in laboratories. • Do not store or consume food in the lab or supply room.
Animals	• Maintain any animals kept in the lab in a clean, healthy environment.

Specific laboratory procedures

A number of specific laboratory operations deserve special attention when micro-organisms are involved.

Pipetting – The greatest hazards are:	• Production of aerosols – avoid by: – never using a pipette to bubble air through a contaminated liquid – never forcefully blowing liquid out of the pipette – discharging the pipette with the tip below the surface of the receiving liquid – immediately after use, immersing contaminated pipettes in a germicidal solution, and then autoclaving • Accidental ingestion of fluid – avoid by using a pipetting bulb • Contamination of the mouthpiece – avoid by using a pipetting bulb
Using syringes – The greatest hazards are:	• Accidental inoculation • Aerosol production
Inoculating loops	• The film held by a loop may break and cause atmospheric contamination. • A hot loop may cause a liquid to spatter on insertion into the liquid. Allow it to cool first. • A contaminated loop may produce an aerosol by boiling and volatilization when it is placed in a flame for sterilization, even before all pathogenic organisms are killed. • Avoid any actions that might result in the generation of an aerosol (e.g., jerky motions, shaking the loop, agitating liquids). • Dip inoculating loops into ethanol before flaming to prevent aerosol formation. **Note:** Care must be taken because of the flammability of ethanol.
Using centrifuges	• Clean centrifuges with ethanol, using the fume hood, to kill any bacteria present.
Growing your own bacterial cultures	• It is always possible to introduce a few spores of pathogenic bacteria from the atmosphere. Be sure the culture medium is properly sterilized by autoclaving. After inoculating the medium with bacteria, wash hands and clean up any spills with a good disinfectant. • Disposable petri dishes are recommended. • When you are finished with the bacterial cultures, collect the dishes in a biohazard plastic bag and then autoclave before disposal.

Use of human tissue and fluids

A review of information and concerns expressed about the potential risk of transmitting hepatitis or AIDS through activities that involve the extraction and analysis of samples of human fluid or tissue led to the following recommendations in British Columbia:

- Activities involving the extraction and analysis of human fluid or tissue should not be attempted in BC schools without the written permission of both school and district authorities.
- Activities such as blood typing, cheek cell scraping, or urinalysis may be replaced or modified with use of prepared microscope slides or audiovisual materials.

5.6 Radiation Hazards

Radiation is everywhere. Radiation sources have increased in school laboratories, as a result of increased electronic equipment and a greater variety of experimental procedures, including nuclear experiments. Radiation is a hidden hazard, because our senses do not perceive its presence. Radiation is capable of causing a variety of types of biological damage, with results ranging from no observable effects to serious disability and death.

Radiation is the emission of energy from a substance. The energy can pass through space and be reflected or absorbed, or may pass through a receiving substance. Radiation may take the form of a particulate or electromagnetic wave (or photon). The emission of radiation can be a spontaneous event or the result of some stimulation of the source materials by its interaction with another source of energy.

In ordinary discussion, "radiation" and "radioactivity" are often used interchangeably. However, radioactivity is just one type of radiation, which includes the following forms, divided into two classes:

Ionizing radiation	**Non-ionizing radiation**
X-rays Cathode rays Radioactivity: • alpha particles • beta particles • neutron (particles) • gamma rays (electromagnetic waves or photons)	Ultraviolet light Visible light: • spectroscopic sources such as mercury, hydrogen, iodine, and sodium vapour (discharge tubes) • infrared light Microwaves Radio waves

When absorbed, ionizing radiation causes atoms in the receiving materials to lose electrons – to become ionized. The result is a drastic alteration of the chemical activity of the atom and, therefore, a change in the nature of any molecule containing the ionized atom. In general, the high energy of short wavelength electromagnetic waves or high-velocity particles is required to cause the ionization of most atoms, especially when they are combined in molecules.

The generally lower-energy, longer-wavelength, non-ionizing radiation can be absorbed by molecules, resulting in heat (an increase in their kinetic energy) rather than causing atoms to lose electrons. The increase in kinetic energy of the molecules sometimes results in an alteration or destruction of the molecule.

Where do the hazards exist?

Ionizing radiation

Radioactive isotope samples – Low-intensity sources of radioactive isotopes that may be purchased include metal discs containing small amounts of the radioisotopes of uranium and thorium and crystalline compounds of the radioisotopes of uranium, thorium, potassium, and rubidium. Uranium and thorium emit alpha, beta, and gamma radiation; potassium and rubidium emit beta and gamma radiation. The metal discs, when unshielded, should not contact bare skin. The powders of the crystalline compounds must be well contained to prevent spilling on skin, clothing, or work surfaces and to prevent escape into the air, where they can contact skin or be inhaled. Powders are most easily contained if they are kept slightly damp.

Vacuum and discharge tubes – Cathode ray tubes operating at accelerating voltages of greater than 5 kilovolts (kV) may emit cathode rays capable of producing tissue damage. In addition, X-rays can be produced by any vacuum tube or gaseous discharge tube operated at voltages of greater than 5 kV. In the absence of any specific information about cathode ray and X-ray emission from the equipment used, operating voltages should be kept as low as possible, with 5 kV as the maximum.

Non-ionizing radiation

Ultraviolet lamps and electric arcs – Ultraviolet lamps, such as those used to detect the presence of certain compounds by their fluorescence, must be used in such a way that the source can never be looked at directly. Electric arcs produce very high intensities of ultraviolet light and must never be used as an open source. If an arc is used to provide intense visible light, it must be enclosed, with the exception of an exit pupil where a filter can be used to absorb ultraviolet light from the desired visible light beam.

Lasers – The beam of light from even low-power lasers, when focused by the lens of the eye, can cause severe retinal damage even with very brief exposure. Lasers must be used under the close direction of a teacher, in a well-lit room so that the pupils of the eye are small, and only when positioned in such a way that the beam cannot enter anyone's eye, either directly or by reflection. It should also be noted that the direct or reflected viewing of any intense visible light source – such as electric arc, burning magnesium ribbon, the sun, and collimated or focused beams from ordinary tungsten lights – can cause retinal damage.

Microwave generators – The microwave radiation generators used in school laboratories are of low intensity. However, exposure to low-intensity microwaves may have biological and psychological effects. Since the generators are a source of radiation that is absorbed by tissue, care should be taken to minimize exposure. Prevent access to the beam by shielding its path or restricting admittance to the area through which the beam passes.

Use of radioactive materials

- **Use of isotopes** – Contact with materials containing radioisotopes can cause severe tissue damage.
- **Use of cathode ray and gas discharge tubes** – Energetic electrons and X-rays emitted from these tubes may cause biological damage if high operating voltages are used.
- **Use of ultraviolet lamps and electric arcs** – Ultraviolet light can cause very painful inflammation of some parts of the eye. The eye can be permanently damaged by intense ultraviolet light from electric arcs. Prolonged exposure of skin can produce "sunburn."

- **Use of intense visible light sources (lasers, etc.)** – The light receiving retina in the back of your eye can be permanently damaged by direct viewing of very bright light sources.
- **Use of microwave generators (and faulty microwave ovens)** – Microwaves can cause the body to overheat and permanently damage heat-sensitive organs.

Protection

- Stay as far away as possible from radiation sources. **Do not** handle radioactive material.
- Use protective shielding between you and the radiation source.
- Work with radiation sources only for brief periods.
- Never look into the beam of a laser, ultraviolet source, or any other bright light.

Radiation protection policy

Most of the radiation hazards in schools are of an insidious nature. Therefore, protection of staff and students from exposure to radiation will require careful planning of experimental set-ups and procedures and maintaining of all radiation sources in good order. All potentially hazardous equipment and materials must be available for use only under the direct supervision of a teacher familiar with the safe use of the item. **The onus is on the teacher to be aware of potential dangers and to convey this information to students. The teacher must instruct students in proper operating and handling procedures and must insist that they be followed.**

The aim of safe procedures for handling radiation sources is to do everything possible to reduce exposure to radiation at all times. Three general principles can be used to minimize exposure:

- Stay as far from the source as possible at all times. For collimated and focused beams of radiation, always stay out of the beam path. For uncollimated emissions, the intensity is inversely proportional to the square of the distance between you and the source. Distance is the best, and often simplest, protection.
- Know what kind of shielding is effective in absorbing the radiation, and use it.
- Keep the time for potential exposure to a minimum. In most cases, your body is capable of quickly repairing, or compensating for, many small amounts of physiological damage spread over a long time. But this ability can be overridden if the same total amount of damage is done during one continuous interval.

5.7 Carcinogens

A carcinogen is a substance that, when absorbed by the body, may start uncontrolled cell growth. Carcinogens are **not** recommended for use or storage in schools unless an absolute need is demonstrated and appropriate use and storage safety procedures are instituted. Contact by any route (respiratory, skin, or oral) should be minimized by fume hoods and the use of personal protective equipment. If it is determined that there is a definite need to use carcinogenic chemicals, obtain additional information on the risk involved. **Remember**: Some carcinogens are more potent than others, and risk increases with the level and duration of exposure.

Useful information on chemicals that are or may be carcinogenic can be found on the US National Toxicology Program website: http://ntp.niehs.nih.gov/pubhealth/roc/roc13/index.html

Removal

Carcinogens should be removed under the direction or supervision of WorkSafeBC or a licensed commercial company. All provincial, local, and federal regulations must be adhered to in the removal process. Once removed, the substances should not re-enter the school. Instructions should be added to the procedures for ordering chemicals to ensure that, once removed, these chemicals are not reordered.

5.8 Mechanical and Electrical Hazards

Mechanical and electrical hazards will seldom exist in a well-maintained laboratory where commercially produced, approved equipment is in good working order. With all protective devices and guards in place, there is little opportunity for an accident to occur.

Mechanical hazards

- **All rotating machinery** – When guards, lids, and covers are not in place over exposed shafts, belts, and pulleys, loose clothing, hands, and long hair can quickly get caught.
- **Use of tools (including for glass-cutting operations)** – Carelessly used tools, and tools in poor condition are the source of many accidents resulting in crushed or cut fingers and hands, eye injuries, and lesions and abrasions on arms, legs, and head.
- **Heavy equipment and materials stored overhead** – A heavy overhead item slipping while being moved can cause mechanical injuries to the back, arms, legs, and head. (Mechanical injuries are the result of excessive forces applied to the body.)

Electrical hazards

- **Faulty equipment** – Poor or broken connections (e.g., frayed connecting cords) to devices may cause overheating of input leads or the devices themselves, or shorting of the circuit to some part of the equipment touched by people (e.g., the metal case). Damage to the equipment or a fire or electric shock may result.
- **Improperly used equipment** – Equipment damage and overheating, and therefore fire, are possible if equipment is in prolonged use at a power rating greater than that for which it was designed.
- **Installations and modification that do not meet building code standards** – Building code specifications are intended to provide safe access to electrical power. If changes or additions are needed in the existing system, they must be made by an electrician. Improperly made alterations can present a fire or electrical shock hazard if excessive current can flow in the new circuits, or if connections are not properly made and insulated.
- **Electrical equipment used near water** – If equipment that is not properly insulated and grounded is used near water (e.g., near laboratory sinks), there is a danger of electric shock.
- **High-voltage equipment (including Tesla coils and charged capacitors)** – Student-wired laboratory set-ups and teacher-made demonstration equipment frequently have exposed connections that present a very real danger of electrical shock when high voltages are being used (e.g., the connection of a high voltage source to a gas discharge tube).

Mechanical and electrical hazards protection policy

Accident prevention depends on the proper maintenance of all mechanical and electrical equipment and careful instruction of students in the safe use of the equipment. The onus is on the teacher to be aware of potential dangers and to convey this information to students.

Teachers/school administration must do the following:

- Maintain all equipment and tools in good working order.
- Instruct students in the safe use of all equipment and tools.
- Be sure that all rotating equipment, such as centrifuges, vacuum pumps, rock saws, grinders, and demonstration motors, are operated with all covers, lids, and guards in place.
- Require that eye protection be used during any grinding or pounding operations.
- Require that students using rotating equipment tie up loose clothing and long hair.
- Clearly indicate a “No Crowding Zone” around all major equipment, within which there must only be the equipment operator.
- Clearly tag all faulty equipment so it will not be used before it is repaired – disconnecting it from the power source if possible.
- Use electrical equipment at its rated capacity only.
- Be sure all equipment is shut off when not in use.
- Ensure that regular safety inspections take place and that inspection sheets are dated and signed.
- Store all heavy items as close to the floor as possible.

5.9 Fires

Burning is the rapid oxidation of a fuel by an oxidizer (usually air) with the liberation of heat and (usually) light. A fire can be started when sufficient energy is present to initiate the reaction. The process of burning involves the four interrelated components: fuel, oxidizer, an energy source, and an uninhibited chemical chain reaction. Removal of at least one of these components is the basis of fire control and safety.

Sources of fires

Fire has always been one of the biggest hazards in school laboratories. Laboratories make use of flammable materials, including solids, liquids, and gases. Common sources of fire hazards encountered in school labs include:

- ignition of solvent vapours
- ignition by reactive chemicals
- uncontrolled chemical reactions
- inadequate storage and disposal methods
- heating due to electrical faults
- loose clothing and hair ignited by a Bunsen burner
- misuse of gas cylinders
- inadequate maintenance
- static electrical buildup
- inadequate laboratory design
- inadequate temperature control, especially in areas where solvents are stored

Fire safety

A goal of every science teacher should be to reduce the chance of fire as much as possible. Elements of a successful fire control program include:

- adequate education of students in the hazards of fire
- use of proper lab procedures
- maintenance of proper chemical storage facilities
- provision and maintenance of effective fire control equipment.

In the case of any fire, the teacher alone should deal with the fire. Students should immediately be told to keep away.

Fire safety equipment

- **Fire blanket** – made of fire-proofed wool/rayon material; not to be used where spillage and fire spreading is possible
- **Sand bucket and scoop** – useful for small fires of all kinds
- **Fire extinguishers** – either cools the area so a fire will not burn (removes energy source) or smothers the fire (removes oxidizer), or both

Fire extinguishers

The type of fire and the type of fire extinguisher to be used are related. Teachers should learn the different classes of fire and the proper extinguisher to use.

Fire classification	Fire extinguisher
Class A – fires involving ordinary combustible materials such as wood, cloth, and paper	Water Dry chemical extinguisher can also be used
Class B – fires involving flammable liquids such as solvents, greases, gasoline, and oil	Dry chemical foam, CO_2
Class C – fires involving electrical equipment	Non-conducting agents such as dry chemical or carbon dioxide
Class D – fires involving combustible metals such as magnesium, sodium, lithium, and powdered zinc	Special dry powder medium or dry sand

Basic requirements for the location and condition of fire extinguishers include the following:

- Locate extinguishers close to where they will be used.
- Locate extinguishers conspicuously, preferably near an exit, and mark the location with signs.
- Mount extinguishers at an accessible height.
- Clearly mark all extinguishers with their class and use.
- Maintain fire extinguishers in operable condition. Have a complete check at least annually, and check pressure monthly.
- Never reuse a used extinguisher. Have used extinguishers recharged.

Dealing with a small fire

- If only a small amount remains to burn and flames are unlikely to ignite other materials, leave it to burn out.
- If the fire is in a beaker or other container and more than a small amount remains to burn, wearing a face shield and heat-resistant gloves, place a fire-resistant cover over the mouth of the beaker or container. Avoid breathing fumes.
- If the fire appears to be controllable, and where there is little personal risk, use the fire extinguisher available in the laboratory:
  - Direct the discharge at the base of the flames.
  - Start at one side and work across the base.
  - Always fight a fire from a position of escape.

Dealing with a large fire

If the fire is burning over an area too large to be extinguished:

- Vacate the room.
- Instruct a particular student to sound the nearest fire alarm.
- Ensure that evacuation is not hampered by students attempting to retrieve outdoor clothing or other personal belongings.
- Monitor movement of students to prevent crowding, running, and pushing.
- Escort students outside along the predetermined exit route to the assembly area.
- Ensure that all students are accounted for.
- If it is safe to do so:
  - Close all doors and windows to localize the fire before leaving.
  - Shut off electrical circuits and gas lines.

Dealing with a person on fire

- Drop and roll the individual.
- Douse the individual with water.
- Wrap the person in a fire blanket.
- **Note:** A person on fire should not, under any circumstances, run to get help.

Some don'ts

- Don't throw water over a chemical fire.
- Don't use a fire extinguisher on standing beakers and flasks.
- Don't turn on water after a flaming container is placed in a sink.

For more information, visit the Office of the Fire Commissioner website at http://www2.gov.bc.ca/gov/content/safety/emergency-preparedness-response-recovery/fire-safety

6 Field Trips

The benefits of field trips are often so significant that a field trip may be the only part of a science course that students remember, long after the course is completed. Whether the trip involved an afternoon at the aquarium or four days on the West Coast Trail, it was special. The routine of school life was broken, and an opportunity to explore the "real world" was provided.

For the teacher, however, the field trip represents myriad logistical issues that must be dealt with long before the event itself. Each of these issues has at its root potential safety problems. If not dealt with appropriately, the consequences of incomplete planning could be disastrous.

The primary purpose of a field trip for a science class is to investigate applications of science or to explore some aspect of the natural environment. Field experiences may be classified in two groups: routine and special. Routine field trips usually are of one day or less in duration and involve a facility such as a museum, zoo, factory, or research centre, possibly at a university. Special field trips are usually to outdoor sites – for example, a backpacking trip on the West Coast Trail or a day hike to investigate glacial and volcanic formations on a nearby mountain. Here the element of risk is greater, and consequently the need for thorough planning is essential.

> When planning a field trip, review school district field trip policies and ensure that all of the required forms are completed and the appropriate permissions are received in writing. Use the appropriate parental consent forms to gain parental permission for students to go on the field trip.

The routine field trip

The major challenge to be dealt with on the routine field trip is often transportation. If all students travel together in a bus, there should be no problem. If other methods of transportation are to be used, review school district policies and ensure that parents are given the opportunity to consent to the given method of transportation. However, if teachers, parents, or students drive other students in private cars, you must find out if this complies with school district policies.

You must obtain written permission from parents before taking students on any field trip. In addition, find out if the site itself poses any special hazards to students, by questioning the contact person at the site before you arrive. Let your students know about the hazards before you leave, and remind them again on arrival at the site.

Adequate supervision is important. The number of additional adults who should accompany your students to the site will vary according to the age of the students, the number of planned activities, and the site itself. Consultation with site staff to confirm adequate numbers is suggested.

The special field trip

What makes this type of field trip "special" is that it usually involves a more remote wilderness destination than a routine trip would. As with routine field trips, discuss the trip with your school administrator, outline the trip to your students and their parents, and obtain written parental permission. Important medical information must also be gathered.

A major concern is potential teacher and school district liability arising from outdoor field trips to remote or wilderness areas. If you have some special expertise – for example, training as a canoe instructor or gymnastics instructor – you will be expected to exercise that skill while instructing and supervising students in activities involving those skills. If you fail to exercise such skills or care, and a student is injured as a result, you and the school district may be liable for the loss the student has suffered.

Apply the following test when considering the appropriateness of an activity for a school activity:

- Is the activity suitable to the age and condition (both mental and physical) of the students?
- Have the students been progressively trained and coached to do the activity and avoid the foreseeable dangers?
- Is the equipment that will be used adequate and suitably arranged?
- Will the activity, particularly if it is inherently dangerous, be properly supervised?

An important factor is the level of qualification possessed by the leader and other adults on the trip. Adults leading trips into wilderness areas should have current first aid certification.

Leading students in wilderness areas of BC takes more than just "common sense." The leader should have visited the area before taking students into it, and students should be well prepared for environmental conditions.

Travelling to the United States or other countries

If your field trip will take you to the United States or another country, you will have to investigate health and safety issues. What health coverage do you and your students have should you be hospitalized while in the United States or abroad? Extra medical insurance is mandatory no matter how long the stay. Also, you must ensure that all students have passports and any other visa or immigration documents required to enter the destination country.

Please note: If any serious injuries or incidents occur on a field trip, parental consent forms and all associated documentation relating to the trip should be preserved for at least two years following the trip. The duration required for retaining records may vary by school district. Refer to your school district policy.

7 Facilities

Science laboratories come in a variety of shapes, sizes, and uses. It is important to consider these three factors in determining the relative safety of any particular activity.

The following additional points also deserve attention:

- Science activities generally require a flat, horizontal, solid bench for student work.
- Teachers should have easy eye contact with all students and with their work surface and area. This can be achieved only with students facing the teacher.
- The number of students who can safely participate in science in a given laboratory at any given time depends on many factors. It is recommended that school districts determine safety standards for the number of students that should be under the guidance of one teacher in a given facility. In situations where existing facilities render conditions unsafe for undertaking science activities, class size should be reduced.
- Science laboratories should never be crowded. Maximum occupancy of a room is often dictated by design. A rough guideline for overall dimensions may be found by allocating 5 square metres (m^2) for each student. This area per student is derived by dividing student-accessible area by the maximum number of students using the room at any given time. The student-accessible area used in the calculation should not include teacher facilities or desk, cupboards, shelves, hallways, or corridors.
- The Ministry of Education Area Standards designate a "science module" allowance of 140 m^2 in the design of new secondary schools. This space may be supplemented by using some of the facility's "design space" allowance. The 140 m^2 includes preparation areas as well as student-accessible areas; sharing preparation facilities may be one method of increasing instructional space.
- All science teaching areas should include teacher facilities and desk, as well as cupboards and shelves for adequate storage of materials and equipment. A separate, locked science storage/preparation room with adequate preparation facilities and chemical storage area should be provided.
- All laboratories must be adequately ventilated.

Specialized discipline area requirements

Biology: animal study centre, controlled environment centre, growing cart, aquatic study centre, skeleton storage, herbarium, germination bed, specimen storage, microscopic storage

Chemistry: acid and reagent dispensing centre, titration station, spectrophotometer, pH meters, electronic balances, compact storage centre, protective clothing storage, safety glass storage, general storage

Physics: apparatus storage, tool storage, demonstration apparatus set-up

Geology/general science: cleanup and rinse-away sink centre, rock and mineral storage, rock saws, polishing apparatus

Preparation and Storage Area

Suggestions: wash-up sink, disposal, under-counter dishwasher, refrigerator, freezer, teacher's work station, teacher's desk

Potential Structural Hazards in the Laboratory and Storeroom

Structural hazards refer mainly to shortcomings in the accommodation. It is important to recognize them, in order not only to effect improvement, but also to take particular care until improvements can be made.

Facilities	Comments
Floors	• Floors should be level throughout, with no steps in the laboratory/ stores area. • Floors should be without defects (e.g., loose or broken tiles, uneven patches, cracks), which can harbour spilled chemicals. • In chemical storerooms, floors should have an adequate drain at the lowest point to cope with flooding. • Floors should be washable. • Flooring is far preferable to tiles or carpeting.
Doors	• No doors should be defective or jam. • All doors should open toward the nearest safety exit without use of a key. • All doors should have a safety glass window at eye level. • No doors should be situated in an obscure area (e.g., around a blind corner).
Exits	• All science classrooms should have a minimum of two exits. • Exits should be clearly marked.
Ceilings	• Ceilings should be non-flammable. Flammable ceiling materials, such as polystyrene tiles, should be removed and replaced with materials that have a low flame-spread rating (e.g., drywall).
Plumbing	• Laboratory water faucets with goosenecks must be protected by vacuum breaks meeting the requirements of ANSI Standard ANSI/ASSE 1001-1990, Pipe Applied Atmospheric Type Vacuum Breakers, or other standard acceptable to the school district. • A vacuum break must be maintained in a state of good repair and must be tested in accordance with the manufacturer's requirements. • The location of an in-line vacuum break must be clearly identified.

Facilities	Comments
Fume hood	• Fume hoods are necessary in each science classroom. Refer to the WorkSafeBC website (http://www.worksafebc.com/default.asp) for current safety requirements for laboratory fume hoods.
Extractor fans	• Laboratories should be adequately ventilated by extractor fans that are in addition to the fume hood system. For normal laboratory purposes, a minimum of 5 changes of air per hour or 15 litres per second per occupant is satisfactory.

8 Safety Contacts List

BC Hydro

Website:	http://www.bchydro.com/
Telephone:	General Inquiries – 1-800-224-9376

British Columbia Schools Protection Program – Risk Management

Website:	http://www.bcspp.org/
Email:	protection.program@bcspp.org
Telephone:	250-356-1794

Canadian Centre for Occupational Health and Safety (CCOHS)

Website:	www.ccohs.ca
E-mail:	inquires@ccohs.ca
Toll-free:	1-800-668-4284

Canadian Red Cross

Website:	http://www.redcross.ca/

First Aid Information

Telephone:	1-877-356-3226
Fax:	1-800-811-8877
E-mail:	myrcsupport@redcross.ca

Labour Canada

Website:	http://www.labour.gc.ca/eng/health_safety/
Telephone:	Vancouver – 1-800-641-4049

Natural Gas Safety

Fortis BC

Website:	www.fortisbc.com
Emergency telephone:	1-800-663-9911

Pacific Northern Gas Ltd.

Website:	www.png.ca
Emergency telephone:	1-800-663-1173

Office of the Fire Commissioner

Website:	http://www2.gov.bc.ca/gov/content/safety/emergency-preparedness-response-recovery/fire-safety

Safety Authority

Website: http://www.safetyauthority.ca/

St. John Ambulance

Website: http://www.sja.ca/

Workplace Hazardous Materials Information System (WHMIS) – Health Canada

Website: http://www.hc-sc.gc.ca/ewh-semt/occup-travail/whmis-simdut/index-eng.php

WorkSafeBC

Website:	http://www.worksafebc.com
Claims telephone:	604-231-8888
Toll-free:	1-888-967-5377
Claims fax:	604-233-9777
Toll-free:	1-888-922-8807

Employer services/Assessments

Employer Service Centre: 604-244-6181
Toll-free: 1-888-922-2768

Prevention services

Information Line: 604-276-3100
Toll-free: 1-888-621-SAFE (621-7233)

Health and safety emergency and accident reporting

Monday–Friday, 8:30 a.m.–4:30 p.m.: 604-276-3100
Toll-free: 1-888-621-SAFE (7233)
After-hours toll-free: 1-866-WCB-HELP (922-4357)

9 References

American Chemical Society (2001). *Chemical Safety for Teachers and Their Supervisors – Grades 7–12*. American Chemical Society.

Benedict, Kathryn G. (2004). *How Can I Prevent Laboratory Accidents?* Pfizer Global Research and Development.

California Department of Education (2012). *Science Safety Handbook for California Public Schools, 2012 Edition*. California Department of Education.

National Science Teachers Association Safety Advisory Board (2013). *Safety in the Science Classroom, Laboratory, or Field Sites*. National Science Teachers Association.

Science Teachers' Association of Ontario Safety Committee (2014). *Safety in Elementary Science and Technology: A Reference Guide for Elementary School Educators*. Science Teachers' Association of Ontario.

Science Teachers' Association of Ontario Safety Committee (2011). *Safe on Science: A Reference Guide for Secondary School Science*. Science Teachers' Association of Ontario.

U.S. Consumer Safety Product Commission (2006). *School Chemistry Laboratory Safety Guide*. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

Appendix A

Laboratory Safety Checklist

The following checklist is intended to assist school and district staff in ensuring a safe environment in the science areas of their schools. The laboratory safety checklist could be completed by each science teacher each year as part of an overall safety program, while the lists of carcinogens, mutagens, and explosives included in chapter 5 Lab Hazards, should be used to identify potential hazards for immediate removal.

Please note that the checklist is neither comprehensive nor prescriptive. The criteria should be reviewed and modified to suit local situations.

Place a check mark in the appropriate column, based on current practice. Where applicable, indicate the date of the most recent maintenance or inspection under "Date." Check marks in the "No" column suggest a potential problem.

Laboratory Safety Checklist	Yes/Date	No	N/A
A. Space and Class Size			
1. 140 m^2 floor space per laboratory (including preparation areas)			
2. 5.0 m^2/student in combined classroom/laboratory (rough guide)			
3. Class size is appropriate and safe for room design			
4. Sinks (with mats) – 1 per 4–5 students			
B. Communication System			
1. Phone			
i. Accessible phone located nearby			
ii. Current emergency phone numbers posted			
2. Intercom system			
3. Co-operative emergency plan with nearby colleagues			

Laboratory Safety Checklist	Yes/Date	NO	N/A
C. Safety Instruction			
1. Safety pretest given to students (for use in planning instruction)			
2. Safety rules posted and copy provided to each student			
3. Safety posters displayed in room			
4. Appropriate “Hazardous Materials” warning signs posted			
5. Safety contract between teacher and student/parent signed and on file			
6. Safety included as part of each pre-lab instruction			
7. Safety procedures documented in lesson plans			
8. Appropriate facilities for special needs students			
9. Safer chemicals substituted in lab activities when possible			
10. Hot plates or microwave ovens substituted for open flames when possible			
11. Students instructed in proper handling of glass tubing			
12. Students instructed on biohazards in animal handling			
13. Field manuals available with safety instruction for field trips			
D. Master Cut-Offs			
1. Master control cut-off valves available, and location known and accessible to teachers, administrators, and custodians			
i. Gas			
ii. Electricity			
iii. Water			
2. Master control cut-off clearly labelled			
i. Gas			
ii. Electricity			
iii. Water			
3. Gas valves inspected for closure at end of each day			
4. Gas cut off with master control when not in use			
E. Fire Control			
1. ULC Listed 2A10BC dry chemical fire extinguisher			
i. Suitable size, easily handled			
ii. Evidence of quarterly check (indicate most recent date)			
iii. Safety seal intact			
iv. Easily visible, with no obstructions			
v. In every storeroom or preparation room			
vi. Located near escape route from lab			
vii. Access to a second fire extinguisher			
viii. Clean (CO_2 or Halon) extinguisher available in areas where dust-sensitive equipment used or stored (e.g., computer, electronic balance, microscope)			
ix. Teacher trained in use of fire extinguisher through actual fire situations			
x. Teacher trained within the last year			
xi. Alternate plan in case extinguisher malfunctions			
2. 5–10 L container of clean, dry sand for class D (flammable solids – i.e., sodium, potassium, etc.) in each room			
i. Earth Science/Geology room			
ii. Biology room			
iii. Chemistry room			

Laboratory Safety Checklist	Yes/Date	NO	N/A
iv. Physics room			
v. Storeroom			
vi. Any area where chemicals are stored or used			
vii. Teacher has knowledge of when and how to use			
3. Fire blanket			
i. Standard fire-proof woollen blanket in every lab and storeroom			
ii. Easily visible and location known to teacher and students			
iii. Regular inspection for rips and holes (indicate most recent date)			
iv. Stored at eye level			
4. Fire exits and drills			
i. Two fire exits in each laboratory, clearly marked			
ii. Two fire exits in each storeroom/preparation room			
iii. Unobstructed and unlocked fire exits			
iv. Labelled and functioning doors on exits			
v. Posted and practised fire drill procedures			
vi. Functioning general alarm system for entire building (indicate date of most recent inspection)			
5. Smoke alarm			
i. Smoke alarm in each laboratory			
ii. Smoke alarm in each storeroom			
iii. Evidence of regular maintenance (indicate most recent date)			
6. Automatic sprinkler system (indicate date of most recent inspection)			
7. “No Smoking” signs posted in lab and preparation areas			
F. Availability of First Aid Treatment			
1. School nurse available			
2. First aid kit in each laboratory and storeroom/preparation room			
3. First aid kit visible and accessible			
4. Separate kit for chemical first aid			
5. Evidence of regular inspection and restocking of kits (indicate most recent date)			
6. Instructions for emergency action/first aid posters displayed prominently			
7. Teacher trained in CPR within the last year			
8. Teacher trained in first aid within the last year			
9. Established first aid policy (e.g., protect; treat only major injuries)			
G. Ventilation			
1. Forced ventilation capability in each laboratory, with manual control (**Note:** A fume hood or air conditioner is not acceptable for evacuation of room air at a rate of five air changes per hour (preferably at floor level).)			
2. Continuous ventilation in storeroom			
3. Exhaust (on roof) ventilated away from air intake			
4. Fume hood			
i. Ventilation to roof (away from intake)			
ii. Not used as a storage area			
iii. In every chemistry laboratory for use with hazardous, vaporous chemicals			
iv. Evidence of regular maintenance for exhaust rate and leakage (indicate most recent date)			
v. Minimum of 0.5 metres per second of air movement provided at hood face with sash open 20 cm above bench (can be measured with a district-supplied velometer)			

Laboratory Safety Checklist	Yes/Date	NO	N/A
H. Lighting			
1. Safe light level in laboratory (500–750 lux ambient plus task lighting)			
2. Emergency light			
i. In each laboratory (**Note:** May not be necessary if adequate natural light is available.)			
ii. In each storeroom/preparation room			
iii. Evidence of regular maintenance (indicate most recent date)			
I. Personal Protection			
1. Safety shower			
i. One in each chemistry laboratory			
ii. Functional (with water turned on) unobstructed shower and valve handle			
iii. Rigidly fixed valve handle (no chains unless provided with large ring)			
iv. Plainly labelled valve handle			
v. Sufficient water pressure			
vi. Floor drain			
vii. Large enough to accommodate more than one person			
viii. Evidence of regular maintenance (indicate most recent date)			
2. Eyewash			
i. Available and visible in each laboratory			
ii. Training in eye-wash procedures within last year (indicate most recent date)			
iii. Type of eyewash (**Note:** Squeeze bottles or single-head eye drench are not recommended.)			
a) dual eyewash fixture or portable pressurized eyewash pump			
b) one located near a safety shower			
iv. Equipment to treat both eyes simultaneously with instant, gentle, tempered flow of aerated water for 10–15 minutes			
v. Evidence of regular maintenance (indicate most recent date for each):			
a) change solution(s)			
b) check for pressure			
c) check for breakage			
3. Protective clothing			
i. Aprons			
ii. Gloves			
a) heat-resistant gloves			
b) chemical-resistant gloves			
iii. Safety goggles/eye protectors for each student when needed			
iv. System for disinfecting goggles/eye protectors			
v. Eye protectors/goggles are clean and in good condition			
vi. Face shields			
vii. Enforcement of standard procedures for use of protective gear			
4. Carriers available for chemicals and acids			
5. Belt guards on all belt-driven equipment (e.g., rock saw)			
J. Storage			
1. Chemicals			
i. Regular inventory and disposal of unused hazardous chemicals (indicate date of most recent inventory)			
ii. Chemicals not stored in areas regularly travelled by students			

Laboratory Safety Checklist	Yes/Date	NO	N/A
iii. Correctly labelled when transferred from original container			
iv. Quantity of chemicals stored not excessive (enough for one or two semesters)			
v. Properly and clearly labelled to WHMIS standards, with:			
a) secure, water-proof labels			
b) date of acquisition			
c) hazard alert			
d) name of supplier			
e) chemical's strength or purity			
f) Materials Safety Data Sheets properly filed			
vi. Stored in compatible chemical families (not by alphabetical or other unsafe methods)			
vii. Acids stored separately on non-metal, non-wood shelves			
viii. Flammables in dedicated and approved cabinet or safety cans			
ix. Poisons locked up at all times			
x. Immersion fluids regularly topped up (including sodium and other alkali metals with kerosene) (indicate most recent date)			
xi. Stored in a regulated area with entry allowed only for authorized personnel			
xii. "Authorized Persons Only" sign on the door			
xiii. Inside of storage rooms sufficiently fire resistant			
xiv. Teachers have received WHMIS training			
2. Cabinets			
i. Secured to floor and/or wall and free from corrosion			
ii. Lockable			
iii. Locked in cabinets:			
a) hypodermic syringes			
b) drugs			
c) dangerous chemicals			
iv. Lab refrigerator stores only chemicals and living cultures (no food)			
v. Explosive-proof refrigerator for storage of explosive chemicals (e.g., ether)			
3. Shelves			
i. Equipped with lip edge to prevent bottle roll-off			
ii. Portable shelves secured to wall or ceiling			
iii. Chemicals stored at or below eye level			
iv. Glass cylinders stored off the floor			
v. Chemicals stored off the floor			
vi. Large containers stored in a tray to contain spillages			
vii. Tall items stored at back of shelf			
viii. Heavy glassware stored on lower shelves			
ix. No double-stacking of chemical containers			
x. Glass rods and tubing stored horizontally, with no pieces protruding over edge			
4. Gas cylinders			
i. Capped			
ii. Supported to prevent rolling or tipping			
iii. Placed away from heat sources and open flames			
iv. Clamped tightly in place after being positioned for use			

Laboratory Safety Checklist	Yes/Date	NO	N/A
K. Animal Cages/Tanks			
1. Cleaned regularly			
2. Adequate food and water provided for animals			
3. Animals appear to be in healthy condition			
4. Animals do not pose a threat or health hazard to people in the room			
L. General Storeroom or Lab Safety			
1. Centrifuges			
i. Anchored securely			
ii. Instructions labelled			
iii. Positive locking head			
iv. Top equipped with disconnect switch that shuts off if top is inadvertently opened			
2. Electrical			
i. Outlets carry grounding connections			
ii. Sufficient electrical outlets provided to eliminate use of extension cords, overlapping wires, or multiple plugs			
iii. No outlets close to faucets			
iv. All major lines fused or on circuit breakers			
v. Location of circuit breakers known to teachers, custodians, and administrators			
vi. Evidence of regular inspection (indicate most recent date)			
vii. Floor plugs securely fastened			
viii. Recessed floor plugs water-proof			
ix. Extension cords are 18-gauge or heavier			
x. No extension cords across aisles			
xi. DC and AC lines clearly labelled			
xii. Sockets and switches securely screwed, without cracks			
xiii. No loose or exposed wires			
3. Preparation/workroom			
i. Large sink			
ii. Hot water			
iii. Rules posted for safe handling, clean-up, disposal, protective equipment, conduct			
4. Presence of:			
i. Bulb (not mouth) pipettes			
ii. Fan guards			
iii. Material Safety Data Sheets (MSDS) for each hazardous chemical			
iv. Automatic request for MSDS on all purchase orders			
v. Aisles wide enough that teachers and students can move freely without interfering with others (no books or coats on floor)			
vi. Work surfaces made of non-porous and chemical-resistant materials			
vii. Non-reactive chemical waste container(s) available			
5. Clean-up materials for chemical spills			
i. Chemical spill kit			
ii. Spill pillows			
iii. Protective clothing			
iv. Approved waste disposal procedures used			

Laboratory Safety Checklist	Yes/Date	NO	N/A
6. Laboratory chemical and biological waste disposal system for:			
i. glass			
ii. dry chemicals/reagents			
iii. liquid chemicals/reagents			
iv. biological wastes			
7. Respirator available (**Note:** Ensure that any respirator is appropriate for its intended use; check with WorkSafeBC.)			
8. No pathogenic bacteria			
9. Evidence of annual safety inspection (indicate most recent date)			
10. Chemicals in original containers not available for student use			
11. "Do Not Eat" sign posted on icemaker			
M. Housekeeping			
1. Labs, storage, and preparation rooms are organized and clean			
2. Aisles are clear			
3. Supplies and equipment (cleaned) are returned to proper storage area			
4. Work surfaces are clear and clean			
5. Floor is in safe condition			
6. Garbage containers are available in adequate numbers and sizes			
7. Glassware is free of cracks, chips, and sharp edges			
8. Bunsen burner tubes are free from leaks			

School ______________________ Inspection by ______________________

Classroom location ______________________ Date ______________________

Actions taken and other recommendations

Teacher signature ______________________ Date ______________________

Copies of completed survey should be given to safety chairperson, science department head, and school administration.