1 Skills and Processes of Chemistry

This chapter focuses on the following AP Big Idea from the College Board:

Big Idea 1: The chemical elements are fundamental building materials of matter, and all matter can be understood in terms of arrangements of atoms. These atoms retain their identify in chemical reactions.

By the end of this chapter, you should be able to do the following:

- Demonstrate appropriate safety techniques and proper use of protective equipment
- Demonstrate skills in measuring and in recording data
- Communicate results and data in clear and understandable forms

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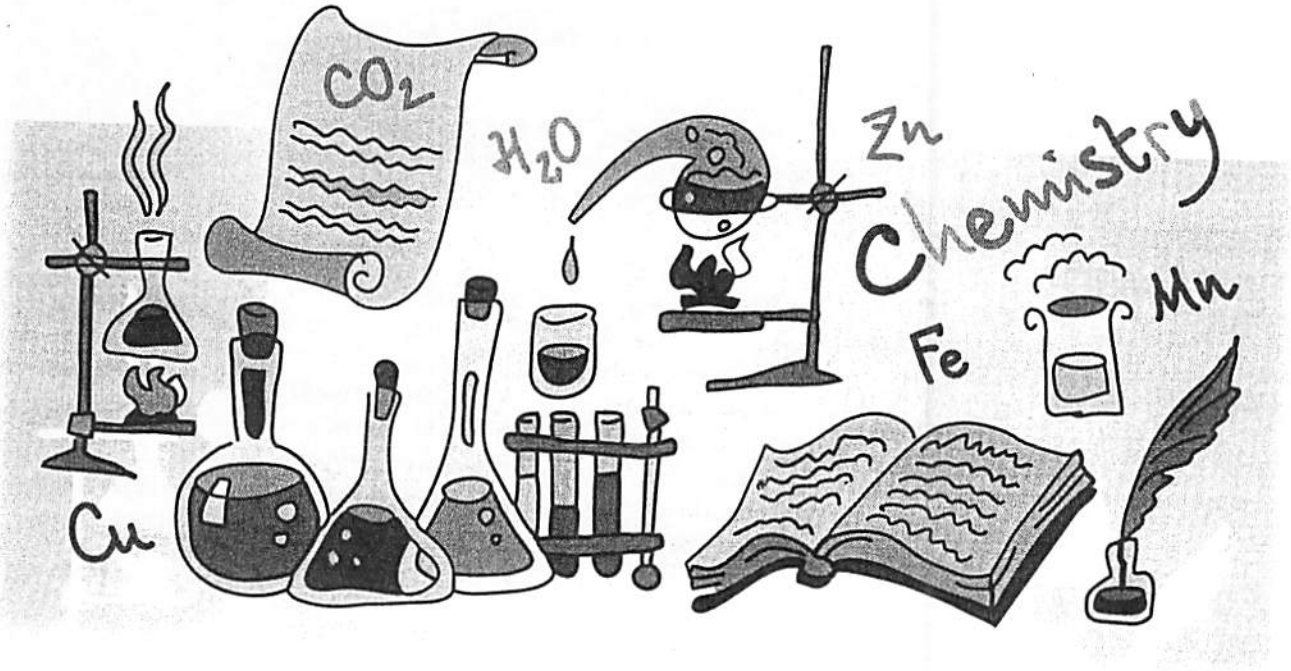
By the end of this chapter, you should know the meaning of these **key terms**:

- accuracy
- analysis
- interpretation
- observation
- precision
- SI unit
- significant figures
- unit



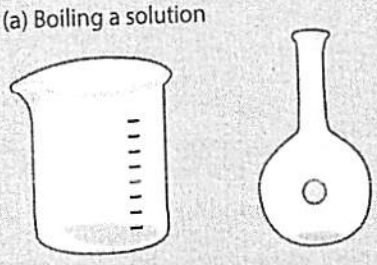
In this chapter, you'll learn about the range of tools, skills, and techniques you'll be using as you study chemistry.

1.1 Staying Safe Around Matter

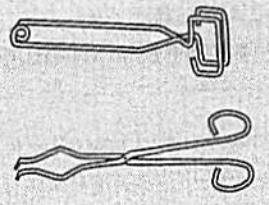
Warm Up

- Examine each of the following pairs of equipment.
- Consider how the structure of each piece relates to its function.
- Circle the better piece of equipment for each task.

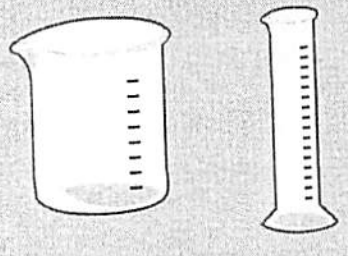
(a) Boiling a solution



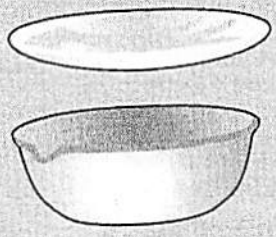
(b) Holding a hot test tube



(c) Measuring a volume of liquid



(d) Evaporation over a hot flame

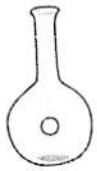
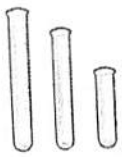
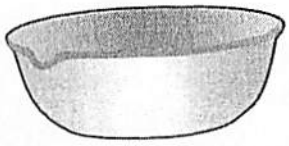
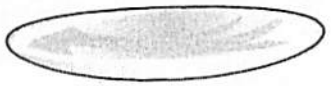


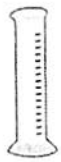
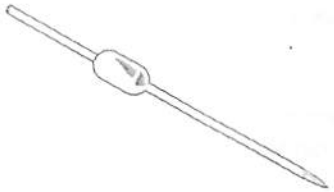
Chemistry Equipment and Its Uses

The equipment used for manipulating and measuring chemicals can be classified in a variety of ways. One of the most common methods of classification is based on the material it is made from. Tables 1.1.1 and 1.1.2 divide equipment into glassware and hardware.

Most of the glassware found in the laboratory is made of a special type of glass with a low *coefficient of expansion*. This simply means the glass expands so slowly as it is heated that it is unlikely to break. Two common brand names for this type of glassware are Pyrex® and Kimax®. Some glassware is made of ceramic material. It may be heated to red-hot temperatures without breaking or melting. Hardware is made of various types of metal including wrought iron, stainless steel, aluminum, and brass.

Table 1.1.1 *Commonly Used Glassware in the Chemistry Lab*

Glassware	Name	Use
	beaker	Holding liquids • may be graduated (sometimes in two directions) • has a white spot for labeling • various sizes including 50, 150, 250, 450, 650, and 1000 mL
	Erlenmeyer flask	Holding liquids • shape avoids loss due to splashing • used for titration • common sizes include 125, 250, and 500 mL
	Florence flask	Heating liquids • shape allows even distribution of heat while boiling • never graduated • common sizes include 250 and 500 mL
	test tubes	Holding liquids or solids • can be heated directly or in a water bath • may be used to mix small quantities of chemicals • large variety of sizes
	fluted funnel	Funneling liquids • useful for pouring liquids through small openings • can contain filter paper for separating solids from suspensions by filtration
	evaporating dish	Evaporating solvent • evaporation from a solution • can be used to dry a damp product • ceramic material allows direct heat to high temperatures
	watch glass	Holding or covering • useful for holding a sample of chemical • may cover a beaker or flask to prevent evaporation • holds chemicals while drying
	crucible	Heating to high temperatures • heating covered or partially covered samples • ceramic material may be directly heated until red hot

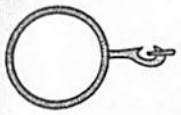
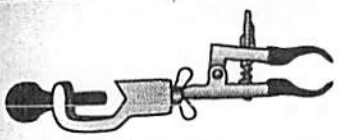
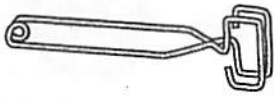
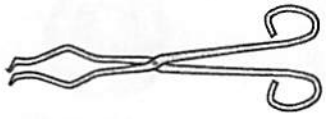
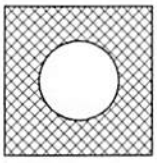
	pipe stem triangle	Providing a base to hold a crucible • sits atop a wrought-iron ring • stems are made of ceramic material
	graduated cylinder	Measuring volumes of liquids • sizes vary • commonly 10, 25, 50, 100, and 250 mL
	burette	Measuring volumes of liquids • delivers various volumes through a valve called a stop cock • more precise (exact) than the graduated cylinder
	pipette	Measuring volumes of liquids • may be graduated • may be volumetric (designed to deliver one specific volume) • liquid is drawn up with a pipette bulb or suction device
	thermometer	Measuring temperatures • bulb should be submerged in the fluid being measured • temperature ranges vary • most contain dyed alcohol • more precise thermometers contain mercury • commonly measure temperature in degrees Celsius

Quick Check

Working with a partner, design a classification scheme and use it to put the glassware into groups according to common characteristics.

Compare your classification scheme with that of another pair of students.

Table 1.1.2 *Commonly Used Hardware in the Chemistry Lab*

Hardware	Name	Use
	ring stand	Providing a post to attach • ring clamps, burette clamps, extension clamps, etc. • also called a utility stand
	ring clamp	Attaching to a ring stand • supports a ceramic pad, a pipe stem triangle, or an evaporating dish • may surround a beaker as a safety ring
	burette clamp	Attaching to a ring stand • holds a burette • may hold a test tube in a stationary position • may support the neck of a flask
	flint striker	Lighting a Bunsen burner • provides a spark by moving a flint across a file
	bunsen burner	Providing heat • adjusts flame temperature by addition of air through the barrel • adjusts flame height by turning the regulator valve
	test tube holder	Holding hot test tubes • used for heating test tubes over flame • used for removing test tubes from water baths
	beaker tongs	Lifting hot beakers • rubber cover allows tongs to firmly grasp and move beakers of all sizes
	crucible tongs	Holding hot crucibles • may remove or adjust crucible lid • holds hot evaporating dishes • NOT designed for lifting beakers or test tubes
	ceramic pad	Providing a base to hold glassware • sits atop a wrought-iron ring • provides a flat surface for beakers or flasks • sometimes called a wire gauze
	scoopula	Moving samples of solids • sometimes called a spatula • should NOT be used as a stirring rod (stirring rods should be glass)

Quick Check

Working with a partner, design a classification scheme and use it to put the hardware into groups according to common characteristics.

Compare your classification scheme with that of another pair of students.

Labelling Chemicals

Workplace Hazardous Materials Information System

The **Workplace Hazardous Materials Information System** (**WHMIS**) is the Canadian system for communicating information about the safety requirements for working with chemicals. The main components of WHMIS are:

- a labelling system consisting of eight specialized safety icons (see below)
- training programs for people who work with chemicals
- **Material Safety Data Sheets** (**MSDS**) providing information about chemicals

compressed gas

flammable and combustible material

oxidizing material (increases risk of fire)

poison and infectious material causing immediate and serious toxic effects

poison and infectious material causing other toxic effects

biohazardous infectious material

dangerously reactive material

corrosive material

People who work with chemicals are required to take WHMIS training with varying frequencies depending on their jobs. It is possible that you or some of your classmates may have taken WHMIS training for a part-time job. Your chemistry teacher has certainly had WHMIS training.

As a condition of sale, a Material Safety Data Sheet (MSDS) must be provided with every chemical purchased in Canada. Your chemistry teacher has a binder full of these sheets containing hazard information and safety procedures associated with each and every chemical in your science stock rooms and elsewhere in the school.

Quick Check

An excerpt from an MSDS for hydrochloric acid solution follows the questions below. This is only an excerpt. An actual MSDS may contain more than 15 sections, each of which may be quite detailed. Read this abbreviated excerpt carefully and answer these questions.

1. What WHMIS labels would you expect to find on hydrochloric acid?

_____

2. Give a synonym for hydrochloric acid.

_____

3. What are the chemicals that make up hydrochloric acid?

_____

4. What are the hazards of spilling hydrochloric acid on the skin?

_____

5. How should you treat a person who has ingested hydrochloric acid?

_____

Material Safety Data Sheet

1. Product Identification

- Hydrochloric Acid
- Synonym: Muriatic Acid

2. Composition/Information on Ingredients

- Hydrogen Chloride 38% by weight
- Water 62% by weight

3. Hazards Identification

- Potential acute health effects
  - Skin Contact: Corrosive, irritant, permeation causing itching, reddening, scaling, or blistering
  - Eye Contact: Corrosive, irritant causing redness, watering, and itching
  - Inhalation: Irritation of respiratory tract, coughing, choking, or shortness of breath
- Potential chronic health effects
  - May be toxic to: kidneys, liver, mucous membranes, upper respiratory tract, skin, eyes, circulatory system, and teeth

4. First Aid Measures

- Eye contact: Remove contact lenses, rinse with cold water for 15 minutes, get medical attention immediately.
- Skin contact: Remove effected clothes, rinse with cold water for 15 minutes, get medical attention immediately.
- Inhalation: Remove to fresh air, if breathing is difficult; give oxygen, if not breathing; give artificial respiration.
- Ingestion: If swallowed, do not induce vomiting, loosen tight clothing, get medical attention immediately.

5. Handling and Storage

- Storage: Keep container tightly closed in a cool, well-ventilated area.

6. Stability and Reactivity Data

- Is highly reactive with metals.
- Reactive with oxidizing agents, organic materials, alkalis and water

Household Hazardous Products Labels

The Consumer Chemicals and Containers Regulations (CCCR) require specific packaging and lab
of **household products**. There are only four different household labels. These labels may be bor
in two different ways. The border indicates whether the label refers to the *container* or th
within the container. The octagonal border refers to the contents of the labelled container while
triangular border refers to the container itself. The latest household labels are as follows:


corrosive product


flammable product


poisonous product


explosive container

Quick Check

What household labels would you expect to find on a container of muriatic acid?

Safety in the Chemistry Lab

Safety Equipment

Every chemistry laboratory has a number of items "built in" to the facility for use in case of an
or simply to ensure the safest laboratory operation possible. It is important to know the locati
instructions for operation of each of these items. Table 1.1.3 summarizes important informati
each of these important pieces of equipment.

If you think you might need to use any of the equipment in this table for an emergency
hesitate. Call out to inform others of the situation and immediately use the equipment as inst
Note that any accident requiring the use of the eyewash station, safety shower, or fire blanke
serious enough that medical attention should be sought quickly after using the equipment.

Table 1.1.3 *Laboratory Safety Equipment*

Safety Equipment	Information Regarding Operation
Fume hood	• Enclosed area equipped with fans to draw vapours out of the hood and vent them outside • May contain gas jets, sinks, lights, and electrical outlet • Enclosed by a sliding safety glass window • May store chemicals emitting toxic fumes • Useful for venting odours, smoke, and toxic fumes
Eyewash station	• If a chemical is splashed or spilled into the eyes, they should be held open and rinsed continuously for 10 to 15 min. Contact lenses should be removed. • Eyewash stations may be operated by pushing on a hand bar and/or a foot pedal. • Some labs may use a squeeze bottle apparatus or a piece of rubber tubing attached to a sink.
Safety shower	• Spills over a large portion of the body require removal of clothing and washing of the entire region for 10 to 15 min under the safety shower. • Safety showers are operated by pulling on a ring that will begin the flow of some 200 L of water over a drained area of the lab.

Fire extinguisher	• Small fires such as those that occur in a beaker or a crucible usually may be smothered by placing a ceramic pad or cover on top.
	• If a larger fire occurs, pull the safety pin from the top of the extinguisher, point the hose at the base of the fire, and squeeze. Extinguishers operate by depriving the fire of oxygen and by lowering the temperature.
	  • There are five classes of fires:
	  • Type A: wood or paper
	  • Type B: oil or grease (most chemicals)
	  • Type C: electrical equipment
	  • Type D: metals (such as magnesium)
	  • Type E: radioactive materials
	• Most extinguishers contain carbon dioxide and are good for class A, B, and C fires.

Fire blanket	• A fire extinguisher should *never* be used on a person. • *STOP, DROP, and ROLL* is the best way to extinguish a fire involving a person. A fire blanket may be used in combination with this process to smother the fire. • Fire blankets may be enclosed in a box or a cylindrical container attached to a wall, or they may be upright. An upright blanket may be wrapped around the victim while he or she is standing.
Emergency gas shut off	• The emergency gas shut off valve allows *all* gas outlets in the laboratory to be shut off at once. • To use the shut off, turn a handle so it is perpendicular to the gas line or simply push a large red button. • At the end of the day, this valve should always be left in the off position.
Spill control station	• Spill control stations contain absorbent pillows to soak up spills, safety goggles and gloves, and chemicals to neutralize acid and base spills. • Some labs simply have the neutralizing chemicals stored in a dedicated area. • Acid spills should be neutralized with sodium bicarbonate or baking soda. • Base spills should be neutralized with acetic acid or vinegar. • Neutralization is only necessary for large spills of concentrated reagents. Smaller spills may simply be diluted with water and wiped up with paper towel.

First aid kit	• All labs should have access to a first aid kit. The kit may be stored in a common storage area adjacent to the lab so that all teachers have easy access. • Such a kit should contain an antibiotic cream or ointment and plenty of bandages. • Burns are the most common injury in the chemistry lab. While ice followed by cold water is generally enough, the kit may contain a topical anesthetic cream. It is critical to ensure a student has no anesthetic allergies before using such a product. • Avoid burns from hot glass or metal by bringing your hand near the object first to test for heat. • Small cuts closely follow burns on the list of chemistry lab injuries. These may be treated with the antibiotic cream and a bandage.
Glass disposal container	• Broken glass should never be placed in the garbage can as this presents a hazard to the custodian. • A plastic bucket or a specially designated recyclables box can be found on a counter or the floor for the disposal of broken glassware or glass tubing.
Chemical disposal	• Containers clearly marked "Chemical Disposal" should be used for disposing solutions or precipitates containing heavy metals or any other toxic chemicals. • Some organic waste may release toxic fumes. Such waste often warrants its own container, which may be covered and/or placed in the fume hood. • Some chemicals such as dilute solutions of acids and bases and non-toxic salts may be flushed down the sink with plenty of water. • The ultimate judge of correct chemical disposal is, of course, your lab instructor.
Fire alarm	• Though it may be in the hall outside of your lab, you must know where the fire alarm is located.

Quick Check

1. How would you deal with each of the following accidents should it occur during a lab you are performing this year?

   (a) While heating a small amount of alcohol in a beaker, it bursts into flame.

   (b) Your partner hands you a piece of hot glass they've just bent after heating over a Bunsen burner.

   (c) A test tube full of concentrated hydrochloric acid is dropped and broken on the floor.

2. How could you have prevented each accident from happening to begin with?

Safety Procedures

Any time you know you will be working in the laboratory, it is important to arrive fully prepared to perform all work as safely as possible. We call this *lab preparedness*. The following are some things you should always do *before* you begin doing a lab.

- Read the entire experiment carefully, paying close attention to any safety issues. Prepare any data tables that may be required. Your teacher may ask you to prepare an abstract (summary) or a flow chart before you arrive for lab.
- Clear all binders, backpacks, book bags, coats, etc. away from your work area.
- Always wear eye protection during the laboratory period.
- Wear lab aprons or lab coats if available.
- Tie back long hair to keep it away from flames or chemicals.
- Secure loose sleeves or jewellery to keep them away from flames or chemicals.
- Consider wearing clothing made of natural fibres such as cotton and wool, as those are the most fire resistant fibres.
- Do not wear open-toed shoes during laboratory work.
- Be sure all equipment is in good working order. Do not use chipped glassware or damaged electrical equipment.
- Never attempt laboratory procedures without your instructor's permission and direct instruction.

Laboratory Technique

There are several things that all good chemists know about using equipment and chemicals in the lab. We refer to these things as *proper laboratory technique*.

- Always approach lab work with a business-like attitude and keep voices kept to a reasonable volume.
- Do not consume food or drink or chew gum during laboratory period.
- Never touch or taste chemicals.
- Never inhale chemicals directly. Use your hand to sweep odours toward you.
- Bring your hand near metal or glass to test for heat. Handle hot equipment with appropriate tongs, test tube holders, or mitts.
- Never use open flames around flammable materials. Use a hot plate or mantle.
- Clamp test tubes near the top and hold at a 45° angle with constant motion and the end pointed away from everyone during heating.
- Never pipette liquids directly by mouth.
- Never leave heat sources unattended. Turn off Bunsen burners and hot plates when not in use.
- Read the labels on all chemicals at least twice. Always grasp bottles on the label side so that drips do not obscure the label.
- Always use an appropriate lubricant such as glycerin or saliva when inserting glass tubing or thermometers into rubber stoppers.
- When diluting chemicals, always begin with water. It is particularly important to add acid to water, never the other way around.

Laboratory Clean Up

Last, but not least, there are a number of things that relate to **laboratory clean up**. Some of these things may be related to accidents that occur in the lab. Others simply relate to leaving the lab in as good, or better, condition than you found it.

- Sweep broken glassware into a dustpan and place it in the proper disposal container. Always notify neighbours of any broken glass.
- Clean up spilled chemicals immediately as outlined in Table 1.1.3. Be sure to notify neighbours of any chemical spill.
- Never return unused chemical to the original stock bottle. Either share it with another student or properly dispose of any excess.
- Always wash glassware well with soap and a proper brush, then rinse it, and leave it to air dry.
- Rinse your hands well following the use of any chemicals. Wipe your lab bench with a damp paper towel when you have completed your lab.
- Clean up should begin with a reasonable amount of time to allow all equipment to be washed well and replaced in the appropriate spot.
- For experiments that run for more than one period, clearly label all materials and leave them in the appropriate place as instructed by your teacher.

1.1 Activity: Safety in the Laboratory

Question

Where is the safety equipment located in your chemistry laboratory?

Procedure

1. In the space below, draw an outline map of your chemistry laboratory, including every item in Table 1.1.3.

2. Add at least five more items that contribute to safety in your lab.

1.1 Review Questions

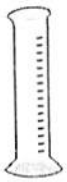
1. Where is the closest fire alarm to your chemistry laboratory?

2. Outline the route you should follow in case of a fire alarm while you are in chemistry class.

3. How many fire extinguishers are in your laboratory? What are their classifications?

4. Knowing you have lab on a particular school day, describe how you should dress.

5. Give the *name* and *use* of each of the following pieces of equipment:


6. List three things you should do before beginning any chemistry experiment.

7. Give three uses for the fume hood.

8. What is the most common injury in the chemistry lab? How might you avoid this injury? How would you treat this injury?

9. How would you assist your lab partner in each of the following cases?
   (a) Partner has spilled a chemical into his or her eyes.

   (b) Partner's clothing has caught fire.

   (c) Partner has spilled concentrated acid onto the floor.

   (d) Partner took more chemical than required for the lab.

   (e) Partner has broken a test tube on the floor.

10. What is the meaning of each of the following labels?





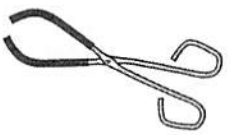
11. Outline a three-step procedure for cleaning glassware at the end of the period.

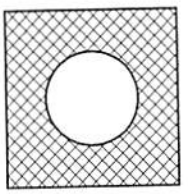
12. Why should long hair always be secured back during lab?

13. Why do you suppose food and drink are not allowed during lab?

14. What do you think is safer: the laboratory or your kitchen? Explain why.

15. Give the name and use of each of the following pieces of equipment:





16. Where should binders, book bags, and backpacks be stored during the lab?

17. What is an MSDS? Where might an MSDS be found in your school?

18. Where would you dispose of each of the following?
(a) a few milliliters of excess dilute acid

(b) a sample of heavy metal precipitate

(c) an excess piece of glass tubing

(d) used litmus paper

(e) a few milliliters of excess acetone (nail polish remover)

19. What is the meaning of each of the following labels?

20. Give four things to keep in mind while heating a test tube half-filled with liquid.