UNIT

A

Energy and Matter in Chemical Change

A technician (lower right) monitors reactions in a factory that produces chemicals for the pharmaceutical industry.

In this unit, you will cover the following ideas:

A 1.0 **The understanding that particles make up the underlying structure of matter has led to advancements in technology.**

A 2.0 **Elements combine to form many substances, each with its own set of properties.**

A 3.0 **Chemical change is a process that involves recombining atoms and energy flows.**

Focus on the Nature of Science

In this unit, you will study transformations of matter in chemical changes and the role that energy plays in these changes. You will learn to identify and classify chemical changes, and write word and balanced chemical equations for significant chemical reactions. As you work through this unit, think about the following questions:

1. How has knowledge of the structure of matter led to other scientific advancements?
2. How do elements combine? Can these combinations be classified, and can the products be predicted and quantified?
3. Why do scientists classify chemical change, follow guidelines for nomenclature, and represent chemical change by equations?

At the end of the unit, you may be asked to do these tasks:

Case Study Air Quality

In this case study, you will analyze some of the factors that affect air quality. Based on your analysis, you will recommend legislation that should be developed to address one of these factors.

Project Classifying Chemical Reactions Involving Magnesium

For the project, you will perform tests to distinguish between several types of chemical reactions. By noting the reactants and observing the chemical changes, you will classify the reactions and write balanced equations to describe them.

Exploring

Burning methane hydrate, a compound of ice and methane (natural gas)

Locations where methane hydrates have been discovered

Ice burning like a candle! Is this a trick photograph? No, this substance is called methane hydrate, and it's a combination of ice and natural gas (methane). Found at depths of 500 m to 3000 m, it forms under conditions of cold and great pressure. Methane is a molecule made up of atoms of carbon and hydrogen. (A molecule is a group of atoms bonded together.) In methane hydrate, the methane molecules are trapped in tiny cages formed by molecules of water freezing together to form ice.

Methane hydrate is no mere curiosity. It has now been discovered under the seabed at the edges of every continent in the world and under the arctic permafrost. It is the most abundant hydrocarbon in the world. An estimated 10 to 25 thousand billion cubic metres of natural gas is trapped in methane hydrate. This is greater than the total of all known coal and petroleum reserves.

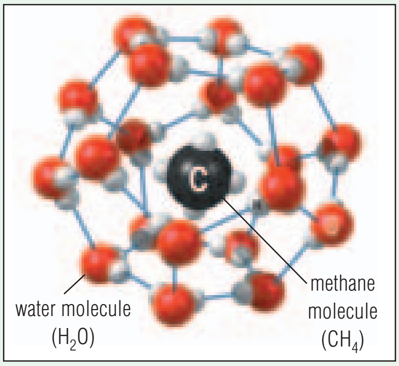
In 2002, a group formed by the Canadian Geological Survey, the Japanese National Oil Company, and agencies from the United States, Germany, and India demonstrated the first commercial extraction process for methane from methane hydrate deposits in the Northwest Territories. Hot water piped underground melted the ice and released the methane. Why has this only been done recently? The total amount of methane is vast, but it is not very concentrated when compared with conventional sources of methane and oil. That makes it more expensive to extract.

This vast new energy source raises many issues. Here is a low-cost, plentiful supply of natural gas that could be exploited commercially. But would we want to do so? Methane is a greenhouse gas. When it is burned it produces carbon dioxide, another greenhouse gas. Do we want to continue using substances that could contribute to climate change?

An interesting aspect of methane hydrate is that it may already have had a significant impact on global climate. It might be a controlling factor in the ice age cycle. Scientists know that in the past, vast amounts of ice formed on the continents over thousands of years, but then melted in several hundred years. A large release of methane hydrate may have been responsible for the end of the ice ages.

The hypothesis works like this. During an ice age, water evaporates from the oceans and freezes in glaciers on land. Sea level drops. Less water in the oceans means less pressure on the methane hydrate under the ocean floor. At some point, this pressure drops below a critical value, and a worldwide release of methane gas occurs. A massive amount of methane in Earth's atmosphere would have caused sudden global warming, ending the ice age. It is known that at the end of the last ice age 14 000 years ago, sea levels were 100 m lower than they are today. The ice age ended abruptly in North America at that time. Temperatures increased and sea levels rose.

Is the role of methane in ending ice ages a scientific fact? No, it is a hypothesis that needs evidence to support or disprove it. Scientists continue to do research on methane hydrate, sharing ideas and individual insights.



Methane hydrate

Activity A1

QuickLab

Combustible Bubbles

(Teacher Demonstration)

A safe and interesting chemical reaction is the combustion of hydrogen gas inside a soap bubble. Note that safety glasses are necessary, but gloves are not—even if you are holding the bubble in your hand when you light it.

Purpose

To observe the combustion of hydrogen and oxygen in a soap bubble

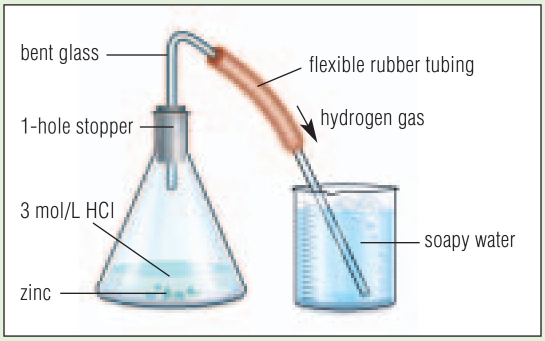
Materials and Equipment

- soapy water (use liquid dishwashing soap)
- hydrochloric acid (3 mol/L)
- 5 g mossy zinc
- 400-mL beaker
- 50-mL graduated cylinder
- Erlenmeyer flask
- one-holed rubber stopper with glass fitting and flexible rubber tubing
- candle

Procedure

Part 1: Getting Ready (Your teacher will do this part.)

1. Fill the beaker with soapy water.
2. Set a lit candle in a handy place near the apparatus.
3. Place 20 mL of hydrochloric acid in the Erlenmeyer flask, and drop in 5 g of mossy zinc. Place the rubber stopper–tubing set on the flask, and place the end of the tubing in the soapy water, as shown in the diagram.



Apparatus for generating hydrogen gas

4. Use the hydrogen gas to blow a soap bubble. Sometimes, it helps to pick one of the larger bubbles and blow hydrogen gas directly into that.

   Important: Place the end of the tubing back under water before lighting the soap bubble.

CAUTION: Never light the hydrogen gas coming directly out of the generator. It will backflash into the flask, causing it to shatter.

Part 2: Causing Hydrogen Combustion

5. Place your hand into the water under a large hydrogen bubble and carefully lift the bubble out onto the palm of your hand.
6. Bring the bubble over to the candle flame. Watch as the bubble ignites.

Question

1. Suppose you could put both hydrogen gas and oxygen gas together into the soap bubbles. How do you think this would affect the way the bubbles ignite?

UNIT A

1.0

The understanding that particles make up the underlying structure of matter has led to advancements in technology.

Key Concepts

In this section, you will learn about the following key concepts:

- Workplace Hazardous Materials Information System (WHMIS) and safe practices
- evidence of chemical change
- how chemical substances meet human needs

Learning Outcomes

When you have completed this section, you will be able to:

- illustrate an awareness of WHMIS guidelines, and demonstrate safe practices in the handling, storage, and disposal of chemicals in the laboratory and at home
- identify examples of how early humans worked with chemical substances to meet their basic needs
- outline the role of evidence in the development of the atomic model consisting of nucleons (protons and neutrons) and electrons through the work of Dalton, Thomson, Rutherford, and Bohr
- describe evidence for chemical change

FIGURE A1.1 All the materials we wear and use result from the various ways that atoms combine. These combinations form substances with different properties.

Our world is full of a rich and complex variety of materials, both natural and manufactured. Cotton and wool fabrics clothe us. Precious jewels decorate our bodies. Metal and concrete form skyscrapers. Plastics are everywhere. We wear them; we eat off them; and we drive in them. They are one of the most commonly used materials in the world today.

People have discovered and taken advantage of different properties of materials for thousands of years. To do this, they have invented a variety of chemical technologies.

In this section, you will begin by reviewing lab safety rules and safety symbols. Then you will review the differences between physical and chemical properties of substances and how to recognize chemical reactions. You will also read about various ways in which early human societies discovered and used naturally occurring materials. Finally, you will learn how an understanding of matter developed gradually over the centuries, and how experimental evidence led to changing models of the atom.

A 1.1 Safety in the Laboratory

Safety must be an essential part of all your science studies. Your safety and the safety of your classmates and your teacher are of the highest importance.

Safety depends on awareness, knowledge, and action. You must be aware of known hazards and alert to the possibility of unforeseen ones. You must know how to use the right equipment and what to do in an emergency. But knowing isn't enough. Ultimately, it's what you *do* that makes the difference to your being an asset or a liability to others. Fooling around is forbidden. Everyone in the class must act safely and responsibly.

Working in the science laboratory involves taking precautions and minimizing hazards. For example, to avoid poisoning, we take the precaution of never eating in the lab. We also minimize the chance of poisoning by washing our hands. We avoid scalding by keeping far enough away from beakers with boiling water so that, even if they break, the water will not reach us. If we must move a beaker of hot water, we make sure to inform others so they can stay out of the way, and we use the correct kind of tongs for lifting.

Eye safety, in particular, is critically important. The eye's surface is very fragile tissue, and damaging it can have life-long consequences. Regular eyeglasses are not enough protection. Eyewear approved by your teacher will have side shielding and other safety features.

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According to the Alberta Department of Human Resources and Employment, workers with less than six months of experience are three times more likely to be injured than those with a year or more of experience. Young workers are 33% more likely to be injured on the job than older workers.

Understanding the Rules

Safety rules also help you minimize the risks of working in the lab. It's important to understand and follow the list of safety rules below. Your teacher will discuss any other specific rules that apply to your classroom. For more information on lab safety, see Student Reference 1: Safety.

Science Laboratory Safety Rules

1. Read all written instructions carefully before doing an activity.
2. Listen to all instructions and follow them carefully.
3. Wash your hands thoroughly after each activity and after handling chemicals.
4. Wear safety goggles, gloves, or an apron as required.
5. Think before you touch. Equipment may be hot and substances may be dangerous.
6. Smell a substance by fanning the smell toward you with your hand. Do not put your nose close to the substance.
7. Do not taste anything in the lab.
8. Tie back loose hair and roll up loose sleeves.
9. Never pour liquids into containers held in your hand. Place a test tube in a rack before pouring substances into it.
10. Clean up any spilled substances immediately as instructed by your teacher.
11. Never look into test tubes or containers from the top. Always look through the sides.
12. Never use cracked or broken glassware. Make sure you follow your teacher's instructions when getting rid of broken glass.
13. Label any container you put chemicals in.
14. Report all accidents and spills immediately to your teacher.
15. Read the WHMIS (Workplace Hazardous Materials Information System) safety symbols on any chemical you will be using and make sure that you understand all the symbols. See Student Reference 1 at the back of this book.

FIGURE A1.2 Hazard symbols indicate both the type of hazard and the degree of hazard.

Safety Hazard Symbols

The first step in doing any science activity is to read the procedures all the way through to make sure you understand them. Carefully note any "Caution" boxes containing specific safety warnings. All activities in this text that require special precautions have safety icons next to the "Materials and Equipment" heading. These icons will alert you when you need to wear safety goggles, gloves, or an apron, and when you must be careful handling glassware.

The next step before beginning an activity is to check the warning symbols in the list of materials you will be using. Also check for hazard symbols on the containers of these materials. All hazardous materials have a label showing a hazard symbol. You may have seen these labels on chemical substances in your kitchen or garage. For example, window cleaner may contain ammonia, which is toxic and corrosive. Spray paint cans show labels warning that they are flammable and explosive.

Each hazard symbol shows two pieces of information:

- the degree of hazard, indicated by the shape and colour of the border. The degree increases from a yellow triangle meaning "caution," to an orange diamond meaning "warning," to a red octagon meaning "danger."
- the type of hazard, indicated by a symbol inside the border

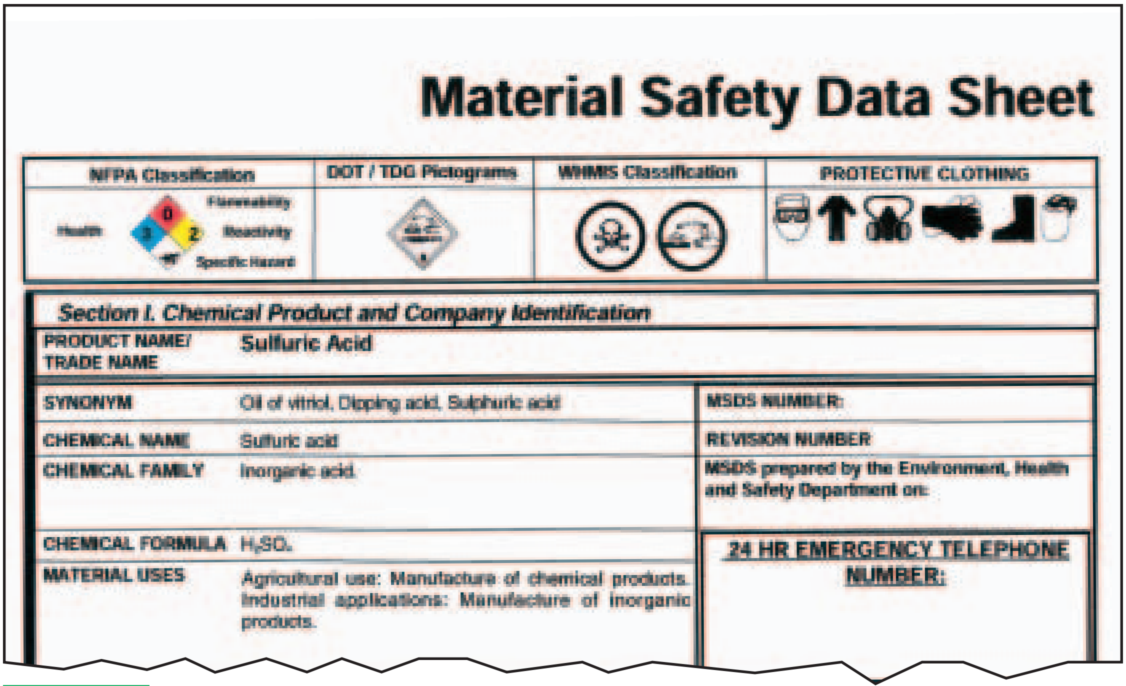
Examples of these hazard symbols are shown in Figure A1.2. Figure A1.3 shows an example of hazard symbols on a common household product.

FIGURE A1.3 This spray paint is both flammable and explosive.

WHMIS

The **Workplace Hazardous Materials Information System (WHMIS)** is another system of easy-to-see warning symbols on hazardous materials, shown in Figure A1.4. These eight symbols are designed to help warn and protect people who use hazardous materials at work. You will see the symbols for dangerously reactive material, corrosive material, and poisonous material next to the names of some of the chemicals you will be using in this unit. Follow your teacher's instructions in carefully handling and disposing of all chemicals.

FIGURE A1.4 WHMIS symbols



Material Safety Data Sheet

NFPA Classification	DOT / TDG Pictograms	WHMIS Classification	PROTECTIVE CLOTHING
Health 3, Flammability 0, Reactivity 2, Specific Hazard			

Section I. Chemical Product and Company Identification

PRODUCT NAME/ TRADE NAME	Sulfuric Acid		
SYNONYM	Oil of vitriol, Dipping acid, Sulphuric acid	MSDS NUMBER:	
CHEMICAL NAME	Sulfuric acid	REVISION NUMBER	
CHEMICAL FAMILY	Inorganic acid	MSDS prepared by the Environment, Health and Safety Department on:	
CHEMICAL FORMULA	H_2SO_4	24 HR EMERGENCY TELEPHONE NUMBER:	
MATERIAL USES	Agricultural use: Manufacture of chemical products. Industrial applications: Manufacture of inorganic products.		

FIGURE A1.5 An MSDS provides information about a specific chemical.

Material Safety Data Sheets

In Canada, manufacturers of all hazardous products used in workplaces, including schools, must provide information sheets about their products. The **Material Safety Data Sheet (MSDS)** identifies the chemical and physical hazards associated with each substance. It includes physical data, such as melting point and boiling point, toxicity, health effects, first aid, and spill and leak cleanup procedures. WHMIS regulations require employers to make these sheets available to employees who use hazardous substances in their work. Figure A1.5 shows an example of an MSDS for a substance that you might use in a science activity.

Minds On... Reading an MSDS for Household Bleach Solution

Your teacher will give you a copy of an MSDS for bleach solution. Use this MSDS to answer the following questions.

1. List three synonyms for the name “bleach.”
2. Bleach solution has two ingredients. What are they? Which of these ingredients are hazardous?
3. Find the hazard identification section. Under “Emergency Overview,” there is a short summary. Find the summary and record it.
4. Read the list of potential health effects. Copy down the potential health effect caused by eye contact.
5. Find the section under “First Aid Measures” and record the instructions for what to do in case of eye contact.
6. If a fire were to break out near bleach, should the bleach itself be considered a fire hazard? What special equipment is required to fight a fire in which bleach is present?
7. Suppose someone drank bleach. Should the first aid procedure include inducing vomiting to get the solution out of the person? What other treatments are possible?
8. Find out what is meant by the term “chronic exposure.”

reSEARCH

If you have a job, find out what questions you should be prepared to ask your employer about your safety on the job. Also find out the answers you should expect to get. Begin your search at www.pearsoned.ca/school/science10

The Most Important Safety Feature

You are the most important safety feature in the lab. If you or your classmates do not behave safely, all the safety information, equipment, and procedures will not protect you. Know how and when to use safety equipment in your science lab. Be aware that emergencies can happen suddenly and unexpectedly. Spend some time working out emergency scenarios, and decide in advance what needs to be done. Know where the safety equipment is and where the MSDSs are.

Activity A2

Decision-Making Investigation

Student Reference 4, 9

Required Skills
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Chemical Information

Begin your search at www.pearsoned.ca/school/science10

The Issue

You will be given a list of the top 20 chemicals by volume produced in North America. Most of these chemicals have hazards of some sort associated with them. Your teacher will assign you one of these chemicals to research.

Background Information

Using the Internet or other information resources, find an MSDS for your chemical. Look for the basic safety information about it. In particular, investigate chronic and acute hazards, and handling procedures. Look up the terms "chronic" and "acute" if you do not know what they mean.

Using the Internet, find out some of the important uses of your chemical and whether debate exists about its manufacturing, use, transportation, or disposal. Is there any concern about this chemical in your community?

Many debates over chemical use are quite complicated. Try to find a balance of opinions representing a variety of viewpoints.

Analyze and Evaluate

1. From your research, do you think your chemical would be safe to use in the home and in the lab? Explain.
2. Prepare an information pamphlet or a poster that can be read easily from a distance of about 1 m. Set up your poster in three parts:
   a) Description: the chemical's name or names, its ranking by volume, relevant safety information, and most common uses
   b) Issues About Its Use: any special considerations or regulations about its use; any issues related to its use, storage, or disposal. Try to give a variety of perspectives.
   c) Conclusion: conclusions you have drawn about this chemical; suggestions for further information needed to help people decide about using this chemical

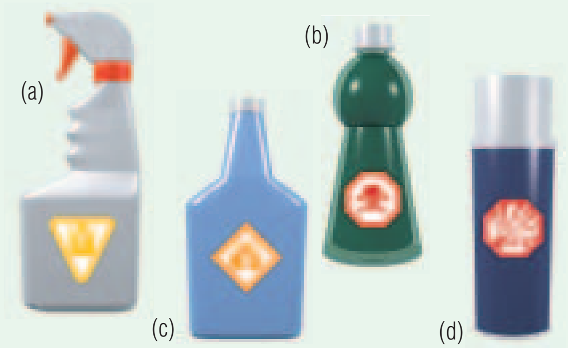
Environmental Safety

In Canada, many regulations govern the safe production, transport, storage, usage, and disposal of chemicals. One of the main reasons for these rules is the protection of the environment. A chemical release in the wrong place can kill plants and animals, contaminate a water supply, or lead to the entry of poisons into the food chain. For this reason, never pour any chemical down the sink unless your teacher gives permission first. If in doubt, ask or refer to a Material Safety Data Sheet. You will learn more about chemicals and the environment in section A2.5.

A1.1 Check and Reflect

Knowledge

1. Why is it important for all students to follow the safety rules in a science class?
2. List precautions used in the science laboratory to minimize the following risks:
   a) poisoning
   b) scalding
   c) eye damage
3. What does the hazard warning label mean on each of the chemical containers shown in the diagrams below? In your answer, specify both the type and degree of hazard.



Warning labels for question 3

4. Provide an example of a hazardous substance that you would find in the:
   a) kitchen
   b) bathroom
   c) garage
   d) garden
   e) automobile
5. What does WHMIS stand for?
6. What is a Material Safety Data Sheet? List three specific types of information that it provides.
7. List the steps you should take before starting a science activity.
8. Draw a sketch of your classroom or science lab indicating the location of all emergency equipment and exits.

Applications

9. Write the words "lab safety" in the middle of a page. Draw at least 10 lines radiating out from it. At the end of each line, list important ideas relating to safety in the science classroom.
10. What safety rules specific to your class has your teacher given you?
11. List the steps that you would need to take to help someone in the following scenarios.
    a) During cleanup after a lab, acid splashes in someone's eye.
    b) While using an open flame, someone's fuzzy sweater catches fire.
    c) While your partner is boiling water in a beaker, the fire alarm goes off.
    d) Your partner has just poured some bleach into what you thought was a beaker of water. You see many bubbles rapidly beginning to form throughout the mixture.

Extension

12. Read the labels of several hazardous household products where first aid treatment is described. What do the treatments have in common?

A1.2 Properties and Classification of Matter

How many dogs are there in the world? Even if you could find an accurate answer to this question, it would not tell you very much about dogs. You can learn much more about dogs by looking at their different classifications. Breeders have classified dogs into several hundred breeds. Each breed has unique markings, physical attributes, and personality types (Figure A1.6). The various breeds can be combined into a smaller number of groups that identify what they are used for, such as companion dogs or hunting dogs. Other ways of classifying dogs are based on their size or geographic origin.

Similarly, scientists use classification systems to help them work with the millions of compounds that have been discovered or synthesized. No one can possibly know more than a small fraction of them in detail. Chemists get around this problem by classifying compounds by their characteristics. They use several different classification systems, depending on which is most useful at the time. For example, all matter at room temperature (25°C) can be classified as solid, liquid, or gas. However, this system has limited usefulness. For example, bromine, mercury, and water are all liquids, but they have very few other properties in common. A more useful way to classify compounds is by their physical and chemical properties.

infoBIT

Why do prospectors carry hydrochloric acid? Gold and pyrite look very similar but only one of them is valuable. Pyrite is known as fool's gold because so many people have been fooled into thinking it was real gold. But the two minerals have different chemical properties. Pyrite dissolves in hydrochloric acid, and gold does not.

FIGURE A1.6 Organizing dogs into breeds helps to classify them. Each breed is recognized by certain characteristics.

Minds On... Classification

Sometimes, mixtures need to be separated into pure substances. The first step is to classify the components of the mixture according to their physical properties. The differences between these properties can be used to separate the substances. For example, in a mixture of water and sand, one is a solid and the other is a liquid, and they have different densities. Separating them is easy: simply let the mixture sit until the sand settles out. Working with your partner, develop a procedure to separate each of the following mixtures.

a) sugar, water, sand
b) table salt, aluminium filings, iron filings
c) vegetable oil, aluminium filings, table salt, water
d) water, table salt, sugar

Properties Used to Classify Substances

Physical properties describe the physical appearance and composition of a substance. Table A1.1 lists common physical properties used for classifying substances.

TABLE A1.1 Common Physical Properties Used for Classifying Substances

Physical Property	Description
boiling point or condensation point	temperature of boiling or condensing
melting point or freezing point	temperature of melting or freezing
malleability	ability to be beaten or rolled into sheets without crumbling
ductility	ability to be stretched without breaking
colour	colour
state	solid, liquid, gas
solubility	ability to dissolve
crystal formation	crystalline appearance (Figure A1.7)
conductivity	ability to conduct heat or electricity
magnetism	magnetic attraction between objects (iron, cobalt, and nickel, and electromagnets)

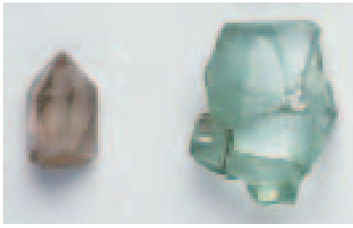


FIGURE A1.7 The formation of crystals is a physical property that can be used to classify substances. On the left is a typical crystal formed by the mineral quartz ($SiO_{2(s)}$). Glass (right) is an amorphous substance: it never forms crystals.

Chemical properties describe the reactivity of a substance. For example, calcium reacts vigorously when placed in water (Figure A1.8). This is one of calcium's chemical properties. Table A1.2 lists some common chemical properties used for classifying substances.

TABLE A1.2 Common Chemical Properties Used for Classifying Substances

Chemical Property	Description
ability to burn	combustion (flame, heat, light)
flash point	temperature needed to ignite a flame
behaviour in air	tendency to degrade, react, or tarnish
reaction with water	tendency to corrode or dissolve
reaction with acids	corrosion, sometimes bubble formation
reaction to heat	tendency to melt or decompose
reaction to red and blue litmus	red—acid; blue—base; no colour change—neutral

FIGURE A1.8 Calcium reacts vigorously with water.

Pure Substances and Mixtures

Recall from science classes in other grades that matter can be classified as pure substances and mixtures (Figure A1.9). In a **pure substance**, all the particles that make up the substance are identical, so its chemical and physical properties are constant. A pure substance may be an **element** or a **compound**. Recall from grade 9 science that an element is a pure substance that cannot be broken down into other substances. It is a substance made up of only one type of atom. For example, both gold and helium are elements. A compound is a chemical combination of two or more elements in a specific ratio. For example, water is a pure substance made up of water molecules. Each water molecule consists of two hydrogen atoms and one oxygen atom. Its formula is $H_2O_{(l)}$. Water's properties are constant: it is a liquid at 25°C. It freezes at 0°C, and it boils at 100°C at sea level.

A **mixture** is a combination of pure substances. The proportions of the pure substances in a mixture vary, so the properties of the mixture vary as well. For example, the sweetness of lemon juice increases as the proportion of sugar in it increases. In a **mechanical mixture**, such as soil, the different substances are visible. It is also called a **heterogeneous** mixture. (The prefix "hetero-" means "different.") A **suspension** is another kind of mechanical mixture, where the components are in different states. For example, mud is a suspension of dirt in water, and a sandstorm is a suspension of sand in air. A **colloid** is similar to a suspension but the suspended substance cannot be easily separated from the other substance.

In some mixtures, the separate components are not visible. These are **solutions**. They are called **homogeneous** mixtures because they look the same throughout. (The prefix "homo" means "same.") In a solution, one substance is dissolved in another. For example, a soft drink is a solution composed mainly of sugar dissolved in water.

Mixtures such as paint, glue, and motor oil are important materials. However, they can be difficult to classify because they are not pure substances and do not have constant properties. Pure substances are much easier to classify. Elements are classified in the periodic table, and many compounds can be classified either as ionic or molecular. Another important method of grouping compounds is as acids, bases, or neutral solutions. You will learn more about acids and bases in section A2.4.

*info***BIT**

Paint is a heterogeneous mixture that contains at least three components: pigment, resin, and solvent. The tiny bits of pigment provide the colour and float in a mixture of resin and solvent. The resin forms a film to hold the pigment in place when dry. The solvent keeps the paint liquid until it is applied. Most paints are toxic until dry.

FIGURE A1.10 Paint is a heterogeneous mixture.

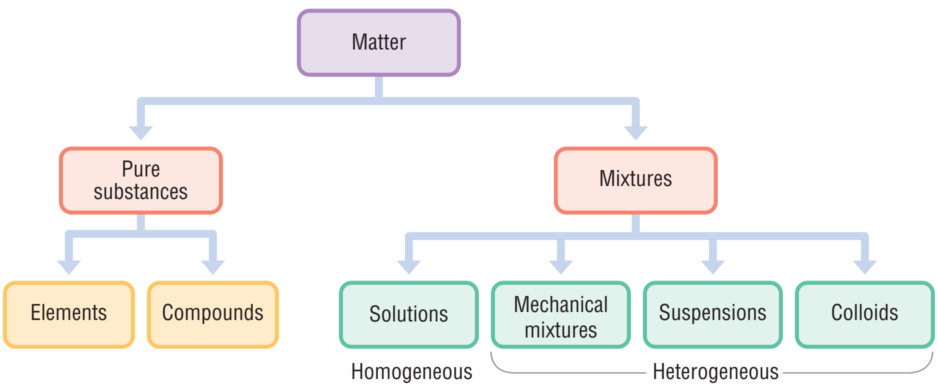


FIGURE A1.9 Classification of matter

You can identify pure substances by observing their physical and chemical properties. The melting point, boiling point, state, and colour of a substance are examples of physical properties. A physical property is measured without changing the identity or composition of a substance. For example, to find the melting point of water, you could heat a block of ice until it melts. The melting point is the temperature at which the ice changes to liquid water (0°C). The liquid water differs from ice in appearance, but it has the same composition. The formula of the ice, $H_2O_{(s)}$, is the same as the formula of the liquid water, $H_2O_{(l)}$. In fact, we can freeze the liquid water to obtain the ice again.

Chemical Reactions

To observe a chemical property, you must see a chemical change. For example, one of the chemical properties of hydrogen gas is that it can combine chemically with oxygen to form water. To observe this property, we must burn hydrogen with oxygen. Through the chemical change, the original hydrogen gas disappears, and a new substance, water, takes its place. (The oxygen gas also disappears.) We cannot recover the hydrogen easily from the water by any physical means, such as melting or boiling. In another example, an iron nail rusts from contact with water and air. This tendency of iron to corrode when wet is one of its chemical properties. This property can be used to distinguish iron from less reactive metals, such as platinum.

A chemical change is more formally called a **chemical reaction**. A chemical reaction is a process that occurs when a substance or substances react to create a different substance or substances. Chemical reactions always involve the production of new substances with their own physical and chemical properties. As well, energy is always absorbed or released during a chemical reaction.

Skill Practice — Preparing for a Lab Activity

In Activity A3, you will complete and observe several chemical reactions. Chemical reactions may produce gases. Solids (called **precipitates**) may form when two solutions are mixed. Colour changes may occur. Two solutions that are clear and colourless may produce an opaque, or light-blocking, precipitate. The precipitate may look cloudy and may be white or some other colour. Temperature changes may occur, which can sometimes be detected just by wrapping your fingers around the test tube.

1. Define or describe each of the following terms, which you may use in your observations:
   a) precipitate
   b) homogeneous
   c) heterogeneous
   d) opaque

2. Many solutions are coloured, but many are not. Distinguish between the terms "clear" and "colourless."

3. Observations describe a fact or facts. Interpretations explain a fact or facts. Which of the following are observations, and which are interpretations? If you think you need more information to decide, state what else you would need to know.
   a) Mixing the two chemicals caused the production of a white precipitate.
   b) The white precipitate was silver chloride.
   c) The solution began to boil.
   d) The solution began to form bubbles.
   e) Mixing the two chemicals caused a gas to be produced.

Activity A3

Inquiry Lab

Student Reference 2

Required Skills
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Evidence of Chemical Change

The Question

What observable changes happen when a chemical reaction occurs?

Materials and Equipment

1 piece of zinc metal
dilute hydrochloric acid
sodium hydroxide solution
phenolphthalein indicator
2 pieces of magnesium metal strip
dilute sulfuric acid
bromothymol blue indicator
sodium chloride solution
silver nitrate solution
iron(III) chloride solution
vinegar
7 test tubes in test tube rack
candle
matches

CAUTION: Acids and bases can burn. If any spill, wash immediately with cold water.

Procedure

1. Read through the procedure and make a data table that includes space for the eight reactions in step 2. For each reactant, you will record its observable characteristics before the reaction, including colour and state (solid, aqueous). In your table, you will also record changes that you observe when you mix the reactants. Remember to give your table a title.

2. At the top of the right column is a list of pairs of reactants from (a) to (h). For each pair, record your observations about each reactant. For (a) to (g), carefully mix each pair in its own test tube. For (h), carefully light the candle. Observe the results, and record as many observations about chemical change as you can.
   a) zinc metal and hydrochloric acid
   b) sodium hydroxide solution and phenolphthalein indicator
   c) magnesium metal strip and dilute sulfuric acid
   d) hydrochloric acid and bromothymol blue indicator
   e) sodium chloride solution and silver nitrate solution
   f) iron(III) chloride solution and sodium hydroxide solution
   g) magnesium metal strip and vinegar
   h) candle wax and oxygen

3. Your teacher may instruct you to add some tests by mixing any two of the substances in the materials section in combinations that were not tried in step 2. Do not mix any substances unless instructed to by your teacher. Record observations that may indicate that a reaction, if any, has occurred.

4. Follow your teacher's instructions for disposing of the substances you have used.

Analyzing and Interpreting

1. Consider those reactions in which a metal was placed in an acidic solution, such as reaction (a). Were the reactions similar in any way?

2. Consider any reaction in which a solid (or cloudiness) was produced. Is there anything similar about the reactants in each reaction?

3. What evidence is there that a burning candle involves a chemical reaction?

Forming Conclusions

4. List the types of observations you made in this activity that indicated that a chemical reaction had taken place.

Extending

5. List other types of measurements or experiments that could be done with the products to indicate that a reaction was occurring or that new substances had been produced.

Recognizing Chemical Reactions

Some chemical reactions are simple, and some are complex. All reactions share certain characteristics. These include:

- All reactions involve the production of new substances with their own characteristic properties. These properties include: state at room temperature, melting point, colour, and density.
- All reactions involve the flow of energy. This may be detected by a change in temperature.
- Many reactions cause a phase change, such as the formation of a gas (bubbles) or of a solid that appears as cloudiness in a previously clear solution.

You will learn more about chemical reactions in section A3.0.

reSEARCH

Besides the states of matter you are familiar with, there are less common states, known as "exotic" states. One example is the gas inside a fluorescent light bulb when the light is turned on. Research one of the following exotic states of matter: plasma, liquid crystal, the superconductive state, or other exotic state of your choice. Begin your search at www.pearsoned.ca/school/science10

A1.2 Check and Reflect

Knowledge

1. Define the following terms:
   a) boiling point
   b) malleability
   c) ductility
   d) solubility
2. State the observations that would lead to the following conclusions:
   a) A solid is forming.
   b) A gas is being formed.
   c) The temperature increases.
3. Water freezes at 0°C. At what temperature does it melt?
4. A blue crystal is placed in water. After much stirring, the crystal disappears and the water becomes blue. The liquid is then heated. Eventually, all the water evaporates and many small blue crystals appear. Has a chemical reaction taken place? Explain.
5. List two features common to all chemical reactions.

Applications

6. A waxy material is heated very slowly. Rather than melting at a particular temperature, it melts gradually over a range of temperatures starting at 52°C and finishing at 65°C. Is this material a pure substance or a mixture?
7. A black solid with a constant melting point is heated to a high temperature, producing a gas, and a shiny brown metal. The boiling point of the gas is measured at –183°C, and the melting point of the metal at 1085°C. Is the black solid an element, a compound, or a mixture? Explain.
8. Diamond is a pure substance and an element (carbon). Water is a pure substance and a compound. Suppose a number of diamonds are placed in water, and the water is then frozen. How should this material be classified?
9. Fresh milk separates spontaneously into cream, which floats to the surface with a watery layer below. Homogenized milk is made by breaking the cream into tiny droplets and mixing them into the rest of the milk. This prevents the cream from separating. Is homogenized milk homogeneous or heterogeneous?

Extensions

10. Find out whether homogenized milk is a suspension, a colloid, or a solution.
11. The formation of bubbles in a liquid may mean that the liquid is boiling. Or it may mean that a chemical reaction is producing a gas. List two ways to determine which is occurring: boiling or a chemical reaction.

info BIT

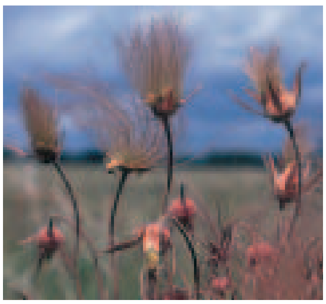
Ancient Egyptians may have been the world's first chemists. Eye makeup has been found preserved in tiny vases inside tombs. Analysis of the makeup has shown that it was made of compounds that do not generally occur naturally.

A 1.3 Developing Ideas about Matter

Chemistry is about understanding the nature of matter and changing matter in useful ways. Ancestors of the First Nations people used their knowledge about the nature of matter and its processes to help them meet their basic needs. For example, the Blackfoot and Blood peoples of Alberta, like most Aboriginal groups around the world, have extensive knowledge of the use of plants. The prickly rose in Figure A1.11(a) produces fruit that can be eaten fresh, roasted, or dried and eaten in the winter. The roots, leaves, and seeds of many other plants, such as old man's whiskers in Figure A1.11(b), are also used by First Nations people for medicines.

Early in human history, people began to understand the relationship between temperature and the states of matter—solid, liquid, and gas. The discovery of how to start fires and keep them going led to new ways of processing and using materials. Water could be turned quickly from ice to liquid water to steam. Food could be cooked to make it tastier and to delay spoiling. Heat from fire could turn mud into brick, clay into ceramic, and sand into glass.

(a) Prickly rose



(b) Old man's whiskers

FIGURE A1.11 Plants used by Alberta First Nations for a variety of purposes

Food Chemistry

Cooking food was an important step in human survival, and so was the development of food preservation techniques. These physical and chemical techniques have been known for thousands of years and include drying, heating, freezing, fermentation, and chemical preservation.

In earlier grades, you learned the difference between a physical change and a chemical change. In a **physical change**, the chemical components remain the same. No new substances form. Freezing is a physical change. A **chemical change** always results in the formation of different substances. For example, if you analyzed a cake after it's baked, its chemical composition would be different from the ingredients that were originally mixed to make it.

Heating and Freezing

Heating food temporarily sterilizes it. Sterilization is any process that kills micro-organisms. Roasting meat on a spit, or sharp stick, will heat sterilize it. So will cooking a hamburger, provided it is cooked thoroughly all the way through. Canning involves heat sterilization followed by sealing in an oxygen-free atmosphere. Freezing is another physical process that can preserve food almost indefinitely. The very low temperature prevents the growth of micro-organisms that cause decay.

Salting

Salting is a method of preserving meat and fish and is actually a method of drying. The salt draws water out of the meat. It also draws water out of bacteria, either killing them or making them inactive. Salted meat was used by sailors before other preservation techniques for meat were found.

Fermentation

Unfortunately, certain nutrients, such as vitamin C, were not always retained when food was preserved. The absence of vitamin C in sailors' diets caused the disease known as scurvy. Captain Cook, who explored much of the eastern Pacific Ocean for Great Britain, brought pickled cabbage on his voyages because it was known to prevent scurvy. Pickled cabbage (sauerkraut) has a high vitamin C content, and was produced through a process called **fermentation**. Wine and beer are also made by a process of fermentation.

You may be surprised that ancient peoples knew how to preserve vegetables for very long periods without the need for canning machines or freezers. One way this was done was through fermentation. Fermentation is a biochemical preservation technique involving bacteria called *lactobacilli*. These bacteria are present on the surfaces of all living things. They convert starches and sugars present in fruits and vegetables into a chemical called lactic acid. Lactic acid is a preservative that prevents the growth of bacteria that cause food to rot. The lactobacilli bacteria are beneficial to food because they make it more digestible and increase vitamin levels. Think about that the next time you bite into a pickle!

Smoking was also a common means of chemical food preservation and is still used today. Bacon and smoked fish are common examples. Smoking introduces chemicals called antioxidants that slow the rotting process. Wood smoke contains some formaldehyde, which acts as a preservative.

info **BIT**

Lactic acid temporarily builds up in your muscles after very hard exertion when you can no longer supply enough oxygen. It causes the feeling of fatigued muscles.

Metallurgy—An Early Branch of Chemistry

Another early branch of chemistry was metallurgy, the science of producing and using metals. Until 3000 B.C., the only known metals were gold, copper, silver, lead, and iron. Gold was used extensively in ancient times as jewellery, because it is soft and easy to work with. But its softness—and its rarity—meant it was not suitable for weapons or equipment for hunting or farming.

Copper has many practical advantages over gold. Because it is harder, it can be made into tools and weapons, as well as jewellery. The Inuit used copper found in the Coppermine River, which flows into the Arctic Ocean. This is often referred to as "native" copper because it occurs naturally in pure form. Besides spears, arrows, and knife blades (Figure A1.12), early Inuit also formed the copper into handles for pots, staples, and rivets.

When people first began using copper, they hammered it into shapes, but this caused it to become brittle. Tools made from copper broke easily. A process called "annealing" solved this problem. Annealing is the heating of copper before it is hammered. Annealing changed the metal so it was no longer brittle when hammered. With this discovery, copper could be hammered into sheets and made into stronger tools and weapons.

FIGURE A1.12 Harpoon head with a point made of copper and a holder made of antler. Inuit used it for hunting about 800 years ago.