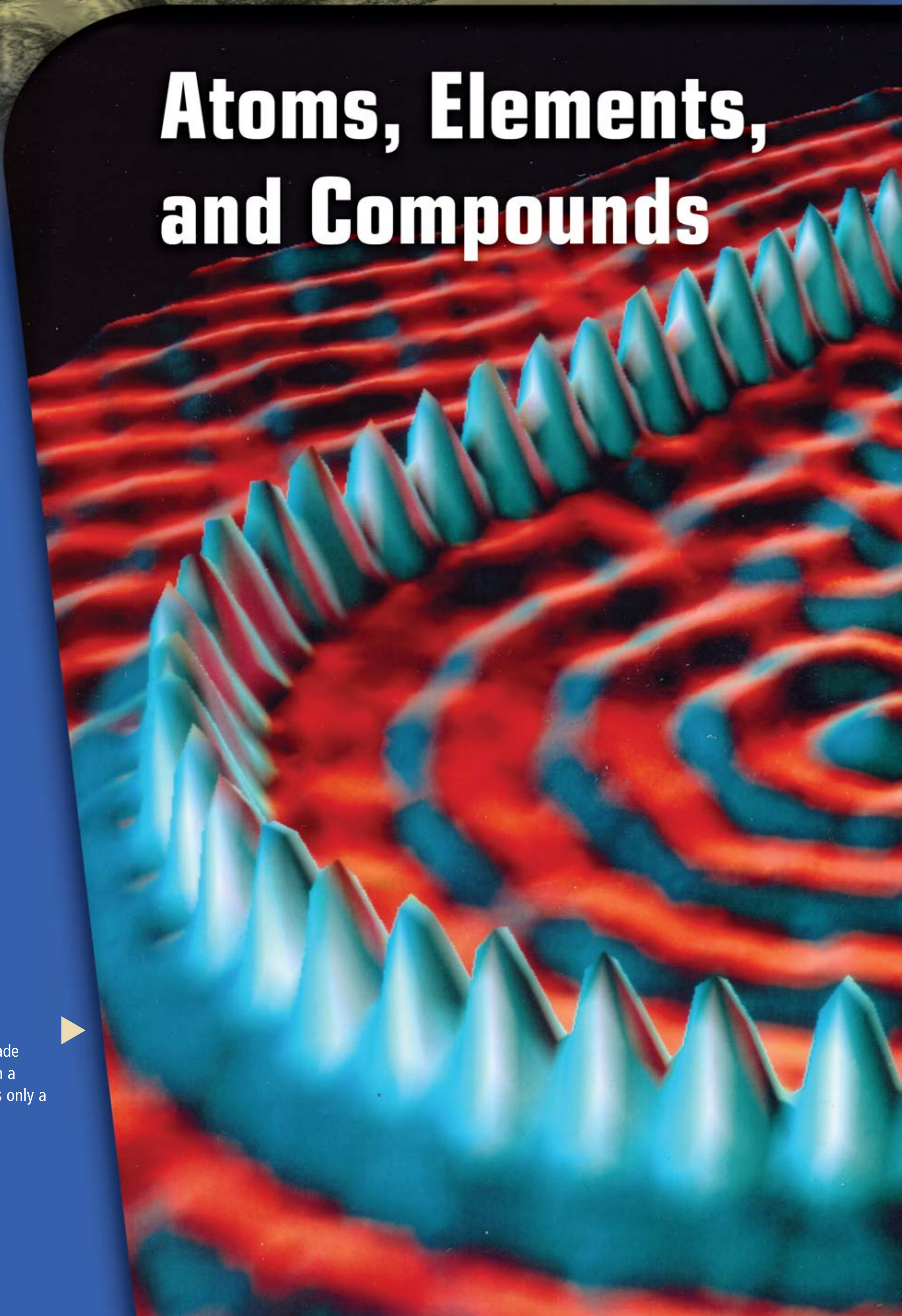
UNIT 1

Atoms, Elements, and Compounds



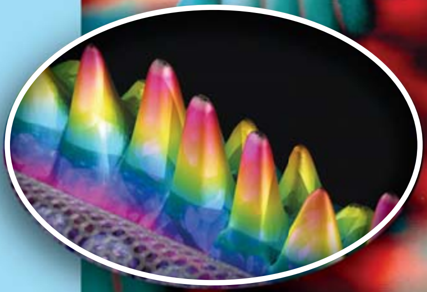
This tiny work of art, called the "Stadium Corral," is made out of iron atoms placed on a copper surface. The corral is only a billionth of a metre across.

Key Ideas

1 Atomic theory explains the composition and behaviour of matter.

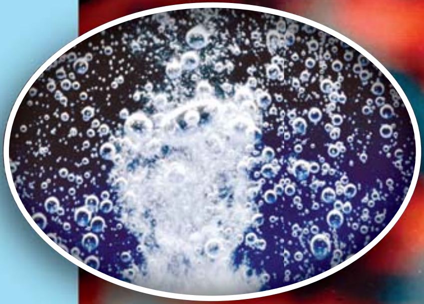
- 1.1 Safety in the Science Classroom
- 1.2 Investigating Matter
- 1.3 Atomic Theory

2 Elements are the building blocks of matter.



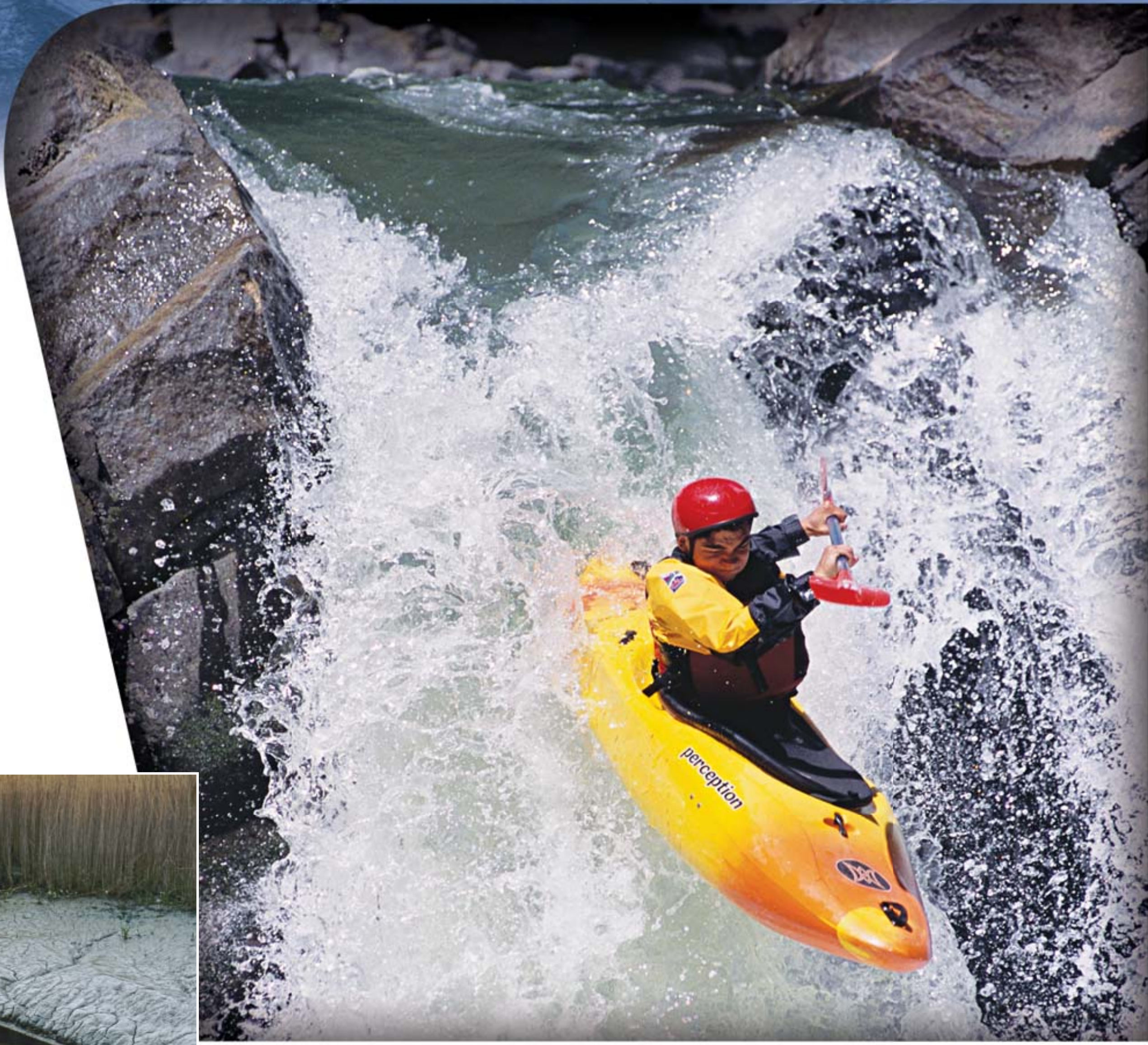
- 2.1 Elements
- 2.2 The Periodic Table and Chemical Properties
- 2.3 The Periodic Table and Atomic Theory

3 Elements combine to form compounds.



- 3.1 Compounds
- 3.2 Names and Formulas of Simple Compounds
- 3.3 Physical and Chemical Changes

Getting Started



Wastewater can contaminate fresh water sources.

Water: we drink it, bathe in it, and grow crops in it. When it is in its liquid state, we play in it, like the kayaker shown here. When it is in its solid state we can ski, skate, and walk across it. Regardless of what state water is in, the tiny particles that make up water stay the same.

Unfortunately, we sometimes add pollutants to water, such as when we mishandle sewage wastes, dump inappropriate chemicals down our sinks, or allow toxic effluents from industry to mix with the water in our streams and lakes.

You may have heard of pollutants such as dioxins, methyl mercury, and lead. All of these chemicals are dangerous water contaminants that can cause disease, nerve damage, and cancer. There are places where these contaminants, as well as others, are present in community water supplies. Thankfully, research is providing new solutions for purifying contaminated water.

In nature, water is purified as it evaporates from the salty oceans and falls back to Earth as pure rainwater. The ground itself is a water filter. Water can flow hundreds of kilometres underground through sand and gravel formations and be cleaned in the process. Forests and woodlands act as natural sponges by slowing water flow, allowing microbes to absorb chemicals, purifying the water. Certain chemicals in the rocks can even destroy some harmful pollutants.

Lee Wilson is an award winning research chemist and a member of the Canadian Métis community. The first person from his village to earn a PhD in chemistry, he applies his understanding of the properties of matter to solving the problem of contaminated water.

Wilson's research involves developing materials with microscopic holes just the right size to trap the particles of pollutants but still let the particles of clean water pass through. Different-sized pores can be manufactured to capture different sizes of pollutants.

Imagine being able to place a pump into polluted water and have drinkable water come out of the pump. Now imagine being able to do this for an entire village or town. In a world where clean water is in short supply, ways to make water clean and keep it clean will always be in demand.

Lee Wilson

internet connect

Find out more about the work of Lee Wilson and his colleagues. Visit **www.discoveringscience9.ca**.

Combining Chemicals

Find Out ACTIVITY

In this activity, you will describe the changes that occur when various chemicals are combined in a beaker.

Materials

- 400 mL beaker
- 50 mL water
- 150 mL vinegar
- 5 raisins
- 25 g baking soda

What to Do

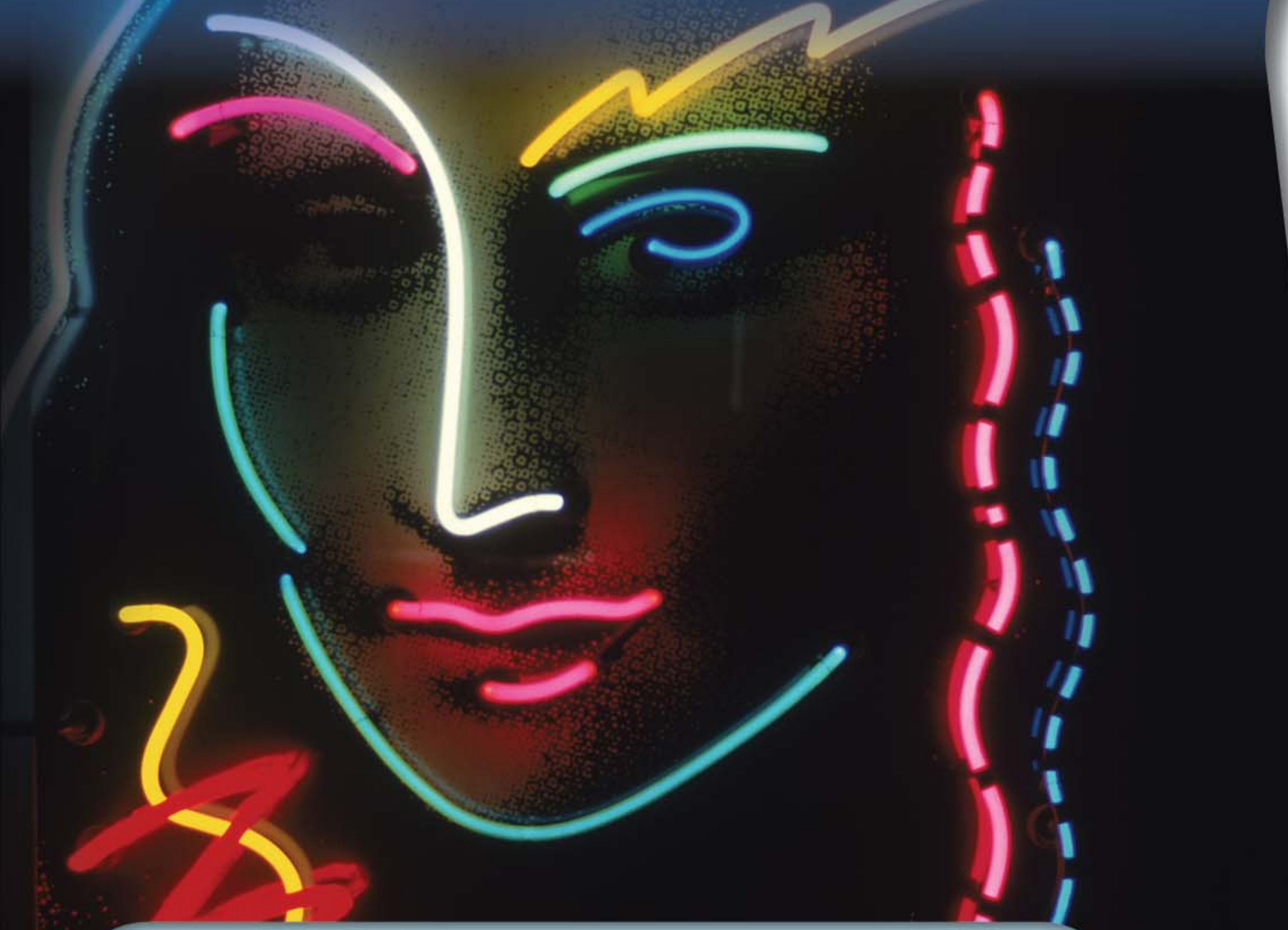
1. Pour 50 mL of water into the 400 mL beaker.
2. Add 150 mL of vinegar to the beaker of water. Record your observations.
3. Add the raisins to the beaker. Record your observations.
4. Slowly add the 25 g of baking soda to the beaker. Immediately record your observations and then describe any changes that occur at 1 min, 3 min, and 5 min.

What Did You Find Out?

1. List and describe the different changes you observed in the beaker.
2. What happened to the solid baking soda that you added to the beaker?
3. Describe and explain what happened to the raisins after the baking soda was added.

Chapter 1

Atomic theory explains the composition and behaviour of matter.



The original *Mona Lisa* was created with oil paints that were loaded onto a brush and smoothed across a canvas surface. The paints' properties of colour, lustre, and ability to spread made them ideal for 16th century paintings. Today's artists also use the properties of matter in their work. The brilliance of this updated *Mona Lisa* comes partly from neon, a gas that has the property of glowing when an electric current is passed through it. Atomic theory helps to explain the composition and behaviour of matter and how we can use its properties in both science and art.

What You Will Learn

In this chapter, you will
- **identify** and **describe** physical and chemical properties of matter
- **describe** the development of atomic theory
- **identify** and **describe** three subatomic particles that make up an atom

Why It Is Important

Matter can appear in many forms. One way scientists try to understand matter is by studying its properties. Another way is by using models to describe the nature of matter itself. Both methods enrich our understanding of the physical world.

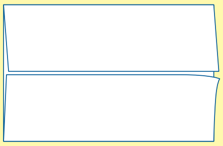
Skills You Will Use

In this chapter, you will
- **work** co-operatively and safely in a laboratory setting
- **observe** differences in the properties of various substances
- **explain** subatomic particles based on their properties and location in an atom
- **use** models to understand the structure of matter

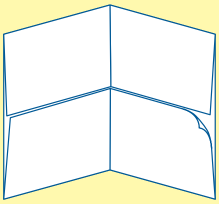
FOLDABLES™
Reading & Study Skills

Make the following Foldable and use it to take notes on what you learn in Chapter 1.

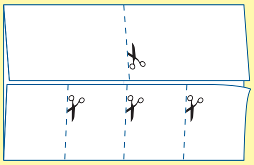
STEP 1 **Make** a shutterfold using one sheet of paper.



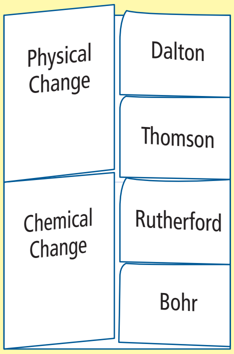
STEP 2 **Fold** the shutterfold in half like a wallet. **Crease** well.



STEP 3 **Open** the Foldable and **cut** the top flap in half along the fold. **Cut** the flap on the bottom into four small tabs.



STEP 4 **Label** the Foldable as shown.



Organize As you read this chapter, use your Foldable to organize your notes on physical and chemical properties. On the right side of the Foldable, describe the development of atomic models, and include information on the identification of subatomic particles.

1.1 Safety in the Science Classroom

Safe practice in the science lab includes knowing how to behave safely during lab activities and what to do in an emergency. Lab safety rules restrict certain kinds of activities, such as horseplay or eating during a lab. But they also make it possible for you to safely carry out investigations that contain an element of risk. Warning labels are used on commercial, industrial, and home products that contain hazardous chemicals. Several labelling systems are used, including the Workplace Hazardous Materials Information System (WHMIS).

Key Terms

hazard symbol
WHMIS

Welcome to the science laboratory! In this unit, you will gain experience observing and controlling changes in matter. Experimenting is a central part of science, and no study of chemistry is complete without it (Figure 1.1). In all activities, you must make safety the first priority. Remember to stay alert in experiments and watch out for your safety and the safety of others.

Make Safety Your First Priority

You need to be careful and considerate in the laboratory. But more than good behaviour is required. To be able to work safely and with confidence, you must have the right kind of knowledge, an awareness of what is happening, and an ability to act.

You need to know safety rules *before* you start a science activity. This knowledge helps you prevent accidents. For example, to prevent broken glass or a chemical damaging your eyes, wear safety eyewear.

Know and follow the safety rules in your lab and know what to do in an emergency. General rules about safety are explained in this section. Your teacher will help you apply the rules to your science classroom.

You need to be aware of safe procedures *while you are doing* your lab activity. Be careful of what you are doing and also of what others are doing.

Figure 1.1 Many discoveries in chemistry are based on experiments done in laboratories.

You can put your knowledge and awareness to good use by acting to prevent or deal with an accident. Most accidents can be prevented. When you spot an emergency, first call out a general warning loud and clear, such as "Fire!" or "Help!"—and then take action.

You should know where emergency equipment is and how to use it. For example, it is important for you to be familiar with the location and use of the eye wash station. Your teacher will explain important safety procedures.

Did You Know?

Accident rates in the workplace are high for young and newly hired employees. This is because safe skills need to be learned and practised until they become second nature.

1-1A Science Lab Safety

Think About It

Safe lab procedures include anticipating dangers and recognizing them when they occur. In this activity, you will identify unsafe practices shown in the illustration. Some are obvious, while others are more subtle. Try to find as many as you can.

What to Do

1. Work with a partner. Identify as many unsafe practices as you can find in the illustration.
2. Make a three-column table. In the first column, list the unsafe practices you have identified. In the second column, list an injury that might occur as a result of each practice. In the third column, suggest a safer, better way to carry out each procedure.

What Did You Find Out?

1. Share your observations with your class.
2. Add to your list any observations another group made that you had not already identified.

Rules to Help You Stay Safe

Rules for safe conduct in the lab are based on common sense and knowledge of safe lab practices and procedures. Keep in mind that careful and orderly behaviour is not just good manners; it protects you and others from dangerous situations that might occur.

Here is a list of safety rules that apply to all lab work in science.

Safety Rules for the Science Lab

General

1. Always work under supervision and only on approved activities. Never change a procedure without your teacher's permission.

2. Make sure you know the procedure and have read it over before you start an activity.

3. Make sure you know how to use your lab equipment properly before you start an activity.

4. Always use appropriate protective equipment, such as a lab coat or protective eyewear. Tell your teacher if you are wearing contact lenses.

5. Do not wear loose clothing, sandals, or open-toed shoes.

6. Do not eat, drink, or chew gum in the laboratory.

7. Never engage in horseplay.

8. Know the location and use of all emergency equipment and emergency exits (Figure 1.2).

9. In case of an emergency, follow procedures your teacher has taught you. Use whatever emergency equipment is appropriate to respond to the emergency. Act immediately to protect people first and then equipment.

Glassware

10. Never use broken or chipped glassware. Dispose of it in a "sharps" bucket or as your teacher directs. Use clean glassware. After using glassware, wash it or put it in an approved place to soak.

Chemicals

11. Know the safety precautions and hazards for all chemicals you are using before you start your lab.

12. If you come in contact with a solid substance, brush it off immediately. For liquid spills, wash the affected area thoroughly with water. If you get anything in your eyes, do not touch them. Rinse them immediately and continuously for 15 minutes and inform your teacher.

Figure 1.2 Know when to use a fire alarm. Know where the fire extinguisher is in your classroom.

13. Hold containers away from your face when pouring liquids.
14. Read labels on containers. Never use a chemical from a container that does not have a readable label. Inform your teacher if label cannot be read.
15. When in the lab, never put anything in your mouth such as fingers, equipment, hair, pencils, or chemicals that you are working with, even if they are food items.
16. Never return a chemical to its original container. Doing this could contaminate the original stock.
17. Never put any chemical down the sink or into the garbage without permission.
18. Clean up any spills according to your teacher's instructions.

Figure 1.3 Never smell anything in the lab directly. Always waft the fumes toward your nose.

19. If you are asked to smell a substance, never smell it directly. Hold the container at arm's length and waft fumes toward you (Figure 1.3).
20. When diluting a concentrated acid with water, add the acid to the water, not the water to the acid. This prevents sudden overheating of the water.

Hot Plates and Open Flames

21. Handle hot objects carefully. Be especially careful with a hot plate even if it looks as though it has cooled down.
22. Know how to light and operate a Bunsen burner.
23. Tie back long hair and avoid fuzzy clothing and long sleeves when you are in an area with open flames.
24. Never leave an open flame unattended, even for a moment. Assign someone else to watch it, or turn the flame off.

Electrical Equipment

25. Make sure your hands are dry when touching electrical cords, plugs, or sockets.
26. Pull the plug, not the cord, when unplugging electrical equipment.
27. Report frayed cords and any other damaged equipment to your teacher.
28. If any electrical component becomes hot during an activity, disconnect the circuit immediately.

Reading Check

1. What do you need to know before you start a science activity?
2. What should you do if you begin using a piece of glassware and then discover it has a small chip or nick in it?
3. Explain what is incomplete about the following rule: Never taste a chemical.
4. What should you do with a chemical container that has a label you cannot read?
5. Describe the safe way to smell a substance.

WHMIS Symbols

An important safety step when using any chemical, whether around the home, in the lab, or in the workplace, is to check the warning symbols on the container. The **Workplace Hazardous Materials Information System (WHMIS)** is used to ensure that everyone has access to appropriate safety information about any hazardous substance they may encounter that is manufactured and sold. In this system, eight symbols provide easy-to-read warnings. A chemical container may have one or more of the symbols shown in Figure 1.4.

Figure 1.4 WHMIS symbols

Other Safety Hazard Symbols

Many products ranging from household cleaners to spray paints are labelled with another type of safety **hazard symbol** (Figure 1.5). You may have noticed these symbols on products used at home in the laundry room or with garden equipment. Each hazard symbol provides two kinds of warnings:

- whether the hazard is the container or its contents, shown by the shape of the border
- the type of hazard—explosive, corrosive, flammable, or poisonous—shown by an image at the centre of the symbol

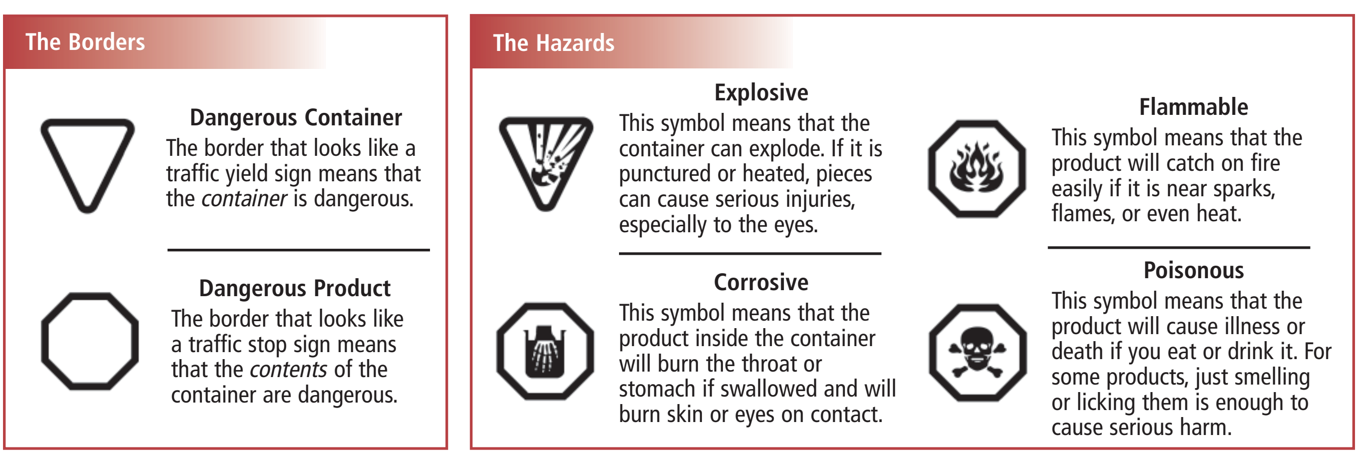


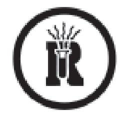
Figure 1.5 Watch for these symbols on products you use at home as well as those you see in the lab.

Reading Check

1. What does WHMIS stand for?
2. Name the hazard that each WHMIS symbol below identifies.

(a) 

(b) 

(c) 

3. Identify each of the following hazard symbols.

(a) 

(b) 

(c) 

Explore More

There is a Material Safety Data Sheet (MSDS) for every chemical used in school classrooms. Find out what an MSDS is. Read the MSDS for bleach or another chemical of your choice. Start your research at **www.discoveringscience9.ca**.

1-1B Safety Guidelines for Your Lab

Think About It

In this activity, you will select a safety rule listed on pages 10 and 11, or one provided by your teacher, and create a poster illustrating the rule. Share your poster with your classmates and then develop safety guidelines customized for your classroom.

What to Do

Part 1

1. Select a safety rule. Think about a way to show the rule visually, such as using an image similar to direction signs in airports or using a short phrase.
2. On a sheet of paper, draw a poster that has strong visual impact and will be a good reminder of one particular rule. Make sure the poster can be read from at least 3 m away.
3. Present your poster to the class, explaining the rule and your choice of illustration.

Part 2

4. Work in pairs or small groups to develop a set of safety guidelines that could be used as a safety contract for the students in your classroom. Your guidelines should incorporate the following:
   - information from the class posters and *Discovering Science 9*
   - information specific to your class about location of safety equipment and procedures for evacuation
   - other information to ensure safe and responsible ways of working in your class
5. Share your contract with several other groups.

What Did You Find Out?

1. How could you improve your safety poster?
2. (a) How could you improve your safety contract based on what other groups have included in their contracts?

   (b) Make your refinements and sign your contract.

Science Watch

Chemistry in a House Fire

Your school has fire drills so you can practise fire safety. But fire safety is important in the home as well. Fire departments around the province recommend that your family have a fire safety plan for your home.

How can you make your home as safe as possible? Keep flammable clutter out of hallways, have functioning smoke and carbon monoxide detectors, and keep fire extinguishers in the kitchen, laundry room, and garage. You should also plan and practise escape from every room in your house.

If trouble should occur, flesh burns are not the only worry. When a home burns, many hot gases are generated. These are collectively called toxic fumes. "Toxic" means poisonous, and simply breathing toxic gases can cause you to lose consciousness long before the flames reach you.

When wood catches fire, carbon dioxide gas is the main product. It is not poisonous, but it replaces oxygen and can suffocate you. Burning wood also creates poisonous gases, the most dangerous being carbon monoxide. But the carbon monoxide released in a fire can also save your life. How? Carbon monoxide moves faster than the fire and can trigger a carbon monoxide detector alarm. Early detection means you can be alerted to the fire before the flames get near you.

The chemicals in paint, furniture fabric, carpeting, and insulation are considered safe under normal conditions. However, when these materials are heated in a fire they release poisons that can quickly make a person lose consciousness.

If a fire does break out in your house, you need to get out immediately using an escape plan you have practised. Do not run. If your clothes catch fire, STOP! DROP! and ROLL! To exit through smoke, crawl low with your face near the floor so you breathe in the cleanest and coolest air. Meet other family members outside and check that everyone is safe. Never go back into a burning house. And if you have not already done so, call your local fire department!

Questions

1. List four ways to make your home safer from fire.
2. Describe the safest way to move through smoke.
3. List two dangers from toxic fumes.

Check Your Understanding

Checking Concepts

1. For each of the following statements, decide whether it is true or false. If it is false, change the statement to make it true.
   (a) Broken or chipped glassware should be disposed of in the garbage.
   (b) If there is a fire, you should call out a warning.
   (c) If the label on a chemical container is not readable or is missing, put it back where it was and do not use it.
   (d) Leftover chemicals should be returned to their original containers to prevent waste.
   (e) It is safe to leave an open flame to do something else if you get someone else to watch it for you.
   (f) Gum chewing is permitted in the lab.

2. Identify the WHMIS symbol that matches each of the descriptions below.
   (a) a test tube with lines coming out of it superimposed on a large capital R
   (b) a skull and crossbones
   (c) a stylized T that looks like an exclamation mark (!)
   (d) two test tubes pouring liquid onto a hand and an object
   (e) a cylinder
   (f) a flame coming out of a flat line

3. What does each of the following warning labels mean?

(a)

(b)

(c)

(d)

Understanding Key Ideas

4. Explain the difference between knowledge of safety procedures and awareness of safety hazards.

5. List any safety rules your teacher has given you that relate specifically to your classroom.

6. List the steps you would take to deal with each of the following situations.
   (a) While you are using a hot plate to heat up a liquid, the fire alarm sounds.
   (b) You are heating a test tube in the flame of a Bunsen burner when you notice that your test tube has a chip near the top.
   (c) While you are using an open flame, the shirt of someone near you catches fire.

7. Make a sketch of your science lab or classroom showing the location of emergency exits, eyewash stations, fire extinguishers, and any other emergency equipment.

Pause and Reflect

Safety symbols are designed to protect people who work with chemicals. Why do commercial products such as bleach or drain cleaner not have WHMIS labels, but similar chemicals used in your science activities do have WHMIS labels?

1.2 Investigating Matter

Matter is anything that has mass and volume. All matter has physical and chemical properties. Physical properties, which include state, colour, and density, can be measured or observed by simply examining an individual substance. Chemical properties, which include reactivity and combustibility, can be detected only by observing how a substance reacts with other substances.

Key Terms

boiling point
chemical properties
combustibility
density
element
mass
matter
melting point
physical properties
reactivity
state
volume

Figure 1.6 Canada Day celebrations are vivid displays of light as well as chemical artistry.

Fireworks! The night sky lights up with a shower of colour, and the air crackles with explosive sounds. You have probably seen such spectacular displays in your community on holidays such as Canada Day (Figure 1.6). Fireworks have an ancient tradition. The Chinese invented them more than 2000 years ago, and since then their use has spread around the globe. Fireworks displays have improved over the years as performance art has been blended with an understanding of chemistry.

Fireworks are a dramatic display of matter. **Matter** is anything that has mass and volume. **Mass** is the amount of matter in a substance or object (often measured in grams). **Volume** is the amount of space a substance or an object occupies (often measured in litres). Matter is made up of elements. An **element** is a substance that contains only one kind of matter and cannot be broken down or separated into simpler substances.

Properties and Change

Fireworks designers achieve their colourful, noisy displays through chemical changes in the substances that make up the fireworks. A chemical change is a change in matter that occurs when substances recombine to form new substances. **Chemical properties** are characteristics that can be observed when substances react with each other. When you light a magnesium sparkler, it goes through a chemical change that you can see—it glows a bright white colour. Burning brightly is a chemical property of magnesium. Some substances combine explosively when heated. Fireworks designers make use of this chemical property. The chemical change that occurs when fireworks are ignited produces new substances—explosive gases and substances that change colour.

Physical change may involve a change of appearance, but no new substances are formed. For example, iron glows a red colour when it is heated. Changes in state (melting and boiling) are also examples of physical change. You will explore chemical and physical change in more detail in Chapter 3.

Did You Know?

The word "pyrotechnics" refers to explosives used in displays or for other purposes such as smoke screens. The prefix "pyro" means fire, and "technics" refers to art.

1-2A Bag of Change

Find Out ACTIVITY

In this activity, you will mix three unknown substances together in a plastic bag and observe the changes that occur. Watch for changes in state (solid, liquid, or gas), colour, volume, temperature, and anything else you can detect.

Safety

- Be careful not to get any chemicals near your eyes or mouth.

Materials

- Chemical A—a white solid
- Chemical B—a white solid
- Chemical C—a blue liquid composed of a blue solid dissolved in water
- 2 small spoons for measuring A and B
- 50 mL graduated cylinder
- 2 resealable plastic bags per group
- water

What to Do

1. Describe and record the physical properties of chemicals A, B, and C. Observations may include the colour or state (solid or liquid) of the chemical.
2. Mix one spoonful of chemical A, one spoonful of chemical B, and 10 mL of chemical C into a plastic bag, and then quickly seal it up.
3. In the first 30 s, squeeze the bag in various places to mix the chemicals. Detect any temperature changes with your hand.
4. Record as many observations as you can.
5. When you are finished, wash all the chemicals down the drain and rinse out the plastic bag.
6. Clean up and put away all the equipment. Wash your hands.

What Did You Find Out?

1. List and describe changes you observed in the plastic bag. Do you think they are chemical or physical changes?
2. Share your list with the class, and add to your list any new observations discussed in class.
3. If time and the quantity of chemicals permit, try to identify which two chemicals are responsible for each effect you observed. To do this, mix just two chemicals together in the bag. You might wish to simply mix water and one of the chemicals. Your goal is to use the minimum number of chemicals to produce each effect.

Describing Matter: Physical Properties

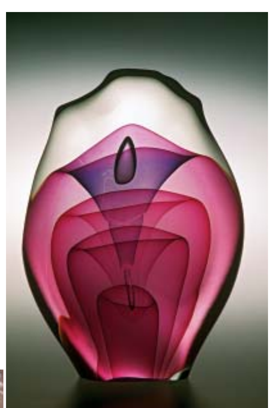
Think of a simple substance you have used recently—maybe sugar or salt or water. What colour was it, or was it colourless? What was its melting point or boiling point? When you answer questions like these, you are describing properties of matter. **Physical properties** are characteristics of matter that are often observed or measured. *Qualitative* properties are properties that can be described but not measured. *Quantitative* properties are characteristics that can be measured numerically. Table 1.1 lists the common physical properties used to describe matter.

Suggested Activity

Conduct an Investigation 1-2C on page 20

Table 1.1 Physical Properties

Physical Property	Description
Qualitative	
State	Solid, liquid, gas
Colour	Colour
Malleability	Ability to be bent or beaten into sheets
Ductility	Ability to be drawn into wires
Texture	Appearance and feel of the surface
Magnetism	Tendency to be attracted to a magnet
Lustre	Degree to which the material reflects light
Quantitative	
Solubility	Ability to dissolve in water
Conductivity	Ability to conduct electricity or heat
Viscosity	Resistance to flow
Density	Ratio of a material's mass to its volume
Melting point	Temperature of melting/freezing
Boiling point	Temperature of boiling/condensing



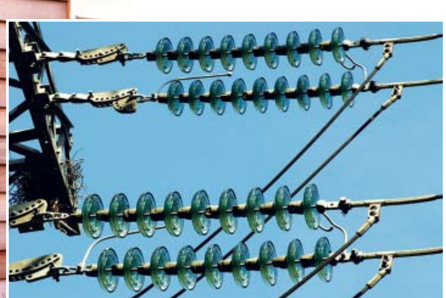


Figure 1.7 Works of art, windows, and electrical systems take advantage of the physical properties of glass.

The usefulness of a substance depends on which properties it has—and sometimes which properties it does not have. Common window glass, for example, does not form crystals and is not a good conductor of heat or electricity. But the absence of these properties makes glass valuable. Because it is not crystalline, it can be easily bent and shaped when heated. It can be made into works of art, huge glass sheets called panes, and thousands of other glass products. Because it does not conduct heat or electricity well, it can be used for insulation. Figure 1.7 shows three results of glass's properties: a decorative glass object, double-paned windows, and insulators for power lines.

Describing Matter: Chemical Properties

The chemical properties of a substance will also determine its usefulness. Jewellery is often made of gold or platinum. These metals do not react easily with air or water, so they will not deteriorate over time as does copper or iron. Copper, iron, and even silver react with air and water, producing a dull finish. Table 1.2 lists the common chemical properties used to describe matter.

Table 1.2 Chemical Properties

Chemical Property	Description
Reactivity	Degree to which the substance combines chemically with other substances (water, acid, other substances)
Combustibility	Degree to which the substance burns (reacts with air or pure oxygen)
Toxicity	Degree to which the substance reacts in the body to produce harmful substances

Explore More

Not all matter changes state in the usual manner. Find out about substances with unusual behaviour when they are changing state. Go to **www. discoveringscience9.ca**.

Reading Check

1. What property does malleability describe?
2. Would smell be a qualitative or a quantitative property?
3. What is the difference between a chemical and a physical property?

1-2B A Chemical Family

Think About It

Elements that have properties in common are sometimes classified as a "chemical family." In this activity, you will determine whether aluminum and iron belong to the same chemical family as copper, gold, and silver.

What to Do

Scan the table below, and answer the related questions.

What Did You Find Out?

1. Which of the properties listed are chemical properties and which are physical properties?
2. Three metals commonly used in coins—copper, silver, and gold—are considered to be a chemical family. List three arguments to explain why.
3. List arguments for and against including aluminum and iron in the family of coinage metals.
4. Do you think aluminum belongs to the same chemical family as iron? List arguments for and against.

Property	Elements				
	Aluminum (Al)	Copper (Cu)	Gold (Au)	Iron (Fe)	Silver (Ag)
Effect of acid on clean, bare, pure metal	Reacts with acid; hydrogen gas released	Unreactive with most acids	Unreactive with most acids	Reacts with acid; hydrogen gas released	Unreactive with most acids
Compound formed with oxygen	Readily	Not readily	Not readily	Readily	Not readily
Malleability	Very malleable	Very malleable	Highly malleable	Malleable	Very malleable
Electrical conductivity	Very good	Second best of all metals	Excellent	Good	Best of all metals

1-2C Physical and Chemical Properties

Conduct an INVESTIGATION

SkillCheck

- Observing
- Recording
- Organizing data
- Making conclusions

Safety

- Handle hot objects with care.
- Keep hair and loose clothing away from the flame.
- Handle corrosive acids with care.
- Do not look directly at a metal when it is in the flame.

Materials

- Bunsen burner or propane burner
- 5 cm metal strips of aluminum, magnesium, iron, copper, zinc, lead
- small pieces of aluminum, magnesium, iron, copper, zinc, lead
- steel wool
- hydrochloric acid (1.0 mol/L solution) in a dropper bottle
- bar magnet
- tongs
- heat resistant pad
- electrical conductivity kit

Science Skills

Go to Science Skill 11 for information about constructing a data table.

All matter can be described and classified using its physical and chemical properties. In this investigation, you will examine and describe a variety of metals in terms of certain physical and chemical properties: lustre, malleability, magnetism, electrical conductivity, reactivity to acid, and reactivity to air when heated. Refer to Table 1.1 on page 18 and Table 1.2 on page 19 for a description of these properties.

Question

What are the chemical and physical properties of various metals?

Procedure

1. Based on your existing knowledge of the metals you will be testing, predict your observations before starting the lab.
2. Make a table to record your observations and give it a title.
3. Examine the lustre of your metal strips. How shiny are they? Using the steel wool, polish the metal strips. How shiny are they after polishing?
4. Try to bend the metal strips to test for malleability.
5. Test each of the metal strips for magnetism using the bar magnet.
6. Place the two wires of the conductivity kit on your metal strips; ensure that they are not touching each other. Does the light go on? If yes, the metal conducts electricity.
7. Place one drop of acid on each of the metals. Observe for 1 minute. Rinse the metals with water and then wipe them dry.
8. Polish a small piece of each of the metals. Using tongs, heat the metal in the Bunsen burner flame for 20 seconds. **Caution:** Magnesium burns with a blinding light. Lead melts to produce drops of hot liquid metal and toxic fumes. Thin strips of iron also catch fire. Exercise caution when performing the flame test.
9. Hold the metal piece in the air to cool slowly. Place it on the heat-resistant pad and leave it to cool to room temperature. Record any changes you observe in the metal.
10. Use the steel wool to clean your metal strips. Clean and put away your equipment.

Analyze

1. Which of the properties you investigated are physical properties? Which are chemical properties?
2. Which physical properties do all of the metals share? Which differ?
3. Which chemical properties do all of the metals share? Which differ?

Conclude and Apply

1. What evidence allowed you to answer the previous three questions? How did your observations compare with the predictions you made in Procedure step 1?

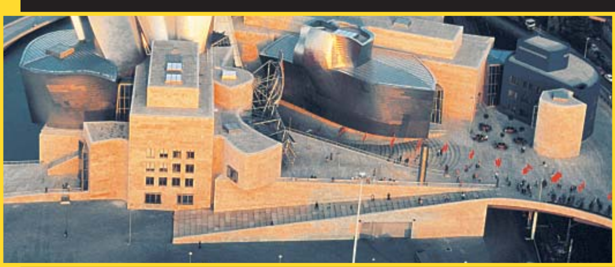
NATIONAL GEOGRAPHIC

VISUALIZING MATTER

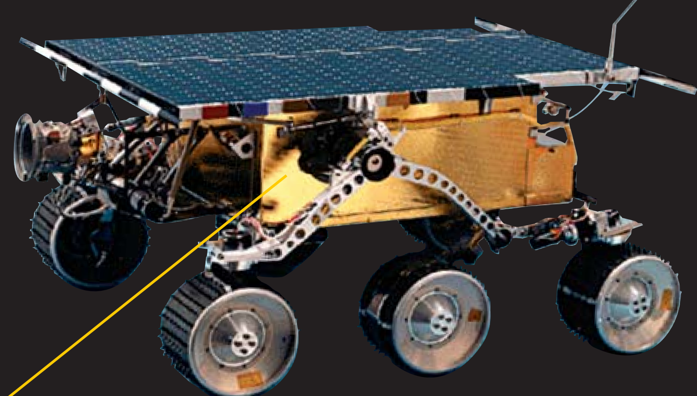
Most of us think of gold as a shiny yellow metal used to make jewellery. However, it is a material that is also used in more unexpected ways, such as in spacecraft parts. On the other hand, some less common elements, such as americium (am uh REE see um), are used in everyday objects. People have developed commercial products based on their knowledge of chemistry and the properties of different materials. Some elements and their uses are shown here.

▲ ALUMINUM
Aluminum is an excellent reflector of heat. Here, an aluminum plastic laminate is used to retain the body heat of a newborn baby.

▲ TUNGSTEN
Although tungsten can be combined with steel to form a very durable metal, in its pure form it is soft enough to be stretched to form the filament of a lightbulb. Tungsten has the highest melting point of any metal.



▲ TITANIUM (tih TAE nee um)
Parts of the exterior of the Guggenheim Museum in Bilbao, Spain, are made of titanium panels. Strong and lightweight, titanium is also used for body implants.



▲ GOLD Gold's resistance to corrosion and its ability to reflect infrared radiation make it an excellent coating for space vehicles. The electronic box on the six-wheel Sojourner Rover, above, part of NASA's Pathfinder 1997 mission to Mars, is coated with gold.

▲ LEAD Because lead has a high density, it is a good barrier to radiation. Dentists drape lead aprons on patients before taking X rays of the patient's teeth to reduce radiation exposure.

◀ AMERICIUM Named after America, where it was first produced, americium is a component of this smoke detector. It is a radioactive metal that must be handled with care to avoid contact.

Liquid Crystals

Have you ever worn a mood ring? These fun pieces of jewellery have been available since the 1960s, and many people think that the changing colours of the ring express the wearer's emotions. Does the ring change colour with a person's mood?

Mood rings respond to temperature, not mood!

The secret to mood rings is a thin layer of reflective liquid crystals under the glass of the ring. These special liquid crystals change shape as temperature changes, which affects how the layer absorbs and reflects different colours. Therefore, as the temperature of your finger (not your mood!) changes, so does the colour of the ring.

This man's back has been sprayed with temperature-sensitive liquid crystals. The very uneven colours indicate he has a back injury.

When you think about it, the term "liquid crystal" might not seem to make sense. How can something be liquid and crystallized? Liquid crystals are a unique group of substances that have properties of both liquids and solids. Liquid crystals behave like solids in the sense that their particles are organized in crystal-like fashion. But unlike a solid, the particles can slide past each other as in a liquid.

Imagine being on a very crowded subway platform, with people so tightly packed that it is impossible to bend, walk, or sit down. This packed arrangement is like particles in a solid. But when a train arrives, the people can twist their bodies, move, and even switch places. Now the people are behaving more like particles in a liquid. Liquid crystal substances behave in a similar way.

The fascinating thing about liquid crystals is that they can be made to move. Some liquid crystals will respond to electricity. By arranging liquid crystals in a very thin layer on an organized electrified grid, we can create a liquid crystal display (LCD). If you are wearing a digital watch, it probably has an LCD. Electricity applied to selected sections makes the liquid crystals twist and line up in such a way that light cannot pass through. This creates the dark areas you see as numbers.

Digits on the watch are due to liquid crystal response to electricity.

Today's LCD technology is responsible for the colourful displays we have in laptops, cellphones, and other flat screen devices. For example, an LCD TV screen has millions of carefully arranged, electrically controlled, tiny areas called pixels. Each pixel allows colours of light to pass through by controlling liquid crystals. Considering the advantages of liquid crystals, we can be thankful they do not strictly obey the rules of solids or liquids!

Questions

1. Compare the behaviour of particles in (a) solids, (b) liquids, and (c) liquid crystals.
2. How do liquid crystals respond to temperature changes?
3. How does a digital watch LCD work?

Check Your Understanding

Checking Concepts

1. Matter can be defined as anything that has two particular physical properties. What are these properties?
2. What happens in a chemical change?
3. What happens in a physical change?
4. Explain the term *combustibility*.
5. Provide an example of a chemical and a physical property of aluminum.
6. Classify the following as chemical or physical properties:
   (a) Cotton balls are soft.
   (b) Water boils at 100°C.
   (c) Diamonds can be used to cut glass.
   (d) Sugar dissolves in water.
   (e) Propane is a gas.
   (f) Propane burns in air.
7. How did you decide whether the properties listed in question 6 were chemical or physical?

Understanding Key Ideas

8. List two chemical and two physical properties of a material that would be suitable to carry liquids.
9. Water and gasoline are both clear liquids at room temperature. Describe one physical property and one chemical property that might be used to distinguish between them.
10. Antifreeze is dissolved in water to lower the temperature at which it freezes. State two quantitative physical properties that change when antifreeze is dissolved in water.
11. What does each of the following terms mean?
    (a) malleability
    (b) boiling point
    (c) ductility
    (d) conductivity
    (e) solubility
    (f) texture
    (g) viscosity
12. Which physical property is the ratio of the mass of a substance divided by its volume?
13. Select any four of the physical properties listed in Table 1.1 on page 18 and use them to describe:
    (a) gold
    (b) sugar
    (c) water
14. 250 mL of water is boiled, converting it into steam. What has changed—its chemical properties, its physical properties, or both? Explain your answer.
15. Describe a candle using a chemical and a physical property.
16. When you are baking cookies, you make use of chemical and physical properties. List two physical properties and one chemical property that are important when you are baking.

Pause and Reflect

In this section, you have investigated the properties of matter. Why is it important to be able to describe the properties of various types of matter?

1.3 Atomic Theory

Atoms are composed of particles including protons, neutrons, and electrons. Atoms have a tiny, positively charged, dense nucleus made up of protons and neutrons. Surrounding the nucleus are one or more electrons. A neutral atom has the same number of electrons as protons. Electrons occupy specific energy levels in the space around the nucleus. The number of protons in an atom is called the atomic number.

Key Terms

atom
atomic theory
electron
neutron
nucleus
proton
subatomic particle

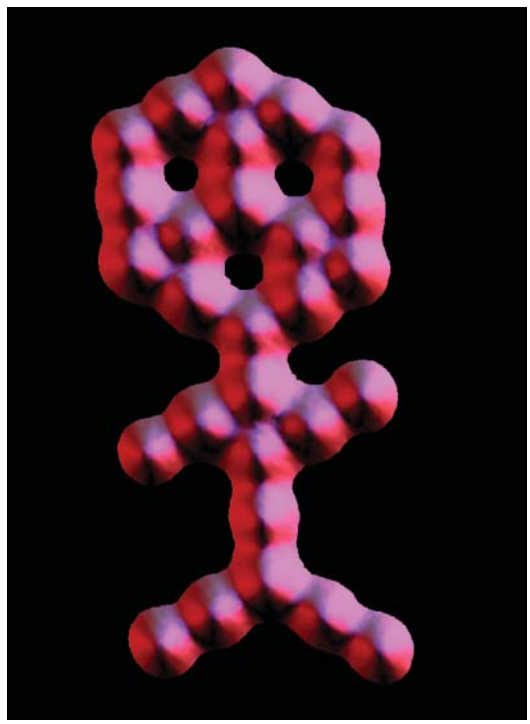


Figure 1.8 This image consists of 28 molecules of carbon monoxide arranged on a platinum surface. Each molecule of carbon monoxide is made up of individual atoms of carbon and oxygen.

Did You Know?

The ancient Chinese believed the world was based on five elements: earth, water, fire, metal, and wood. These elements promoted but also restrained each other. For example, water restrained fire but promoted wood. Fire promoted earth but restrained metal. In this way, the universe remained in balance.

Today, we know that everything—a breath of air, a school of fish, a video game, and a human being—is made of huge numbers of tiny particles like those shown in Figure 1.8. But for thousands of years, people described the nature of matter in very different ways. The various descriptions of matter and how it behaves are called **atomic theory**.

Empedocles, a Greek scientist and philosopher, made one of the first attempts to explain matter 2500 years ago, claiming that matter was composed of four "elements"—earth, air, wind, and fire—in varying quantities. Another Greek scholar, Democritus, countered this theory with one of his own, reasoning that any substance, when cut into smaller and smaller pieces, would eventually be cut into a piece that could not be divided further. He called this piece *atomos*, from which we get the word "atom." However, Aristotle, the most respected philosopher of the day, agreed with the theory proposed by Empedocles. Aristotle's view was highly influential. No one seriously challenged it for the next 2000 years.

Early Ideas about Matter

Alchemists were researchers who worked in Europe and the Middle East during the Middle Ages (Figure 1.9). While they experimented with matter, their main purpose was more technological than scientific. They wanted to turn common metals such as lead and mercury into gold. In pursuing that goal, they combined their investigations with mystical thinking and often worked in secret. Although they tried for more than a thousand years, they did not turn anything into gold.

By the 19th century, many people were doing experiments that led them to question the earth-air-fire-water view of matter. This was the beginning of a revolution in our understanding of matter.

Figure 1.9 The alchemists tried to turn base metals into gold.

Theories and Laws

Scientists' understanding of matter is known as atomic theory. What is the difference between a theory and a law? In science, laws are descriptions of events, patterns, or relationships that have been observed over and over again. Laws do not provide explanations—they simply state what happens. Theories are explanations of observations that are supported by reliable evidence. Scientists propose theories and try to convince others of their validity. Some theories stand the test of time and become generally accepted. Others are modified or discarded because they cannot explain new evidence. Laws are constant, but theories may change as new facts become available. This has been the case with atomic theory, which has changed over time as scholars and scientists have contributed new ideas, evidence, and explanations related to the behaviour of matter.

Development of Atomic Theory

Many men and women in different countries of the world have contributed to our understanding of atoms. The following describes several highlights of their research.

John Dalton

John Dalton (1766–1844) is credited with developing a theory that was a new way of describing matter. He was a British schoolteacher and a scholar. His interest in the gases that make up Earth's atmosphere led him to investigate the composition of a number of substances, such as carbon dioxide, water, and nitrogen oxide. In explaining some of his experimental results, he suggested that the particles that make up matter are like small, hard spheres that are different for different elements. He defined an atom as the smallest particle of an element (Figure 1.10 on the next page). This is the basis for what is now known as Dalton's atomic theory. His theory is summarized on the next page.

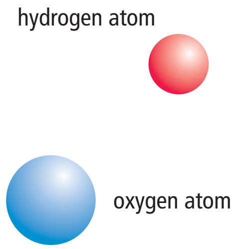


Figure 1.10 Dalton's model: Different elements consist of different atoms.

Dalton's Atomic Theory

- All matter is made of small particles called atoms.
- Atoms cannot be created, destroyed, or divided into smaller particles.
- All atoms of the same element are identical in mass and size, but they are different in mass and size from the atoms of other elements.
- Compounds are created when atoms of different elements link together in definite proportions.

According to Dalton's theory, the atoms that make up gold are different from the atoms that make up lead, and atoms cannot be created or destroyed. You can use these points to explain why the alchemists were unable to change lead into gold (Figure 1.11).

Figure 1.11 Lead (A) cannot be turned into gold (B) because lead atoms cannot change into gold atoms.

J. J. Thomson

Joseph John Thomson (1856–1940) was a British physicist who studied electric currents in gas discharge tubes, which are related to today's fluorescent lights. He determined in 1897 that the currents were streams of negatively charged particles, later called **electrons**. He found that all substances used in his discharge tubes produced these particles. From the results of his experiments, he reasoned that all atoms must therefore contain such particles. In other words, he was hypothesizing that atoms are made up of much smaller particles. This was a startling proposal, since most scientists at the time thought that atoms were indivisible.

Thomson proposed a "raisin bun" model of the atom. His model pictured a positively charged ball like a bun with negatively charged particles embedded in it like raisins (Figure 1.12). His model was short-lived, however. Experiments by his student Ernest Rutherford to both test Thomson's theory and learn more about the structure of the atom soon pointed to a more accurate picture of the particles of an atom.

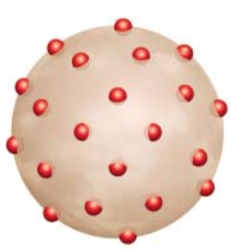


Figure 1.12 Thomson's model: Atoms have smaller particles called electrons.

Ernest Rutherford

Ernest Rutherford (1871–1937) was a scientist from New Zealand who worked for a while at McGill University in Montreal. In 1909, he designed an experiment to probe inside atoms. He exposed a very thin sheet of gold to a stream of high speed, heavy particles that had a positive charge, called alpha particles. The alpha particles were like tiny bullets. Rutherford wanted to see what would happen to alpha particles when they made contact with the gold atoms. He put a detector screen around the gold foil; an alpha particle became visible whenever it struck the screen. Figure 1.13 shows the set-up for this experiment.

Word Connect

"Alpha" is the first letter of the Greek alphabet. Rutherford chose the name alpha particle because he was naming the first radioactive rays he discovered in uranium radiation.

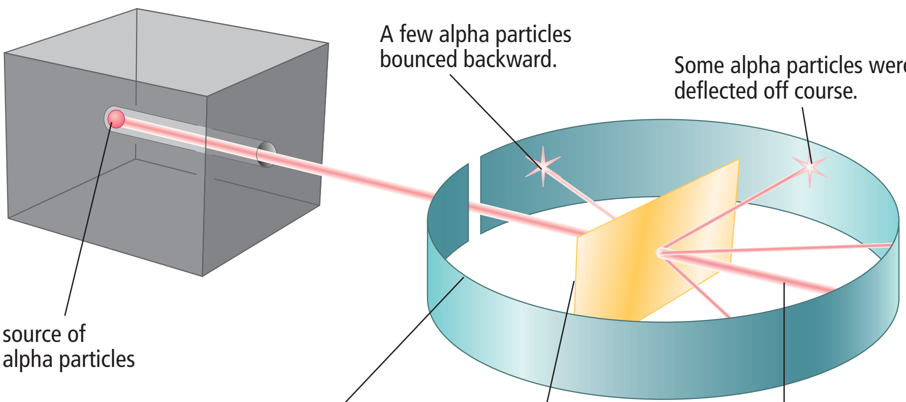


Figure 1.13 Ernest Rutherford discovered the nucleus of the atom with his famous gold foil experiment.

Rutherford's results indicated that most of the alpha particles went right through the gold atoms without being affected. He had expected this, because he knew there must be relatively large space within atoms. However, he was astonished to see that a few alpha particles rebounded from the foil much as a ball rebounds from a solid wall. Rutherford had discovered the **nucleus**—the tiny, dense, positively charged centre of the atom. This was a tremendously important discovery. Rutherford had allowed us to peer inside the nucleus for the first time. A decade later, he also established that there must be at least two kinds of particles inside the nucleus of an atom. One particle, later called a **proton**, had a positive electric charge, and the other particle, called a **neutron,** had no electric charge (Figure 1.14).

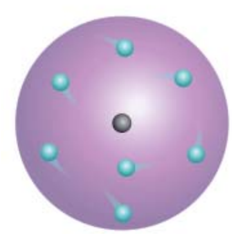


Figure 1.14 Rutherford's model: Electrons move about a nucleus.

Niels Bohr

Niels Bohr (1885–1962), a Danish physicist working under Rutherford, studied the regions surrounding the nucleus, which were now known to contain negatively charged electrons. Bohr studied the results of experiments on the light released by gaseous samples of atoms, such as those of hydrogen. In the experiments, the gases had been made to glow by passing an electric current through them. He proposed that electrons surround the nucleus in specific energy "levels" or "shells." This meant that each electron has a particular amount of energy.

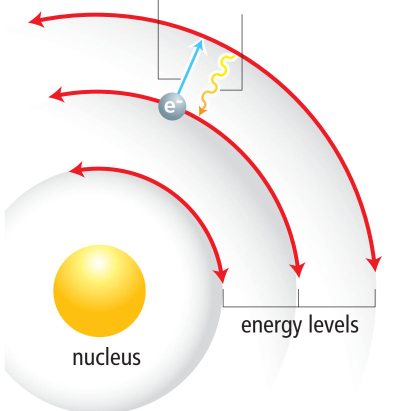


Figure 1.15 Bohr's model: Electrons have different amounts of energy.

If you have ever seen a neon light, you have seen the effect of electrons jumping from one energy level to another (Figure 1.15). When electricity is added to the neon gas, the electrons in the neon atoms gain extra energy. They jump from low to high energy levels. When the electrons drop to lower energy levels, they release energy in the form of visible light. This light is evidence that the electrons exist in specific energy levels and can jump back and forth between them.

Inside the Atom

An **atom** is the smallest particle of an element that retains the properties of the element. We now know that atoms are not the smallest, or most basic, particles. All atoms are made up of three kinds of smaller particles called **subatomic particles** ("sub-" means below). They are called protons, neutrons, and electrons. Each has its own set of properties. All three particles have mass, but only protons and electrons have an electric charge. Neutrons have no electric charge at all.

Mass

Protons and neutrons have much more mass than electrons. This means that when you lift up a large rock, it is the protons and neutrons in the rock that weigh it down. While protons and neutrons have about the same mass as each other, they have about 1800 times more mass than an electron.

Electric charge

Electric charge comes in two types: positive and negative. Protons have a positive charge, and electrons have a negative charge. Because negative and positive charges attract each other, protons (positive) and electrons (negative) are attracted together. Each proton counts as +1, and each electron counts as −1. All atoms have an equal number of protons and electrons. This means that the charges add up to zero, making the atom uncharged or neutral.

Figure 1.16 shows the structure of one type of atom. Table 1.3 lists the three subatomic particles and some of their properties.

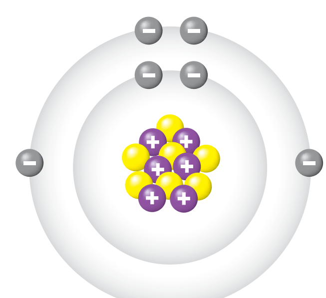


Figure 1.16 Structure of a carbon-13 atom

Connection

Section 7.1 has more information about electric charge in atoms.

Table 1.3 Subatomic Particles

Name	Symbol	Relative Mass	Electric Charge	Location in the Atom
Proton	p	1836	+	Nucleus
Neutron	n	1837	0	Nucleus
Electron	e	1	–	Surrounding the nucleus

The nucleus

The nucleus is a tiny region at the centre of the atom.

- It would take 10 000 nuclei lined up side by side to stretch across the diameter of a typical atom.
- The nucleus always has a positive charge because of its protons. For any atom more complicated than hydrogen, the nucleus must also contain neutrons. Hydrogen is the only element that has a single proton as its nucleus and a nuclear charge of +1 (Figure 1.17). Neutrons have no charge, so the nucleus of a nitrogen atom, with seven protons, has a charge of +7. A nucleus with 92 protons (as in uranium) has a charge of +92.
- Protons and neutrons are held in the nucleus and cannot normally enter or leave it.

Suggested Activity

Conduct an Investigation 1-3B on page 31

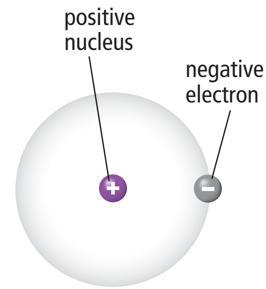


Figure 1.17 Structure of a hydrogen atom

Surrounding the nucleus

Electrons occupy special regions called energy levels, or shells, which surround the nucleus.

- The region that electrons occupy accounts for well over 99.99 percent of the volume of an atom.If a nucleus were the size of a hockey puck sitting at centre ice, the whole atom would include the entire ice sheet, the spectator seats, the building, and the parking lot surrounding it.
- Each electron occupies one whole energy level at a time. An electron is not like a fast-moving particle racing around the nucleus. It is more like a spread-out negative charge that exists in the whole region all at once.

Reading Check

1. What was the main goal of the alchemists?
2. What was the difference between Dalton's model of the atom and Thomson's model?
3. What did Rutherford discover in his gold foil experiment?
4. What was the difference between Thomson's model of the atom and Rutherford's model?
5. What did Bohr discover about how electrons are arranged in atoms?
6. What type of charge does the nucleus have?
7. What type of charge do electrons have?

Explore More

Ernest Rutherford was a student of J. J. Thomson. Niels Bohr was a student of Ernest Rutherford. Each man replaced his teacher's model of the atom with a more refined model. All three received Nobel Prizes for their contributions to science. Find out more about these and other researchers at **www.discoveringscience9.ca**.

1-3A The People Behind the Atom

Think About It

The discovery of the atom has a rich and complex history, filled with fascinating ideas, experiments, debates, and human drama. In this activity, you will research the work of some of the most brilliant scientists in history.

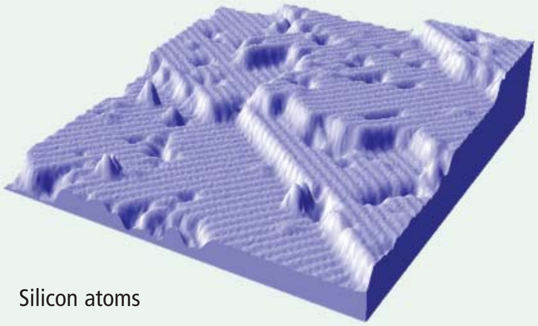
What to Do

1. Select a name from the list that follows on the right.
2. Find a specific topic related to that person. It could be about an important experiment on the atom, a debate between two or more people, or a question about atoms. For example: How have the four statements in Dalton's atomic theory been revised over time? What are some contributions women scientists have made to the development of atomic theory?
3. Consult with your teacher about your topic to make sure it is appropriate.
4. Choose a format for reporting on your investigation. Here are some suggestions.
   - Write a summary of about 500 words.
   - Give a short presentation to the class, explaining what you have found.
   - Design an information poster including your own drawings or photographs with captions.
   - Hold a mock discussion in which members of the class role-play historical figures who explain their ideas.
   - Create a slide show presentation.

Aristotle
Democritus
Isaac Newton
Robert Boyle
Antoine Lavoisier
John Dalton
Michael Faraday
Joseph Priestley
Jöns Berzelius
Joseph Louis Proust
Dmitri Mendeleev
William Crookes
Henry Moseley
J. J. Thomson
Hans Geiger
Ernest Rutherford
Harriet Brooks
Niels Bohr
Henri Becquerel
Marie Curie
Max Planck
James Chadwick
Louis de Broglie
Werner Heisenberg
Richard Feynman
Murray Gell-Mann
Gerd Binnig
Heinrich Rohrer

What Did You Find Out?

1. Post or present your information to your class.



Silicon atoms

Gerd Binnig, a German physicist, and Heinrich Rohrer, a Swiss physicist, invented the scanning tunnelling microscope, the first microscope able to capture images of individual atoms.

1-3B Slivers of Silver

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

- Observing
- Evaluating information
- Predicting
- Explaining systems

It is possible to produce a sample of an element from individual atoms by growing a crystal of it. Even a metal such as silver can have crystals—the atoms simply need to be arranged in a very regular way. In this activity, you will use a dissecting microscope to observe the growth of silver crystals.

Safety

- Handle chemicals safely.
- Wash your hands thoroughly after doing this investigation.

Materials

- microscope slide
- microscope
- copper ribbon
- silver nitrate solution in dropper bottles

Question

How can silver be made in the lab?

Procedure

1. Place a slide on the microscope stage, and put a small piece of copper on the slide.
2. Focus on the piece of copper. Ensure that its image is clear and well lit.
3. Place a drop of silver nitrate solution onto the copper metal.
4. Observe as slivers of pure silver metal grow on the sides of the copper.
5. Clean up and put away the equipment you have used.

Analyze

1. Suggest why the slivers of silver tended to get longer rather than fatter as they grew.

Conclude and Apply

1. Canada is a major exporter of silver ores, which are chemical compounds that contain silver. How might this experiment be applied to the commercial production of silver?

Science Skills

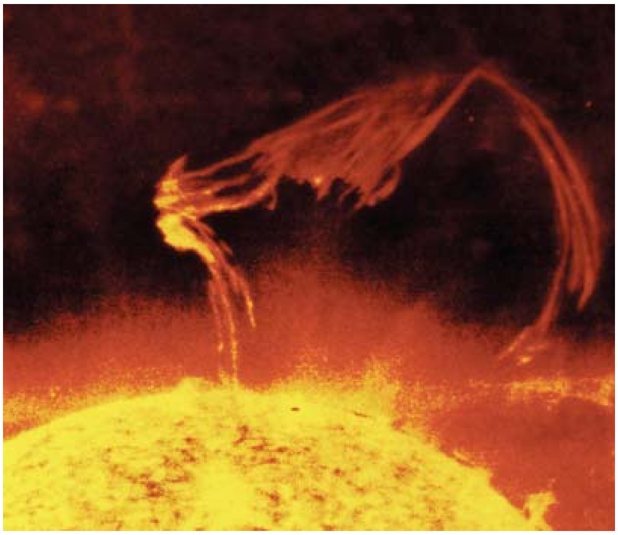
Go to Science Skill 6 for information about how to use a microscope.

Science Watch

Inquiring About Quarks

Nature is full of surprises. In the first half of the 20th century, the discovery of the nucleus, electrons, protons, and neutrons was followed by the discovery of hundreds of new particles. Many of these particles were predicted by scientists before they were observed. For example, one of the predictions was that every particle should have an anti-particle. That is, there should be anti-protons and anti-electrons. Scientists looked for and eventually found these particles.

A more recent discovery is the neutrino, a ghostlike particle with almost no mass that is produced in the core of the Sun. Countless numbers of neutrinos constantly fly out and pass through Earth, as well as through us, on their voyage into deep space.

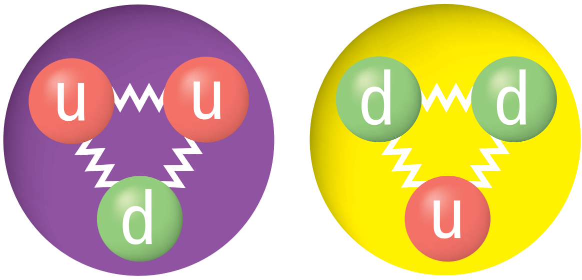


All stars produce vast numbers of tiny particles called neutrinos.

Eventually, a theory called the "standard model" was developed. This theory suggests that electrons are fundamental particles—that they are not made of combinations of anything else. However, protons and neutrons are made of even *tinier* particles called quarks.

Have you ever heard the CBC Radio program *Quirks and Quarks* and wondered what a quark is? Scientists have hypothesized the existence of quarks, but have been unable to isolate an individual quark. A quark is a particle that makes up protons and neutrons. Based on mathematical modelling and their understanding of physics, scientists think that in ordinary matter, there are two kinds of quarks that can combine together in groups of three to form both protons and neutrons. One kind is called an "up" quark (u) and the other is a "down" quark (d). These names do not mean anything. They are just words to help us talk about them. The word "quark" itself is borrowed from a famous book called *Finnegans Wake*, by the Irish writer James Joyce. In the story, "quark" is the sound that seagulls make.

Quarks are connected to each other by a very strong force called, yes, "the strong force." We cannot feel the strong force in our daily lives, but it holds the three quarks together inside each proton and neutron. The strong force has the interesting and unusual property that the farther the quarks get away from each other, the stronger the force holding them together becomes.



Two u quarks and one d quark combine to make a proton.
One u quark and two d quarks combine to make a neutron.

Questions

1. Which subatomic particles are made up of quarks?
2. Quarks have fractional electric charge. An up quark has a charge of $+\frac{2}{3}$, whereas a down quark has a charge of $-\frac{1}{3}$. Use this idea to explain why a proton has a charge of $+1$, whereas a neutron has a charge of zero.
3. Explain why individual quarks are never found in isolation.

Check Your Understanding

Checking Concepts

1. Greek philosophers debated about the nature of matter. What idea did they have that we accept as true today?
2. (a) Who were the alchemists?
   (b) What was their main goal?
3. In Dalton's theory of the atom, in what ways might two atoms of gold be similar?
4. How did Dalton's model of the atom help explain how a piece of gold and a piece of lead have different properties?
5. J. J. Thomson discovered something about atoms that was unknown to Dalton. What did he discover?
6. What did Rutherford's gold foil experiment allow him to discover about the structure of atoms?
7. What are two properties that protons and electrons have in common?
8. Which two subatomic particles are nearly equal in mass?
9. Which part of an atom accounts for most of its volume?
10. What is the difference between a theory and a law?
11. How are new theories developed?

Understanding Key Ideas

12. (a) What did the alchemists do that was an improvement over the Greek method of finding out about matter?
    (b) What did the alchemists do that got in the way of finding out about matter?
13. What part of Dalton's theory did Thomson's studies of the atom show was incorrect?
14. How did Rutherford's gold foil experiment show that atoms have a very dense nucleus at their centre?
15. For each of the following, decide which subatomic particle best fits the description.
    (a) has a positive charge
    (b) is the most massive
    (c) has a negative charge
    (d) gives the nucleus its electric charge
    (e) is in the region surrounding the nucleus
    (f) has no electric charge
    (g) has the least amount of mass
    (h) is in the nucleus along with protons
16. Neutral atoms have no overall electric charge even though protons and electrons have an electric charge. Explain.
17. Imagine that a nucleus of an atom is the size of a baseball. If the baseball is placed on a pitcher's mound, about how large would the whole atom be?

Pause and Reflect

Illustrate and explain your understanding of the current model for the atom. Be sure to include a description of the electric charges and relative masses of the proton, neutron, and electron in your explanation.

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated how atomic theory helps to explain the composition and behaviour of matter. You also studied safety in the science classroom. Create your own summary of key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 8 for help with using graphic organizers.) Use the following headings to organize your notes.

1. Safety in the Science Classroom
2. Properties of Matter
3. Models of the Atom
4. Subatomic Particles in the Atom

Checking Concepts

1. List the safety steps you should take in each of the following situations.
   (a) You notice that your lab partner's clothing has caught fire.
   (b) You splash a small amount of acid into your eye.
   (c) The label on a container of chemicals you are using is not readable.
   (d) You need to unplug an electrical cord.
2. Choose three safety rules. Describe what could go wrong in each case if they were not followed properly.
3. What do the letters WHMIS stand for?
4. What do each of these WHMIS symbols warn against?

   (a) 
   (b) 
   (c) 
   (d) 

5. What do each of these hazard symbols warn against?

   (a) 
   (b) 

6. Explain the difference between a chemical change and a physical change.
7. Which of the following are physical changes and which are chemical changes?
   (a) Ice melts.
   (b) A steak is cooked.
   (c) The filament of a light bulb glows when an electric current flows through it.
   (d) A piece of chalk is crushed.
   (e) A plant grows into a shrub.
8. Which of the following are physical properties and which are chemical properties?
   (a) Lead is a relatively soft metal.
   (b) Copper wires are good conductors of electricity.
   (c) Milk of magnesia neutralizes excess stomach acid.
9. What is an atom?
10. Four researchers who contributed to the development of atomic theory were Dalton, Thomson, Rutherford, and Bohr. Which man first proposed each of the following ideas?
    (a) Atoms contain electrons.
    (b) Atoms contain a nucleus.
    (c) All atoms of the same element are identical.
    (d) An atom is like a raisin bun, in which electrons are the raisins.
    (e) Electrons exist in specific energy levels.
    (f) All matter is composed of tiny, indivisible particles.
    (g) Atoms contain subatomic particles.
    (h) The centre of an atom is positively charged.

11. (a) Define the term "subatomic particle."
    (b) What three subatomic particles are there in a typical atom?
12. Which two kinds of subatomic particles exist together inside a nucleus?
13. Identify the subatomic particle or particles described in each of the following.
    (a) has an electric charge
    (b) is most massive
    (c) is least massive
    (d) has no electric charge
    (e) exists in the nucleus
    (f) have nearly equal mass
    (g) give the nucleus a positive charge
    (h) exists in energy levels surrounding the nucleus
    (i) exist in equal numbers in any atom
14. In a typical atom, how does the size of the whole atom compare to the size of the nucleus?
15. Why does the nucleus of any atom have a positive charge?

Understanding Key Ideas

16. List what you think are the five most important safety rules. Explain why you think each choice is especially important.
17. List a chemical or physical property that could be used to distinguish between the following substances and pure water. Identify whether the property is a chemical or physical property.
    (a) rubbing alcohol
    (b) salt water
    (c) carbonated water
18. Describe water using
    (a) a qualitative physical property.
    (b) a quantitative physical property.
19. Describe iron using
    (a) a physical property.
    (b) a chemical property.
20. (a) What is the difference between a law and a theory?
    (b) How is each one useful in science? Explain using examples you have studied.
21. Explain how Rutherford's gold foil experiment led him to discover that there is a tiny, massive nucleus at the centre of all atoms.

Pause and Reflect

In previous science courses, you were taught that matter was made of tiny, indivisible particles. Describe how your understanding of matter has changed based on what you have learned in this chapter.