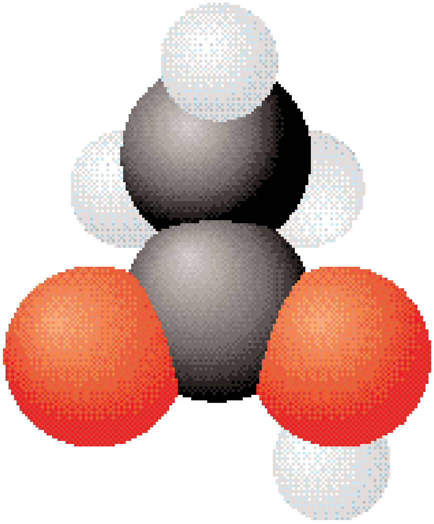
CHAPTER

4 The Periodic Table

Getting Started

1 There are tens of thousands of different chemical compounds that make up our world. Some of these materials are natural. For example, people have used cotton (a plant) for clothing and flint (a rock) for tools for thousands of years. Other materials are **synthetic**—invented and produced by people. Nylon and steel have similar functions to cotton and flint, but they are synthetic. In fact, the substance "nylon" did not even exist before this century. Which of the objects in the photograph are made of synthetic substances? How are these substances made? ➤

2 All substances, whether natural or synthetic, are made of the same building blocks—atoms. Atoms can combine to form molecules. Molecules that are made of more than one type of atom are called compounds and the number of possible compounds is almost infinite. However, there are only about 100 different kinds of atoms to use as building blocks. For example, each molecule of acetic acid is made up of atoms of carbon, oxygen, and hydrogen. What makes these three atoms different from each other? Do any other atoms have similar properties to these three? ➤



3 How does it help you when things are organized? In the last century, a scientist called Dmitri Mendeleev looked for ways to organize the current knowledge about atoms. He invented a **periodic table**—an organized arrangement of elements that explained and predicted physical and chemical properties. Mendeleev's table was the key to understanding elements and discovering new elements and compounds. How did Mendeleev organize his table? Make a list of some of the things that you organize or are organized for you, in your daily life.

Reflecting

Think about the questions in 1, 2, 3. What ideas do you already have? What other questions do you have about the periodic table? Think about your answers and questions as you read the chapter.

Try This: Organizing Elements

Using graph paper or chart paper, cut a strip of paper 20 cm long by 1 cm wide. Draw vertical lines on the paper to divide it into 20 squares. Write the numbers 1 to 20 consecutively in the squares (**Figure 1**). The numbers represent 20 elements. Cut the tape into pieces by cutting along the lines between (a) elements 1 and 2, (b) elements 2 and 3, (c) elements 10 and 11, and (d) elements 18 and 19. You should now have five pieces of paper.

You are told that elements 3, 11, and 19 have similar physical and chemical properties. Line up these elements in a vertical column, and tape the strips of paper into your notebook. The other columns will also line up.

Look at the table you have made. Which elements should have similar properties to element 4? What element should have similar properties to element 9?

Assuming that the elements' numbers are also their atomic numbers, draw Bohr-Rutherford diagrams for elements 3, 11, and 19. What do these elements have in common? Where do you think you should put elements 1 and 2 on your table? Tape them onto your table and explain the reason for your choice.

Write numbers in order on a piece of tape as described.

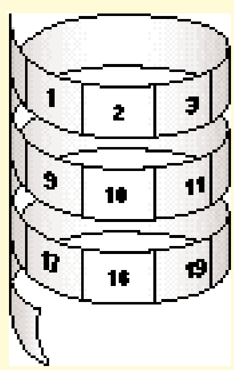


Figure 1

4.1

Organizing the Elements

Figure 1
Physical and chemical properties suggest that elements can be organized into metals and nonmetals.

We often organize things to make them more useful. When you bake a cake, for instance, you might think of the ingredients in categories. You need something sweet for flavour, fat for bonding, flour for substance, and something to help it rise. Many different ingredients can fall into each category. You can combine ingredients from these four categories to make different kinds of cakes.

Up to the mid-1800s, scientists were busy discovering elements and recording their properties. Then they tried to organize their experimental observations in a useful way. At first, they listed the elements alphabetically. But every time a new element was discovered, the whole list had to be changed!

They tried other organizing methods. Could elements be grouped by state and colour? No, too many elements look alike. By taste? Definitely not. Too many elements are poisonous. Also, state, colour, and taste cannot be measured. The scientists also used properties that you studied earlier in this unit. For example, properties such as conductivity, malleability, and lustre suggested that elements could be grouped generally into metals and nonmetals (**Figure 1**).

John Dalton and other scientists then found a quantity that could be measured for an element—its atomic mass. The **atomic mass** is the average mass of an atom (i.e., of all occurring isotopes) of an element. Each element has its own unique atomic mass. Several scientists started to arrange the known elements according to their atomic masses (**Figure 2**).

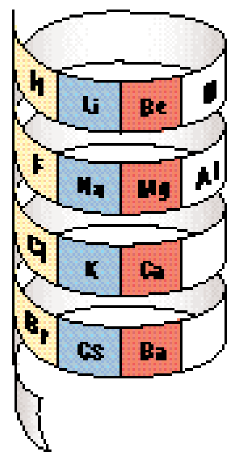


Figure 2
One early scientist organized elements in an arrangement that looked like a coiled spring.

Mendeleev and the First Periodic Table

The best arrangement of elements was produced by a Russian scientist, Dmitri Mendeleev (**Figure 3**). Working with the 64 known elements, he wrote the name of each element on a separate card, along with its atomic mass and other properties such as solubility, density, flammability, and so on. Then he played "chemical solitaire," arranging the cards in different ways to see if he could find any patterns. Perhaps a pattern would explain the behaviour of the known elements. He also hoped this might show a way to discover new elements.

Mendeleev organized his first periodic table by arranging the elements in order of increasing atomic mass. When an element or group of elements seemed to repeat properties he had seen before, he started a new row. Eventually he found that elements with similar properties fit into the same vertical columns. However, often an element seemed to belong in a place based on its mass, but did not fit based on its properties. When that happened, he ignored the mass and moved the element to a column with other elements having similar properties.

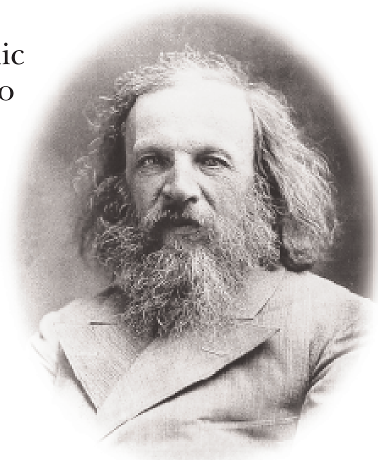


Figure 3
Dmitri Mendeleev's organization of the elements into a periodic table made the study of chemistry manageable.

Mendeleev's arrangement showed a regular pattern, which he described as a law. Simply put, a scientific law is a rule that nature appears to follow. It is a generalization of many observations; a statement rather than an explanation. **Mendeleev's periodic law** states:

> *If the elements are arranged according to their atomic mass, a pattern can be seen in which similar properties occur regularly.*

Testing Mendeleev's Periodic Law

To test a scientific law, you use it to predict new observations. When Mendeleev came to a place in his table in which no known element would fit, he used a blank card (**Figure 4**). Mendeleev predicted that elements would eventually be found to fit the spaces. He also predicted the properties of those elements by examining the elements surrounding the blank spaces. **Table 1** shows two of Mendeleev's predictions and the elements that were discovered to fill in the blank spaces. His predictions were accurate! These discoveries helped convince people that the periodic table worked. A century later, it is still used to summarize chemical facts.

Group		I	II	III	IV	V	VI	VII	VIII
Formula of Compounds		R_2O	RO	R_2O_3	RO_2 / H_4R	R_2O_5 / H_3R	RO_3 / H_2R	R_2O_7 / HR	RO_4
Periods	1	H(1)							
	2	Li(7)	Be(9.4)	B(11)	C(12)	N(14)	O(16)	F(19)	
	3	Na(23)	Mg(24)	Al(27.3)	Si(28)	P(31)	S(32)	Cl(35.5)	
	4	K(39)	Ca(40)	–(44)	Ti(48)	V(51)	Cr(52)	Mn(55)	Fe(56) Co(59) Ni(59) Cu(63)
	5	[Cu(63)]	Zn(65)	–(68)	–(72)	As(75)	Se(78)	Br(80)	
	6	Rb(85)	Sr(87)	?Yt(88)	Zr(90)	Nb(94)	Mo(96)	–(100)	Ru(104) Rh(104) Pd(105) Ag(108)
	7	[Ag(108)]	Cd(112)	In(113)	Sn(118)	Sb(122)	Te(125)	I(127)	

Figure 4

Part of Mendeleev's periodic table, including atomic masses. If he did not know of an element to fit a space, he left it blank and predicted the atomic mass of the element.

Table 1 Two of Mendeleev's Predicted Elements

Property	Gallium		Germanium	
	Predicted 1871	Discovered 1875	Predicted 1871	Discovered 1886
atomic mass	68	69.9	72	72.3
density (g/cm^3)	5.9	5.94	5.5	5.47
melting point	low	30°C	high	2830°C
solubility in acids	medium	medium	low	low

Understanding Concepts

1. What are some of the properties that helped scientists organize elements into metals and nonmetals?
2. (a) What property of atoms did Mendeleev use to organize elements?
   (b) How did he use this property to organize them?
   (c) When did he ignore this property in building his table?
3. Examine the elements in the first column of Mendeleev's first periodic table.
   (a) All but one are shiny metals. What is the exception?
   (b) The first four elements in this group have atomic numbers 1, 3, 11, and 19, respectively. What do these elements have in common?
4. Examine the first two columns of Mendeleev's periodic table. Refer to **Table 2** on page 64.
   (a) What are the combining capacities of the two elements from the first column?
   (b) What are the combining capacities of the three elements from the second column?
   (c) What does this suggest about the combining capacities of all the elements in Mendeleev's periodic table?
5. Sodium chloride, potassium chloride, and calcium chloride are all used for melting ice in the winter. The chemical formula of sodium chloride is NaCl. Predict

Challenge

Make a list of the key points Mendeleev used in creating his periodic table. Speculate on any strengths or weaknesses based on what you know so far.

Inventing a Periodic Table

Mendeleev invented his periodic table by looking for patterns in the properties of different groups of elements. He looked for regularities that would enable him to put elements into families or groups with similar properties. Assuming that not all elements had been discovered, he deliberately left gaps in his table. He predicted that elements would eventually be discovered that would fill these gaps.

Imagine that you own a hardware store. You have received a shipment of nuts and bolts. Unfortunately, the contents spilled and are all mixed together. You also suspect that some of the nuts or bolts may be missing from your original order. You had planned to arrange the twenty types of nuts and bolts in a logical pattern of four rows and five columns on a display rack.

What would be a logical arrangement of the nuts and bolts? Which nut or bolt is missing? How would you predict its characteristics? In this investigation, you will make a periodic table of nuts and bolts to answer these questions.

Part 1: Hardware Items

Materials

- balance
- ruler
- graph paper
- set of 19 nuts and bolts in a resealable plastic bag

Procedure

1 Obtain a bag of hardware items (nuts and bolts). There should be 19 items in the bag. Count them to make sure.

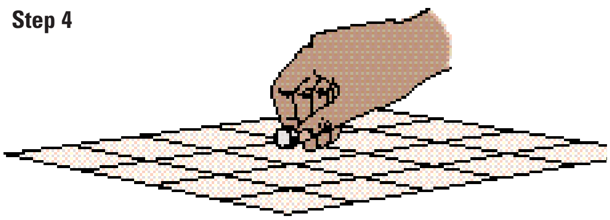
2 There is one hardware item missing from the shipment.

(a) What nut or bolt do you think is missing? Describe the missing item.

3 Draw a large 4×5 grid on a sheet of paper with four rows and five columns. Number the squares from 1 to 20, starting in the top left corner and numbering across the rows. Call these "hardware numbers."

4 In your group, invent a system that you will use to organize your nuts and bolts. Place each item in a square, leaving a space if necessary.

(a) Describe your organizing system.



5 Remove the nuts and bolts from the grid. Now, replace them on the grid using the following new system. Place the smallest bolt in the top left corner and the largest nut in the bottom right corner. Put similar items in the same vertical column. Arrange them so that size increases down each column and generally across each row.

(a) What nut or bolt do you now think is missing? Describe the missing item.

6 Use the balance to measure the mass of each item.

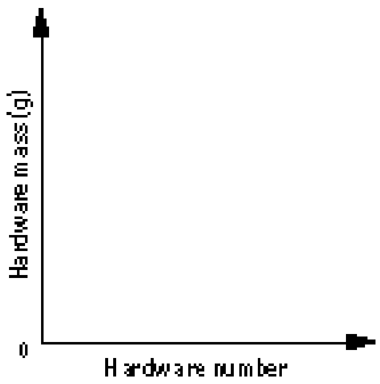
(a) Record the masses in the appropriate square on the grid.

7 Use a ruler to measure the longest dimension of each item.

(a) Record the lengths in the appropriate square on the grid.

8 Count the nuts and bolts and return them to the bag, as directed by your teacher.

9 Plot a graph of hardware mass vs. hardware number (1 to 20). (7B)



10 Plot a graph of hardware length vs. hardware number (1 to 20).

11 Examine your graph of mass vs. number data.

(a) What general trend in mass did you note
(i) across any row of your table?
(ii) down any column of your table?

12 Examine your graph of length vs. number data.

(a) What general trend in length did you note
(i) across any row of your table?
(ii) down any column of your table?

13 Predict the mass and length of the missing item.

Part 2: Store Manager's Dilemma

14 Imagine that you are the manager at a store that sells a wide variety of items, such as a bulk-food store or a stationers'. The store has many different items for sale, and the customers have to be able to find them easily.

(a) Make a list of all the different items you need to find space for in the store.

15 Devise a classification system that would make it easy for customers to find the things they need.

(a) Present your organization system as a detailed floor plan for the store.

Understanding Concepts

1. **(a)** How does your hardware periodic table compare with Mendeleev's periodic table of elements?
   (b) What do you think the mass and length of the nuts or bolts could represent for atoms in Mendeleev's periodic table?
2. **(a)** What groups of elements do you think nuts represent? Why?
   (b) What groups of elements do you think bolts represent? Why?
   (c) Imagine that a nut and bolt are screwed together. What do you think such a combination might represent?
3. How does that process compare with Mendeleev's work?

Reflecting

4. Imagine that you were given a bolt identical to one of the bolts in your set, except that it is made of a more dense material. What do you think this bolt would represent in our atomic model?
5. Some elements in the periodic table never combine with any other elements. What kind of hardware item might you include in this set to represent such an element?

Challenge

What examples of models have you come across earlier in this unit? Which are appropriate for the challenge you have chosen?

SKILLS HANDBOOK: (7B) Constructing Graphs

Exploring the Modern Periodic Table

Mendeleev's periodic table was a major breakthrough in the understanding of the elements. However, he found that organizing elements in order of atomic mass did not always work. In some instances he had to decide whether to place an element by its atomic mass or by its properties. He concluded that his calculation of atomic mass was flawed, trusted his instincts, and went with the properties. This decision proved to be a good one when the nuclear atom and subatomic particles were discovered. People realized that the key to the identity of an element was the number of protons in the nucleus—the atomic number—rather than the atomic mass. A new law was born. The **modern periodic law** states:

> *If the elements are arranged according to their atomic number, a pattern can be seen in which similar properties occur regularly.*

These properties include melting and boiling temperatures and the sizes of atoms. The size of a spherical atom is called the **atomic radius**—the distance from the nucleus to the "outer edge" of the atom.

In the "nuts-and-bolts" activity, you organized the hardware items and looked for trends in properties, such as length and mass, both along a row and down a column. What trends in properties can we observe when we organize elements into a periodic table by atomic number? How does the arrangement of elements in the periodic table relate to the arrangement of electrons in the atoms? Work in pairs and refer to the periodic table on the inside back cover to answer these questions.

Procedure

1 Examine the periodic table on the inside back cover. Note whether the elements are solids, liquids, or gases at room temperature.

(a) Which symbols represent elements that are gases at room temperature?

(b) Name two elements that are liquid at room temperature.

2 Look at the symbols and atomic numbers of the elements.

(a) What is the atomic number of helium (symbol He)?

(b) What is the atomic number of gold (symbol Au)?

(c) What is the symbol of the element with atomic number 22?

(d) What is the symbol of the element with atomic number 33?

3 Look at the atomic masses of the elements.

(a) What is the atomic mass of aluminum (symbol Al)?

(b) What is the atomic mass of silver (symbol Ag)?

(c) What is the symbol of the element with atomic mass 40.1?

(d) What is the symbol of the element with atomic mass 83.8?

4 Mendeleev used atomic masses to organize his periodic table.

(a) What two elements are "out of order" according to atomic mass in the fifth row?

5 Look at the densities and melting points of the elements.

(a) Which element has the highest melting temperature?

(b) Which element has the lowest melting temperature?

(c) Which element has the greatest density?

(d) Which element has the lowest density?

6 Elements 1, 3, 11, and 19 are in the first column of the periodic table.

(a) Draw Bohr diagrams for these elements.

(b) How is the electron arrangement in these elements similar?

(c) How many electrons do you think there are in the outer orbit of the elements Rb and Cs?

7 Elements 9 and 17 are in the second last column of the periodic table.

(a) Draw Bohr diagrams for these elements.

(b) How is the electron arrangement in these elements similar?

(c) How many electrons do you think there are in the outer orbit of the elements Br and I?

8 Look at elements 3 to 10.

(a) Draw Bohr diagrams for these elements.

(b) Describe the general pattern that you observe across a row of the periodic table.

9 Elements in the same column tend to form similar compounds. For example, the compounds that hydrogen forms with elements in the first column are LiH, NaH, KH, and RbH. The compounds that hydrogen forms with elements in the second column are BeH_2, MgH_2, CaH_2, and so on. Hydrogen forms the following compounds by combining with other elements: CH_4, NH_3, H_2O, and HF.

(a) What are the formulas of the compounds formed by the combination of hydrogen with the following?
(i) silicon (Si)
(ii) phosphorus (P)
(iii) sulfur (S)

Understanding Concepts

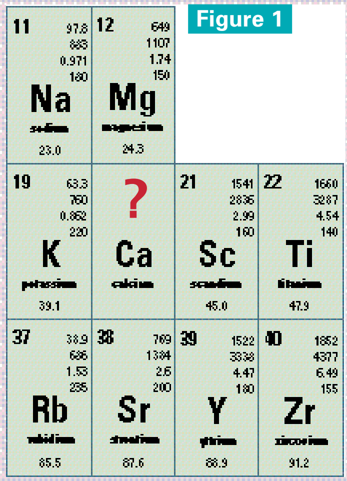
1. In what state are most elements at room temperature?

2. Illustrate how the following properties generally change as you go from left to right in the periodic table.
(a) atomic number
(b) melting temperature
(c) atomic radius

3. Illustrate how the following properties generally change as you go down the columns of the periodic table.
(a) density
(b) melting temperature
(c) atomic radius

4. Look at the portion of the periodic table in **Figure 1**. Facts about calcium have been omitted. Use your understanding of the periodic table to predict the properties of calcium.

Figure 1



5. (a) Plot a graph of atomic radius vs. atomic number for the first 20 elements. 7B
(b) What general trends do you observe in your graph?

Making Connections

6. Elements in the same group have similar properties. Think of two examples in everyday life where similar substances could be substituted for each other. What other factors would you consider before making the substitutes?

Challenge

What were the advantages of working in a group for this activity? What would you do differently in another group situation?

Groups of Elements

When you go to the supermarket, how do you find the foods on your shopping list? If you are looking for yogurt or milk, you look for the aisle marked "Dairy Products." For potatoes or carrots, you look for the "Fruits and Vegetables" aisle. Food in a supermarket is arranged so that people can find things quickly and easily.

In the same way, the periodic table groups elements with similar properties. You can quickly identify an element as a metal if it is on the left or in the centre of the table. Nonmetals are generally found on the right side.

The set of elements in the same column in the table is called a **chemical group**. These elements have similar physical and chemical properties. They form similar kinds of compounds when they combine with other elements. And their behaviour can be explained by the Bohr-Rutherford model of the atom: the elements in a group have the same number of electrons in their outer orbit and tend to form ions by gaining or losing the same number of electrons.

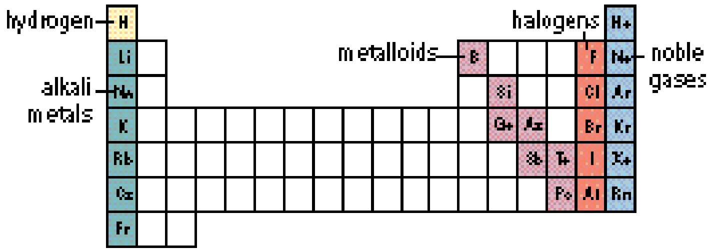


Figure 1
Location of noble gases, alkali metals, halogens, hydrogen, and metalloids on the periodic table. Hydrogen is a unique element.

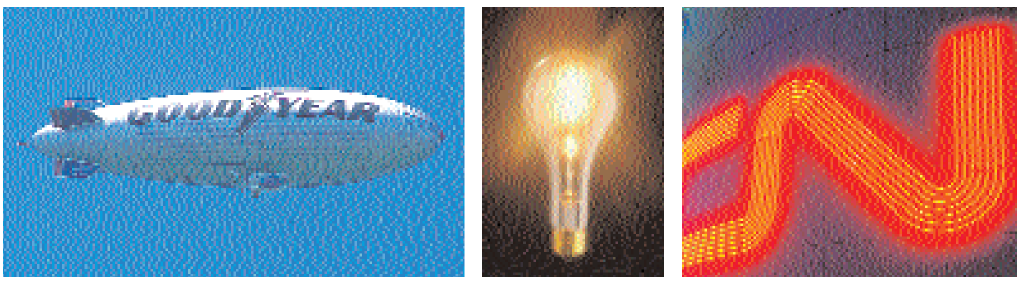


Figure 2
Noble gases have many applications.

Noble Gases

The elements that occupy the far right column of the periodic table (**Figure 1**) are the **noble gases**. All gases at room temperature, the noble gases are often called inert gases because they are so unreactive, almost never forming chemical compounds with other elements.

You might think that such elements would be rare but argon makes up almost 1% of every breath of air that you inhale. Because it is colourless, odourless, tasteless, and nonreactive, no one notices it.

Their lack of reactivity makes noble gases quite useful (**Figure 2**). Helium gas has very low density and is used in lighter-than-air blimps. Neon is used in colourful light displays. Argon is used to fill light bulbs. If ordinary air were used, the metal filament would catch fire and burn out in seconds.

The lack of reactivity of noble gases is explained by their electronic structure. Chemists describe their outer orbits (shown in **Figure 3**) as

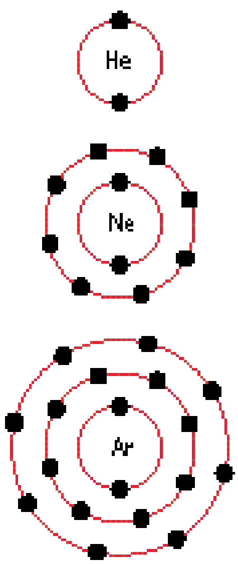


Figure 3
Electron arrangements for three noble gases

"filled." Noble gas atoms do not react with other atoms because they already have a stable arrangement of electrons.

Alkali Metals

The elements that occupy the far left column of the periodic table (**Figure 1**) are called the **alkali metals**. Lithium, sodium, potassium, etc. are all shiny, silvery metals. Unlike the noble gases, they are extremely reactive (**Figure 4**). Because they combine so readily with other elements, they are found in nature only as compounds.

Alkali metal compounds are found everywhere on Earth (**Figure 5**). The most common are sodium compounds, which occur in plants, animals, soil, and sea water. Do you remember the chemical name for salt? Another compound, sodium hydroxide, is used in making soap and paper. Potassium and sodium compounds transmit nerve impulses in your body.

Part of the experimental proof that alkali metals are a group is given by the formulas of the compounds they form: LiH, NaH, and KH with hydrogen; Li_2O, Na_2O, and K_2O with oxygen; and so on. They clearly have a lot in common.

The reactivity of the alkali metals is explained by their electronic structure. The outer orbits (**Figure 6**) have one electron—an unstable arrangement—so alkali metals tend to lose this electron, becoming ions with a charge of +1. These ions readily join with other elements such as oxygen and chlorine.

Figure 4

Like all alkali metals, sodium reacts vigorously with water. The reaction releases heat and produces pure hydrogen gas. Why could this reaction be dangerous?

Figure 5

Alkali metals form compounds such as sodium chloride (salt) and sodium bicarbonate (baking soda). If potassium bitartrate is added to baking soda, baking powder is formed.

Halogens

Fluorine, chlorine, bromine, and the other **halogens** that occupy the seventeenth column of the periodic table (next to the noble gases) (**Figure 1**) are the most reactive nonmetals. Because of their reactivity, they almost always appear naturally as compounds, not as elements. The pure elements you may see in your lab are artificially extracted. For example, chlorine is extracted by the electrolysis of sea water. As shown in the periodic table on the inside back cover, the halogens occur in different states. Fluorine and chlorine are gases, bromine is a liquid, and iodine is a solid at room temperature.

The reactivity of the halogens makes them very useful. The most common halogen compounds are chlorine compounds found in living things, ocean water, and rocks. Table salt is mostly

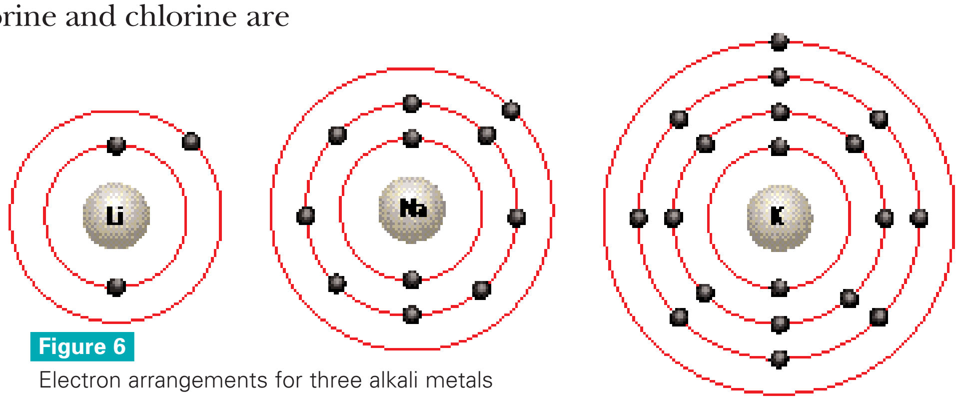


Figure 6

Electron arrangements for three alkali metals

Figure 7
A train derailment involving tank cars containing chlorine gas forced the evacuation of the city of Mississauga, Ontario, in 1979.

sodium chloride but is "iodized" by adding a small amount of potassium iodide to prevent disease of the thyroid gland. Chlorine is used to kill bacteria and purify drinking water, but in large amounts it is extremely dangerous (**Figure 7**). Iodine is dissolved in alcohol to make an antiseptic to treat skin cuts. Sodium fluoride is added to toothpaste because the fluorine atoms bond to tooth enamel, making it less likely to develop cavities.

Halogens are so reactive because of their electronic structure. The outer orbits of the fluorine and chlorine atoms (**Figure 8**) have seven electrons. In chemical changes, halogens tend to gain one electron in order to have a stable arrangement of electrons. Halogen ions have a charge of –1.

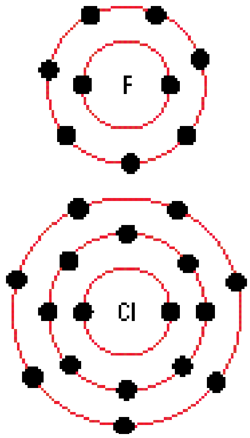


Figure 8
Electron arrangements for two halogens

A Group of One

Hydrogen is a unique element. Its most common isotope has only a single proton and no neutron in its nucleus. Like the alkali metals, it has only one electron in its outer orbit. Losing the electron makes the hydrogen ion positive, so it reacts with other elements, such as the halogens, that need extra electrons to fill their orbits (resulting in negative ions). Hydrogen has little else in common with the alkali metals: it is a colourless, odourless, tasteless, highly flammable gas (**Figure 9**). In other reactions, hydrogen acts like a nonmetal, gaining one electron so it has a complete first orbit. For example,

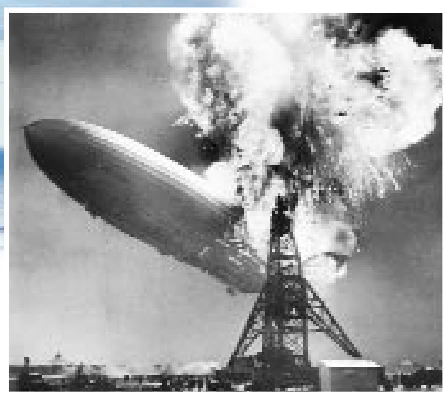


Figure 9
Hydrogen's low density makes it useful for weather balloons. Why is hydrogen not used in blimps that carry people?

Did You Know

When fluorine was first purified, it reacted with most of the containers it was put in! Today we store fluorine in Teflon-coated containers to prevent reactions.

it reacts with the alkali metals to form compounds such as LiH, NaH, KH, and so on.

Almost all of Earth's hydrogen exists in combination with other elements. Its reactivity is too great for it to exist in the atmosphere as a free element. Hydrogen is one of the main elements in all living things, as well as in petroleum, coal, and natural gas.

Metalloids

Metalloids are elements that possess both metallic and nonmetallic properties. Not strictly a group themselves, they are found in different groups on the right side of the periodic table (**Figure 1**), on both sides of the zigzag line that divides the metals from the nonmetals. For example, silicon is a metalloid. It is shiny and silvery, but is not malleable and is only a partial conductor of electricity. Other metalloids are boron, germanium, arsenic, selenium, antimony, tellurium, polonium, and astatine.

The electronics industry uses silicon and germanium, both semi-conductors, to make microcomputer chips. You may have read about arsenic as a poison. Another metalloid, boron, is used in borax water softeners and in the antiseptic, boric acid.

Rows on the Periodic Table

The groups of elements—the columns in the periodic table—have similar physical and chemical properties. These properties, however, vary from element to element in a column. Elements beside each other in the table also show similarities and gradual changes in properties. These horizontal rows of elements are called **periods**. The first period contains two elements: hydrogen and helium. The second period contains eight elements, starting with lithium and ending with neon. As you go from left to right within a row, the atomic number increases and the elements gradually change from metallic (lithium) to nonmetallic (fluorine), and then finally to the noble gases (neon) at the far right.

Challenge

What group of elements do any of the substances in your challenge belong to?

Understanding Concepts

1. Where on the periodic table do you find metals, metalloids, nonmetals, and noble gases?
2. **(a)** Define the term "chemical group."
   (b) Give three examples of chemical groups.
   (c) Compare the arrangement of electrons in the elements in the same group.
3. **(a)** Why are noble gases sometimes called inert gases?
   (b) How is the electronic structure of helium different from other noble gases? Why is it still included in the group?
4. **(a)** List similar properties of the alkali metals.
   (b) What similarities in electron arrangement do the alkali metals show?
5. **(a)** List similar properties of the halogens.
   (b) What similarities in electron arrangement do the halogens show?
6. **(a)** What evidence suggests that hydrogen should be in the first column of the periodic table?
   (b) How is hydrogen different from other elements in the first column?
7. What are metalloids?
8. Rubidium (Rb) is an alkali metal. What are the formulas of its compounds with hydrogen and with oxygen?
9. Write the names and formulas of the four compounds that can be formed by combinations of potassium, lithium, chlorine, and/or bromine.
10. Express, as a law, the relationship between position on the periodic table and number of electrons in the outer orbit.

Making Connections

11. Make a chart listing practical applications of alkali metal compounds.

Exploring

12. One meaning for the word "period" is "a portion of time marked by some returning action or phenomenon." Determine the trends that appear across the periods of the periodic table. Is this definition appropriate? Write a paragraph giving evidence to support your view.

4.5 Investigation

SKILLS MENU
- ● Questioning
- ● Hypothesizing
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ● Communicating

Groups of Elements and Compounds

How can you use the periodic table to make predictions? You know that the position of an element in the periodic table gives a clue to its physical and chemical behaviour. Elements in the same group (column in the table) tend to react in the same way. In this investigation, you will examine some of the properties of four groups in the periodic table: Group 1 (the alkali metals), Group 2, Group 16, and Group 17 (the halogens). The elements you will examine are shown in **Figure 1**.

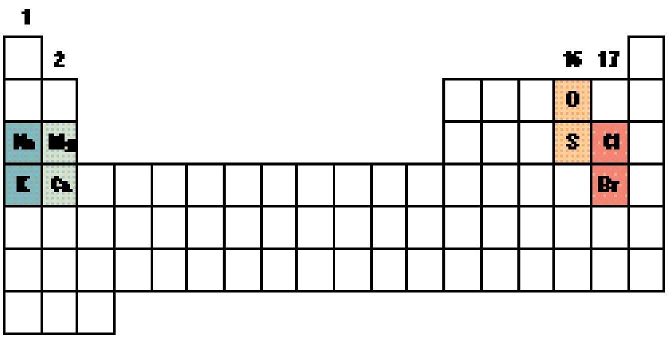


Figure 1
The position of an element in the periodic table can tell something about its properties.

One way to find similarities is to look at the properties of the elements themselves. You will examine Groups 1 and 2 elements directly. Another way is to investigate their compounds. Elements in the same group tend to form compounds with similar properties. In this investigation, you will compare Groups 1 and 2, and Groups 16 and 17, by looking for trends in the behaviour of their compounds. Remember that elements in Groups 16 and 17 change their names slightly when forming compounds: chlorine in a compound becomes chloride, sulfur becomes sulfide, and so on.

Materials

- safety goggles
- apron
- periodic table
- 3 beakers, each 250 mL
- overhead projector
- for teacher demonstration only: sodium metal, potassium metal, calcium metal, phenolphthalein indicator
- microtrays
- toothpicks
- eyedropper
- small samples of the following compounds: copper(II) chloride, copper(II) bromide, copper(II) oxide, copper(II) sulfide, calcium carbonate, magnesium carbonate, potassium carbonate, sodium carbonate

Assume that all powders are poisonous. If you spill any of these powders on the skin, in the eyes, or on clothing, wash the area immediately with plenty of cold water. Inform your teacher of any spills.

Question

1 Write a question that is being investigated. (4A)

Hypothesis

2 Make your own hypotheses at each step, as directed in the procedure.

Procedure

3 Make a full-page data table as shown in **Table 1**.

Table 1

Name of Starting Material	Appearance of Starting Material	Observations
calcium	?	?
sodium	?	?
potassium	?	?
magnesium carbonate	?	?
sodium carbonate	?	?
potassium carbonate	?	?
calcium carbonate	?	?
copper(II) chloride	?	?
copper(II) oxide	?	?
copper(II) bromide	?	?
copper(II) sulfide	?	?

4 Put on your apron and safety goggles.

SKILLS HANDBOOK: (4A) Asking Questions and Hypothesizing

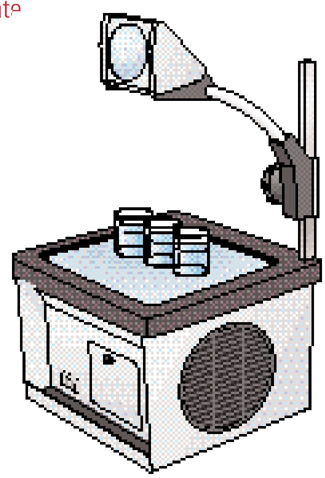
Part 1: Comparing Groups 1 and 2 Elements

(Teacher demonstration using overhead projector)

5 Place a sheet of plastic wrap or an overhead acetate over the screen of the projector to protect it from any splashes. Turn on the projector. Place 3 beakers on the screen. Fill one-third of each beaker with water. Add 2 drops of phenolphthalein indicator to each beaker.

Alkali metals are highly reactive. They must be stored under oil to prevent reaction with air. Use of larger amounts may cause an explosion. Do not cover the beaker with a glass plate as dangerous quantities of hydrogen gas may accumulate.

Step 5



6 Examine a small piece of calcium (about enough to cover your little fingernail).

(a) Predict what will happen when the calcium is added to water.

(b) Record the appearance of the element in the appropriate space on your data table.

7 Add the calcium to one of the beakers. After the reaction stops, note the colour of the indicator and whether the resulting solution is clear or cloudy.

(a) Record your observations.

8 Repeat steps 6 and 7, using a tiny piece of sodium (enough to fit on the flat end of a toothpick).

(a) Record your observations.

9 Examine the periodic table. Which groups do calcium, sodium, and potassium belong to? How should potassium behave?

(a) Make a prediction on the appearance and behaviour of potassium.

10 Repeat steps 6 and 7 using a tiny piece of potassium (enough to fit on the flat end of a toothpick).

(a) Record your observations.

Part 2: Comparing Compounds of Groups 1 and 2 Elements

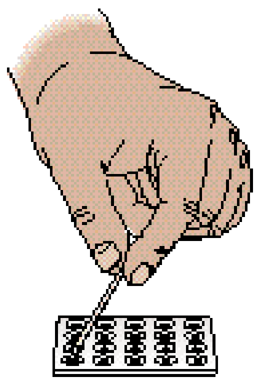
11 Obtain a microtray, a toothpick, and a small amount of magnesium carbonate (enough to fit on the flat end of a toothpick).

(a) Predict what will happen when the magnesium carbonate is added to water.

(b) Record the appearance of the compound.

12 Add the compound to a cell of the microtray that is half-filled with water. Try to dissolve the compound, using a toothpick to stir.

Step 12



(a) Record your observations.

13 Repeat steps 11 and 12 using sodium carbonate.

(a) Record your observations.

14 Examine the periodic table. What groups do sodium, potassium, magnesium, and calcium belong to? How should potassium carbonate and calcium carbonate behave?

(a) Make a prediction on how potassium carbonate and calcium carbonate should behave in water.

15 Repeat steps 11 and 12 using potassium carbonate, and again using calcium carbonate.

(a) Record your observations.

Part 3: Comparing Compounds of Groups 16 and 17 Elements

16 Repeat steps 11 and 12 using copper(II) chloride.

(a) Record the appearance of the compound and your observations.

17 Repeat steps 11 and 12 using copper(II) oxide.

(a) Record your observations.

18 Examine the periodic table. What groups do the elements chlorine, bromine, oxygen, and sulfur belong to? How should copper(II) bromide, and copper(II) sulfide behave?

(a) Record your prediction.

19 Repeat steps 11 and 12, using copper(II) bromide and copper(II) sulfide.

(a) Record your observations.

20 Dispose of the contents of your microtrays and put away your materials as directed by your teacher. Clean up your work station. Wash your hands.

Analysis and Communication

21 Analyze your observations by answering the following questions:

(a) Which metal reacted most vigorously in water?

(b) What evidence did you have that sodium and potassium are alkali metals, but calcium is not?

(c) Compare the appearance and solubilities of the Group 1 and Group 2 carbonates.

(d) Are these results consistent with the location of these elements in the periodic table? Explain.

(e) Compare the appearance and solubilities of the copper(II) chloride, bromide, oxide, and sulfide.

(f) Are these results consistent with the location of these elements in the periodic table? Explain.

22 Write a paragraph summarizing how the periodic table can be used to predict the properties of elements and compounds.

Understanding Concepts

1. Predict what you would see if you added rubidium metal to water.

2. Predict the solubilities in water of

(a) copper(II) iodide

(b) barium carbonate

3. Zinc oxide is a white solid and zinc sulfide is a black solid. Both are insoluble in water.

(a) Are these properties consistent with your experimental observations? Explain.

(b) Are these properties consistent with the periodic table? Explain.

Exploring

4. Obtain a *Handbook of Chemistry and Physics*. Look at the listings of properties of various compounds. Record examples of similarities of compounds of elements in the same chemical groups.

5. Find out what other compounds of Groups 1, 2, 16, and 17 elements are available from your teacher. Plan an investigation, including hypotheses, to investigate the properties of calcium chloride, magnesium chloride, and other compounds in the periodic table. Obtain your teacher's approval before you carry out your investigation.

Challenge

Identify the elements in this investigation that were organized into Mendeleev's periodic table. Compare where he placed them with where they are placed in the modern periodic table.

4.6 Case Study

Elemental Magic

Imagine that you are visiting a sports and camping store. You are thinking of buying skates, and your friend is looking at canoes. How do you decide what to buy? Certainly, price is important! But you also have many choices of materials. The skates could be made of natural leather, a synthetic, or a combination of the two. The canoe could be made of aluminum, fibreglass, Kevlar, ABS plastic, or other substances. Scientists use the "magic" of chemistry to make thousands of materials.

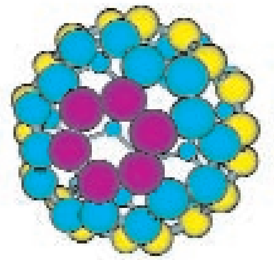


Figure 1
Materials scientists are always looking for new ways of assembling atoms into molecules. "Bucky-balls" are made of carbon atoms arranged in a sphere.

(a) What natural or "traditional" materials can you see around you?

The "magicians" are materials scientists—modern alchemists who make new products by using their knowledge of the periodic table. Understanding the arrangements of elements into groups and periods makes it possible to predict new ways of assembling atoms into molecules (**Figure 1**).

(b) What kinds of elements do materials scientists use?

(c) What are some of the products of this magic?

Table 1

Percentage Use of Different Types of Materials in History

Material	5000 B.C.	A.D. 1800	1960	2000
Metals	5	30	80	40
Polymers	40	35	10	25
Composites	15	5	2	15
Ceramics	40	30	8	20
Total	100%	100%	100%	100%

Over the centuries, people have used four general types of materials to make everything they need: metals, polymers, composites, and ceramics. The relative importance of these substances has changed over time, as you can see in **Table 1**. For example, in 5000 B.C., metals were relatively unimportant. By 1960, they had become by far the most important materials in the world!

(d) What types of metals would have been used in 5000 B.C.?

(e) What types of metals were in wide use by 1960?

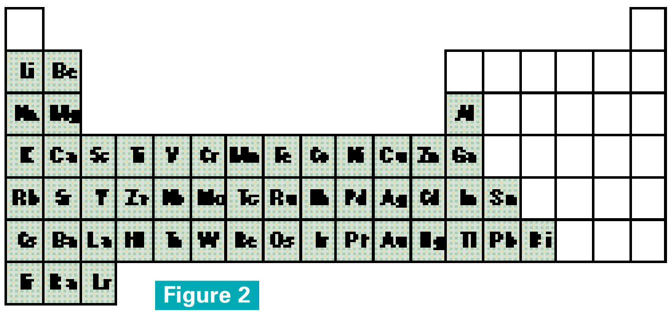


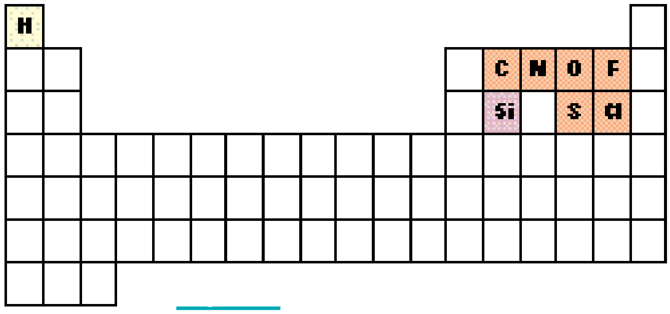
Figure 2
The metallic elements

Metals

Metals form the majority of elements in the periodic table (**Figure 2**). In 5000 B.C., almost the only metals used were gold and copper for jewellery and containers. Because the metals were difficult to produce, they were rare and highly prized. As people discovered ways of purifying and mixing metallic elements, metal alloys such as bronze and steel became more important. They could be used for weapons, utensils, building, and many other uses. By the middle of the 20th century, alloys were used in everything from tractor bodies to building structures to tableware (**Figure 3**). Today super alloys can be specially engineered to be, for example, heat-resistant jet engine parts or corrosion-resistant chimney linings for power plants.

Figure 3

(f) Why are alloys, rather than elemental metals, used for these highly-specialized applications?



The elements in polymeric materials

Polymers

Polymers or elastomers are materials made of long molecules, something like miniature lengths of string. The most important elements in these substances are carbon, hydrogen, and oxygen (**Figure 4**). In 5000 B.C., the only elastomers were natural compounds found in animal and plant fibres. Wool, leather, wood, linen, and cotton were used for clothing, shelter, tools, boats, and so on.

(g) Suggest other natural elastomers, and their uses.

Over the centuries, glues, rubber, and other natural elastomers were discovered. A major breakthrough in polymer chemistry was the invention of plastic polymers (**Figure 5**) in the 20th century, including nylon for clothing, polytetrafluoroethylene for nonstick cookware, and polystyrene for drink cups. Some new polymers are tough, light, and heat-resistant enough to be used in jet aircraft. Try to imagine a world without plastics: no CDs, no disposable food containers, and no plastic toys.

Figure 5
All plastics are examples of polymers.

(h) The development of almost indestructible polymers is not entirely good news. What drawbacks do they have?

(i) What is being done to try to overcome these drawbacks?

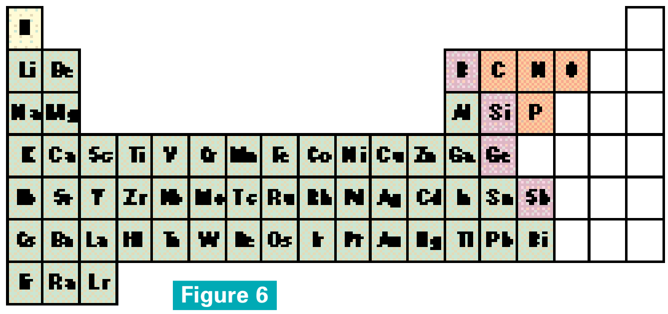


Figure 6
The elements used in ceramic materials

Ceramics and Glasses

Ceramics and glasses are materials derived from minerals and rocks. The elements that are most important in these compounds include silicon, carbon, and oxygen, but many elements can be used, as you can see in **Figure 6**. In 5000 B.C., the most important ceramics were stone for weapons, flint for tools, and pottery for containers. Glass was invented about 2000 years ago. Today tough new ceramics are being engineered that have very special properties (**Figure 7**).

(j) Carbon fibre is a ceramic. What is it used for? Why is it suitable for these uses?

Composites

Composites are materials that are formed by mixing two other materials. The first composite was probably a straw-clay combination used in

Try This — Making Gak

You can make your own synthetic polymer by dissolving enough borax cleaning powder to fit on the end 2 cm of a toothpick in half a teaspoon of water. Add about a teaspoon of white glue to the mixture and mix well. As the reaction continues, you will be able to pick up the polymer and knead it in the palm of your hand to squeeze out the water. Instant goo!

Airborne cleaning powder can irritate eyes, skin, and respiratory tract. Do not ingest.

building bricks. When materials scientists make composites, they try to combine the best properties of the polymers, ceramics, or metals that they put together. For example, fibreglass, a composite of a polymer and tiny glass fibres, can be used to insulate houses or make boat hulls.

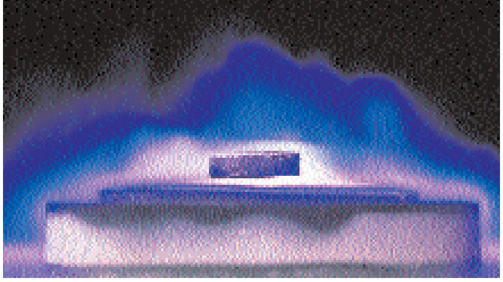


Figure 7

In the future, superconducting electromagnets may power high-speed trains.

(k) Paper is a composite. What substances might it contain?

Materials Science and Canoes

Back in the sports store, your friend is still looking at canoes, and suggests buying one for a canoe trip in northern Ontario. What kind of canoe should you use? What should the canoe be made of? Even for something as simple as a canoe, materials science offers choices in all the categories that you have learned about (**Figure 8**). Depending on whether you want to run rapids or just paddle on a lake, the new alchemists have given you a wide choice of materials.

(l) Research the various materials that are now used for making different kinds of canoes. What are the benefits and drawbacks of each material?

(m) Having decided what kind of paddling you want to do on your imaginary canoe trip, choose the most appropriate canoe to buy.

Figure 8

Canoes for shooting rapids are made of different materials from those used for paddling on quiet lakes.

Understanding Concepts

1. (a) Draw a bar graph to summarize the information in **Table 1**. (7B)
   (b) Examine your graph or **Table 1**. What types of materials were most important in (i) 5000 B.C., (ii) A.D. 1800, (iii) 1960, and (iv) 2000?
2. Give five examples of each type of material that you would use in a typical day.
   (a) polymers (Classify the polymers you chose as natural or synthetic.)
   (b) ceramics
   (c) metals
   (d) composites
3. Why are materials scientists called "magicians"? Write a paragraph comparing them with stage magicians.

Exploring

4. Why did metals peak in popularity and then decline? Research some aspect of the use of metals in Canada and prepare a written or oral report.
5. Research "bucky-balls" and other fullerenes, both named after the scientist, Buckminster Fuller. How do materials scientists hope to use these new molecules?

Reflecting

6. Compare the four types of materials scientists use with the number of elements used. Do you think this affects manufacturing costs?

Challenge

Identify three products that are valuable to you. What are they made of? Include this information in your display. Which substance would you choose to market?

SKILLS HANDBOOK: (7B) Constructing Graphs

4.7 Explore an Issue

Ozone: A Global Environmental Hazard

Can elements in the periodic table occur in more than one form? Can an element be helpful in some situations and harmful in others? The answer to these questions is yes, and oxygen is an example of such an element.

You will recall that oxygen exists in two different forms: oxygen gas and ozone. The colourless, odourless oxygen gas that we breathe has the formula O_2. Without this gas, all organisms would die. Ozone is a pale blue gas with the chemical formula O_3. It is formed by the action of sunlight on oxygen, by lightning, and as a side effect of pollutants released from car engines. At ground level, ozone is poisonous but, in the upper atmosphere, it protects us from the Sun's radiation.

Ozone and Sunlight

You will remember that sunlight contains many different energies or colours of light, represented by the visible spectrum. Sunlight also contains invisible ultraviolet (UV) radiation, which has higher energy than any visible colour. UV radiation is believed to cause skin cancer, decrease the body's resistance to diseases, and can blind u
also harms plant life. Fortu
10% of the Sun's UV radiat
the atmosphere. The reaso
layer: ozone in the upper atmosphere that absorbs the UV radiation, preventing it from reaching the ground.

The Ozone Killer

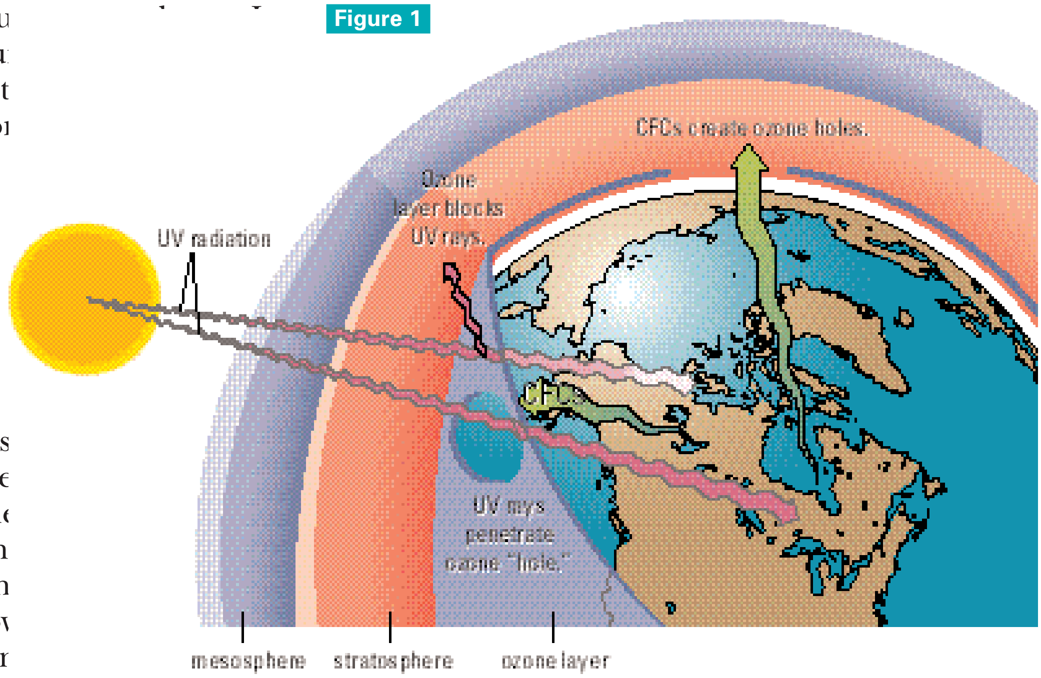
Chlorofluorocarbons (**CFC**s
compounds invented by che
the 1930s by putting togeth
chlorine, and fluorine atom
seemed very safe because th
stable: they didn't break do
they weren't harmful to livi
things. CFCs were used to clean, to cool, and to dissolve other substances. The first CFC, Freon, is probably the coolant in your refrigerator at home.

It took several decades for the first CFCs to work their way up through the atmosphere, where an unexpected reaction took place: UV radiation released chlorine atoms from the CFCs. And each chlorine atom broke apart 100 000 molecules of ozone. As the ozone broke down, the UV radiation was able to penetrate farther through the atmosphere, releasing more chlorine from CFCs as it went (**Figure 1**). An ozone killer was on the loose. Could it be stopped?

The Montreal Protocol

Recognizing the need to stop CFCs from reaching the ozone layer, over 100 countries signed the Montreal Protocol in September 1987, agreeing to cut CFC production in half by January 1996. Equipment that already contains CFCs was not banned for three reasons: the expense; the technology to

Figure 1



completely replace CFCs is not yet developed; and the technology that depends on CFCs, especially the refrigeration of food and medicine, is too important to just shut it down.

Some countries have still not agreed to the Montreal Protocol. Even in countries that are not producing CFCs, there is evidence that these chemicals are being smuggled in and used illegally. The production and use of CFCs remains a global issue. **Figure 2** shows the use of CFCs by region.

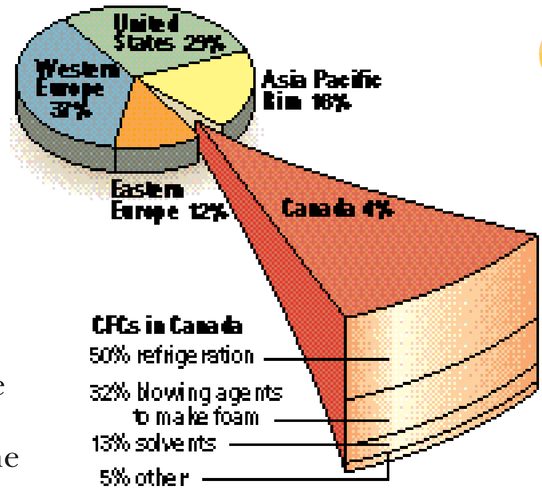


Figure 2

Use of CFCs by region. More than half of all CFCs used each year are released to the air.

Challenge

To prepare a persuasive report, you need to consider all factors related to the points you are trying to make. What factors do you need to consider for the challenge you have chosen?

Issue: Should CFCs Be Banned?

Statement

CFC production should be stopped completely by the end of this year. All refrigerators, air conditioning systems, manufacturing uses, etc., must be converted to allow the use of some other substance.

Benefits of a Ban

Opinion of an atmospheric scientist
If we ban CFCs, damage to the ozone layer may stop getting worse within a few decades. If we don't, the ozone layer will keep getting thinner and thinner.

Opinion of a dermatologist
The sooner CFC use is ended, the less damage will be caused to people's health. The rate of skin cancer may keep on climbing unless we do something now.

Risks of a Ban

Opinion of a consumer group
If there is a total ban, all our fridges and air conditioners will have to be replaced. We can't afford that. Besides, how do we know that the substitutes for CFCs are any safer? We used to think CFCs were safe.

Opinion of a highrise owner
Each of my apartment buildings has a large air conditioner. It would cost $200 000 to replace each one. I'd have to raise my rents.

Opinion of a citizen
It's too late to worry about this. The CFCs are already up there. We can just wear sunglasses and use more sunblock.

What Do You Think?

- Should Canada ban CFCs totally? Should Canada stick to the Montreal Protocol? Is there another alternative? Research these questions. (3A)
- Decide how you feel about this issue and assemble your thoughts and reasons into a position statement. Present your opinions in a letter to your member of parliament or to a local environmental group. (3B)

SKILLS HANDBOOK: (3A) Research Skills (3B) Critical Thinking

4.8 Investigation

SKILLS MENU
- ○ Questioning
- ● Hypothesizing
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ● Communicating

Linking Atomic Structure and Periodicity

In this chapter, you have learned how Mendeleev and modern chemists arranged the elements in the periodic table. This table helps scientists to understand the elements and to predict their properties. Elements in the same group are similar but show gradual changes in properties down a column in the table. Elements also show changes along a row. By studying the elements in Groups 1, 2, and 13 to 18 (**Figure 1**) you can confirm that these changes occur.

How can we show these changes or **periodic trends** down a column or along a row? One choice is to plot graphs on paper or computer. For example, a plot of atomic radius vs. atomic number shows definite trends. Or we can build three-dimensional models to represent such trends. For example, different lengths of straws can represent different atomic radii of atoms. If these straws are placed in a microtray arranged like a periodic table, you can see trends along rows and down columns. In this investigation, you will use this technique to look for periodic trends in the table.

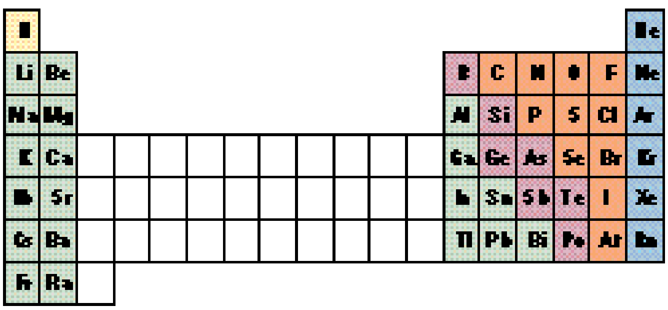


Figure 1

Materials

- periodic table, containing the following properties for each element: atomic radius (in pm), density (in g/cm^3), boiling point (in °C), and melting point (in °C)
- 96-well microtray
- fine-point permanent marker
- straws with diameter the same as the microtray cells
- scissors
- ruler

Question

How can we show trends down a column or along a row?

Hypothesis

1. Write your own hypothesis for the property assigned to you.

Procedure

2. Your group will be assigned a particular periodic property.
3. Using a periodic table, locate the data for your property for each of the elements.
   (a) Make a data table similar to **Table 1**, titled with the property you are representing (e.g., atomic radius or boiling point).

Table 1

Element	Element Symbol	Atomic Number	Number Value of Property from Table	Calculated Length of Straw (cm)
hydrogen	H	1	37	1.9
?	?	?	?	?

Periodic properties for elements can be represented with different straw lengths. For example, hydrogen has atomic number 1 and atomic radius 37 pm. At a scale of 1 pm = 0.05 cm, the straw length will be 37 × 0.05 = 1.85 cm, or 1.9 cm to one decimal place.

   (b) Copy the names and symbols of the elements and their values into the first and second columns of your data table.
4. You need to find the length of straw in cm that you need for each element. The longest straw should be about 10 cm to 15 cm in length. Use the following calculation for each element:

   Length of straw in cm = number value x scale value

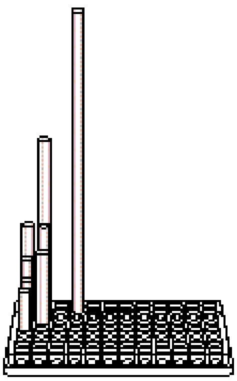
   The scale value depends on which property you are investigating.
   - For atomic radius in picometres, the scale value is 0.05.

- For density in g/cm^3, the scale value is 1.
- For boiling point in °C, to allow for negative values, each straw represents a temperature scale that begins at –300°C and ends at 3600°C. Add 300 to each element's boiling point before multiplying by the scale value, which is 0.003.
- For melting point in °C, again add 300 before multiplying by the scale value of 0.003.

(a) Perform the calculations and complete the table. Record numbers to no more than one decimal place.

5 Obtain a microtray, which will be your "periodic table." Use columns 1 to 8 to represent the eight groups of elements (Groups 1, 2, and 13 to 18). Use rows A to F to represent the five rows of the periodic table.

6 Use scissors to cut lengths of straws to represent the property for each of the elements. As soon as it is cut, place each straw in the appropriate well as shown.



Step 6
An eight-by-five section of a microtray can represent eight columns (Groups 1, 2, and 13 to 18) and five rows of a periodic table.

7 Use the permanent marker to label the outside of your microtray with the property represented.

8 Look at your table and look for general trends in your property (i) across a row and (ii) down a column

(a) Record the trends that you observe.

9 Exchange your microtray with groups that have investigated the other three properties.

(a) Record the trends that you observe for the other properties.

Analysis and Communication

10 Analyze your data by answering the following questions:

(a) What were the general trends in each property across a row?

(b) What were the general trends in each property down a column?

(c) In your opinion, which property showed the most predictable, regular trends in the table? Explain.

(d) In your opinion, which property showed the most unpredictable, irregular trends in the table? Explain.

11 Present your model.

Exploring

1. Each group should remove one straw and hide it. Exchange your microtray with another group. Each group should then try to cut a new straw of a different colour to put into the empty cell. When you have finished, compare the new straw with the hidden straw. Repeat this process with other groups.
2. Use a computer graphing program to plot graphs of
   (a) atomic radius vs. atomic number
   (b) density vs. atomic number
   (c) boiling point vs. atomic number
   (d) melting point vs. atomic number
   Compare the computer graphs with your three-dimensional microtray tables.

Reflecting

3. 4A 4B Discuss, among the members of your group, reasons for the observed trends. Develop hypotheses to account for the trends. How would you suggest testing your hypotheses?

Challenge

What information would you need to add if you were displaying your model rather than presenting it?

Groups of Elements: Profile

In this activity, you will use the combined abilities of a team of students to research, gather, analyze, and produce a profile that represents a group of elements.

Materials

- a container (file folder, large envelope, small pizza box, etc.)
- research materials (library, CD-ROMs, Internet, etc.)
- magazines and newspapers

Procedure

1 You will be a member of a team. Each team should have a variety of different strengths and interests.

2 Choose a group of elements to study: alkali metals, halogens, or any other column in the periodic table. Record your team's choice with your teacher.

3 Research information about the group you have chosen.

4 From the list in **Table 1**, decide on 10 items that will represent your element. Note that

(a) there must be at least one item from each of the eight categories described;

(b) you may choose more than one item from a category, but you must have exactly 10 items.

5 Decide which team members will be responsible for each item. Work individually or as a team to produce the items, making sure that they are clearly related to your group of elements.

6 With your team, assemble the items in your team's portfolio. Add to the portfolio a table of contents listing the 10 items that your team chose. Your team members should all sign this table of contents to indicate their participation in producing the portfolio.

Table 1 Choices for the Profile

thinking visually	• decoration for the portfolio • a collage of magazine advertisements or photos • a poster that describes your elements • a picture, cartoon, drawing, or labelled diagram • your own idea, confirmed with your teacher
writing	• a one-page essay describing properties of your elements • a letter written to government or industry • a poem or short story about your elements • your own idea, confirmed with your teacher
thinking logically	• a graph of data related to the group • a mathematical calculation based on data • a flow chart showing how one of your elements is produced • a coloured periodic table containing all the information you have discovered about your elements • your own idea, confirmed with your teacher
using music	• a song, jingle, or rap • a written reflection on a piece of music that reminds you of your elements • your own idea, confirmed with your teacher
reflecting	• a description of two things about your work that you would like the teacher to pay particular attention to in the portfolio • a description of what you found most difficult in this activity • a description of how one of these elements affects your family or life • your own idea, confirmed with your teacher
using your body	• a dance, pantomime, game, or computer activity • a set of hand signals or special handshake • your own idea, confirmed with your teacher
thinking of nature	• a description of how one of your elements affects organisms, positively or negatively • a record or journal of a field trip • your own idea, confirmed with your teacher
working with people	• an evaluation of how well you functioned as a team, including how you could improve • a record of an interview with someone from an environmental group or the workplace involved in one of your elements • your own idea, confirmed with your teacher

Challenge

What profile choices should you include in the challenge you have chosen?

Career Profile

Science Journalist

Are you a curious person with a wide-ranging interest in the world? Someone who wants to learn a rewarding and highly portable craft? Then journalism may be a good career choice for you, in the opinion of *Globe and Mail* editor Colin Haskin, who looks after the weekly Science page.

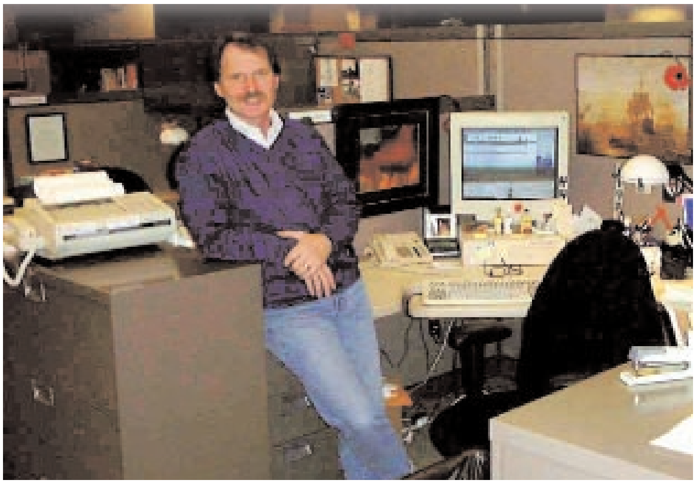
Haskin started off as an intern in his native New Zealand, learning all aspects of the newspaper business. Eager to travel, he soon found himself editing the Campbell River *Mirror* in rural British Columbia, followed by stints at the Vancouver *Sun* and the Los Angeles *Herald Examiner*, before joining the *Globe and Mail.*

> "A good news sense means knowing what is interesting, what will engage your readers."

As editor of the science section, Haskin is involved in all aspects of the story process. He works with writers to help them develop ideas, feeding them research and helping them to craft their stories. "I have always loved science and technology," he says, remembering his fascination with American and Russian space exploration.

Like many journalists of his day, Haskin received most of his training on the job: no university or journalism school. Although he says his math skills were never strong, he did study chemistry, biology, and physics in high school. Like most journalists, he reads widely, subscribing to six different scientific publications. He's always on the lookout for new story ideas, instinctively knowing what stories will interest readers. Sometimes the little ideas make the most interesting stories.

Working as an editor has shown Haskin the importance of interpreting the world of science and scientific research for the general public. "None of us will get rich but our rewards will come in other things," he says, explaining that he is "passionate about his work." Rich reward indeed.



Exploring

1. How has the training process changed, over the past 25 years, for people entering the journalism profession?
2. Why is it essential for a science editor to read a wide variety of science journals?
3. Haskin was originally fascinated by the "space race." What science stories in the media have particularly interested you?

Chapter 4 Review

Key Expectations

Throughout the chapter, you have had opportunities to do the following things:

- Describe how physical and chemical properties, atomic mass, and atomic number were used to organize Mendeleev's and the modern periodic tables. (4.1, 4.3, 4.5, 4.8)
- Relate similarities in atomic structure and properties of elements to their positions in the periodic table. (4.3, 4.4, 4.5, 4.8, 4.9)
- Compare similar properties both between and within groups of elements, such as alkali metals, halogens, and noble gases. (4.4, 4.5, 4.9)
- Use the periodic table to predict physical and chemical characteristics of an element or one of its compounds. (4.1, 4.3, 4.5, 4.8)
- Demonstrate the usefulness of scientific models by building models of the periodic table. (4.2, 4.8)
- Investigate the structure of the periodic table, and organize, record, analyze, and communicate results. (4.5, 4.8)
- Formulate and research questions related to the properties of elements and compounds and communicate results. (4.4, 4.6, 4.7, 4.9)
- Compare the physical and chemical properties of substances and assess their potential uses and associated risks. (4.4, 4.6, 4.7)
- Describe technologies that have depended on understanding atomic and molecular structure. (4.4, 4.6)
- Explore careers requiring an understanding of the properties of matter. (Career Profile)

KEY TERMS

alkali metals	Mendeleev's periodic law
atomic mass	metalloids
atomic radius	modern periodic law
ceramic	noble gases
CFCs	period
chemical group	periodic table
composite	periodic trend
group	polymer
halogens	synthetic

Reflecting

- "The positions of the elements in the periodic table can be used to predict the properties of elements and the types of compounds they will form." Reflect on this idea. How does it connect with what you've done in this chapter? (To review, check the sections indicated above.)
- Revise your answers to the questions raised in Getting Started. How has your thinking changed?
- What new questions do you have? How will you answer them?

Understanding Concepts

1. Make a concept map to summarize the material that you have studied in this chapter. Start with the term "periodic table."
2. The sentences in the list below contain errors or are incomplete. In your notebook, write your complete, correct version of each sentence.
   (a) Mendeleev's table organized elements by atomic number.
   (b) Elements in the same period have similar properties.
   (c) Noble gases are very unreactive liquids.
   (d) Alkali metals include sodium, potassium, and chlorine.
   (e) Halogens include fluorine, bromine, and argon.
   (f) Metalloids are compounds that have both metallic and nonmetallic properties.
   (g) The atomic number decreases from left to right across a row of the periodic table.
3. (a) State Mendeleev's periodic law.
   (b) Find examples of two elements that did not obey Mendeleev's law.

(c) State the modern periodic law.

4. Explain the difference between a period and a group.

5. (a) In the periodic table, where are the metals found?

   (b) Where are the nonmetals found?

6. What kinds of ions, including number and charge, are formed by

   (a) alkali metals? (b) halogens?

7. Make a chart comparing alkali metals, halogens, and noble gases with respect to

   (a) position in the periodic table

   (b) ability to react with other elements

   (c) number of electrons in the outermost orbit

8. Why is ozone described as hazardous at ground level but helpful in the upper atmosphere?

Applying Skills

9. Match the description on the left with one term on the right. Use each term only once.

Description	Term
A produced by people	1 alkali metal
B very unreactive gas	2 composite
C very reactive metal	3 halogen
D very reactive nonmetal	4 noble gas
E very long molecule	5 polymer
F material formed by mixing two or more other materials	6 synthetic

10. Study the periodic table on the inside back cover.

    (a) How many orbits do the elements in the third row have?

    (b) How many orbits do the elements in the fourth row have?

    (c) What conclusions can you draw about the relationship between the period on the periodic table and the number of orbits that the elements in that period have?

11. (a) What are the symbol and atomic number for the element aluminum?

    (b) Draw a Bohr diagram for this element.

    (c) What noble gas has the closest atomic number?

    (d) How many electrons must aluminum lose or gain to form a stable ion?

    (e) What charge of ion will result?

12. A new element has been discovered, and all you know is that it is an alkali metal. Predict

    (a) its state at room temperature

    (b) the number of electrons in its outer orbit

    (c) its possible atomic number

13. Repeat question 12 for a newly discovered halogen.

14. Repeat question 12 for a newly discovered noble gas.

Making Connections

15. List the four different types of materials that people have used over the centuries and give one ancient and one modern example of each type.

16. Classify each of the following as a metal, polymer, ceramic, or composite and describe why each was chosen for its identified use:

    (a) concrete reinforced with steel bars

    (b) a pottery coffee mug

    (c) a bronze statue

    (d) a polyethylene drink bottle

    (e) a shirt that is 40% cotton and 60% nylon

17. Refer to the section on "Corrosion" on page 34. Using your understanding of the reactivities of elements, suggest a reason why magnesium is sometimes attached to ships' hulls to protect them.

18. Elements are the basic building blocks of all the substances in the world. Think of the structure of an atom.

    (a) Which part of the atom is involved in the chemical reactions that form these substances? Give reasons for your answer.

    (b) Identify one substance that is produced by industry, and describe its potential uses and associated risks.

19. CFCs are damaging to the ozone layer, so scientists are searching for replacement substances. Research what properties the replacements must have and how they are being developed. How do they differ from CFCs? Write a report on your findings.

Challenge

Building from the Past to the Present

Throughout history, scientists have observed the physical and chemical properties of elements and compounds, and have created models of matter to help explain those properties. The collection of ideas that is presently used to explain the nature of matter is called the atomic theory of matter. Each of the challenges below provides an opportunity to explain how our understanding of matter has evolved over the centuries.

1 Models for Matter

You have been commissioned to build a display that explains the evolving models of matter to the general public. Your design must convey the idea that scientific discovery is dynamic and that it affects everyone's life directly. Specifically, your display should clearly demonstrate that understanding matter is a key to understanding every object and substance in our lives.

Design and build a display that includes:

- different atomic models, and an explanation of how those models changed with the discovery of new evidence;
- a representation of how the periodic table evolved and different models of the periodic table;
- instances in which the properties of elements and compounds were documented but not understood;
- examples of how the physical and chemical properties of elements determine how they are used in the design and creation of everyday products.

2 Marketing Matter

Where do the materials for consumer products come from? Most materials that we use come indirectly from the ground. For instance, plastics are manufactured from crude oil and alloys are created from metals obtained in mining and metallurgy. You are the inventor of a substance or material that is commonly used today. Promote your material to a manufacturing company that makes products for which your material is well-suited.

Prepare a proposal that includes:

- a description of the material or substance, identifying its elements and compounds;
- a Bohr model of the main elements, and an illustration of their position on the periodic table;
- a description of the structure and properties of the elements and compounds, and an explanation of how these properties will improve the manufacturer's products;

- any safety considerations related to the processing and manufacturing of the material;
- a flow chart showing the steps that lead from the raw material to possible finished products.

3 A "Time Machine" Simulation

Imagine that a time machine has been programmed to travel back in time to 1869 to bring Dmitri Mendeleev to meet you. Prior to his coming you prepare documentation to present the strengths and weaknesses of his periodic table and to show him how his model evolved as knowledge of the structure of the atom evolved.

Prepare a report that includes:

- comparisons of Mendeleev's periodic table with the modern periodic table;
- a model of the nuclear atom, including subatomic particles;
- an outline of the elements discovered since Mendeleev's time and an analysis of whether their properties could have been explained using Mendeleev's periodic table;
- an illustration of where the elements discovered since Mendeleev's time are located in the modern periodic table.

Assessment

Your completed challenge will be assessed according to how well you:

Process

- understand the specific challenge
- develop a plan
- choose and safely use appropriate tools, equipment, and materials when necessary
- conduct the plan applying technical skills and procedures when necessary
- analyze the results

Communication

- prepare an appropriate presentation of the task
- use correct terms, symbols, and SI units
- incorporate information technology

Product

- meet established criteria
- show understanding of concepts, principles, laws, and theories
- show effective use of materials
- address the identified situation/problem

Unit 1 Review

Understanding Concepts

1. In your notebook, write the letters (a) to (p), then indicate the word(s) needed to complete each statement below.

(a) In a(n) ___?___ change, a new substance is produced.

(b) A(n) ___?___ is a mixture of metals.

(c) A solid produced when two solutions are mixed together is a(n) ___?___.

(d) The starting materials in a chemical reaction are called ___?___.

(e) A(n) ___?___ is a sample of matter containing only one type of atom.

(f) Water can be split into two elements (hydrogen and oxygen) in a process called ___?___.

(g) ___?___ is added to farmland to help crops grow.

(h) ___?___ are shiny, malleable, and conduct electricity.

(i) The ___?___ is the number of protons in an atom.

(j) An electrically charged atom is a(n) ___?___.

(k) An atom with an unstable nucleus is described as ___?___.

(l) The ___?___ is the core of the atom, containing most of its mass.

(m) ___?___ gases do not form compounds with most other elements.

(n) The size of an atom is described by its atomic ___?___.

(o) ___?___ materials are made by humans, rather than naturally.

(p) Elements can be arranged in a(n) ___?___ table.

2. Indicate whether each of the statements (a) to (p) is TRUE or FALSE. If you think the statement is FALSE, rewrite it to make it true.

(a) Combustion is the chemical reaction between a fuel and hydrogen.

(b) Colour and hardness are examples of physical properties.

(c) Density is the volume per unit mass of a substance.

(d) A substance that can be drawn into a wire is called ductile.

(e) Viscosity describes the flammability of a substance.

(f) A molecule is a combination of atoms.

(g) A mineral is a compound of a metal mixed with other materials in rock.

(h) The chemical symbol for calcium is Cal.

(i) A flame test can be used to identify an element.

(j) A neutron is positive and located in the nucleus.

(k) The mass number is the sum of electrons and protons in the atom.

(l) A Bohr diagram shows electrons in orbits about the nucleus.

(m) A row of the periodic table is called a period.

(n) The sizes of atoms increase down a column of the periodic table.

(o) Alkali metals include fluorine, chlorine, and iodine.

(p) The modern periodic table organizes elements by atomic mass.

3. Describe the similarities and/or differences between each pair of terms listed below:

(a) physical property, chemical property

(b) combustion, corrosion

(c) ductile, malleable

(d) products, reactants

(e) element, compound

(f) atom, molecule

(g) mineral, ore

(h) metal, nonmetal

(i) atomic number, mass number

(j) proton, neutron

(k) atom, ion

(l) ground state, excited state

(m) natural material, synthetic material

(n) period, group

(o) metal, metalloid

(p) noble gas, alkali metal

For questions 4 to 10, choose the best answer and write the full statement in your notebook.

4. Which of the following is an example of a chemical change?

(a) ice melts
(b) a car rusts
(c) a pottery mug shatters
(d) a snowflake forms
(e) food is chewed

5. What is the mass of a block of wood if its density is 0.75 g/cm^3 and it has a volume of 10 cm^3?

(a) 75 g (b) 7.5 g
(c) 0.75 g (d) 13.3 g
(e) 6.7 g

6. Which of the following is not a property of metals?

(a) malleability
(b) ductility
(c) good conduction of heat
(d) shiny lustre
(e) brittleness

7. If potassium (K) has a combining capacity of 1 and oxygen has a combining capacity of 2, what is the formula for potassium oxide?

(a) K_2O (b) K_2O_2
(c) KO_2 (d) KO
(e) K_2O_3

8. Which of the following combinations describes the proton in the modern atomic model?

(a) negative charge and significant mass
(b) positive charge and very small mass
(c) negative charge and located in the nucleus
(d) positive charge and significant mass
(e) neutral charge and found in the nucleus

9. Which of the following combinations describes the electron in the modern atomic model?

(a) negative charge and significant mass
(b) positive charge and very small mass
(c) negative charge and located in orbit about the nucleus
(d) positive charge and significant mass
(e) neutral charge and found in orbit about the nucleus

10. Which of the following is used to organize the modern periodic table?

(a) atomic number
(b) atomic mass
(c) number of neutrons
(d) atomic size
(e) state at room temperature

11. A friend tells you that an antacid tablet bubbling in water is a chemical change, but the water bubbling in a kettle and turning to steam is not. Do you agree? Explain.

12. Choose a familiar substance. Describe as many physical properties of this substance as possible. State a chemical property, if possible.

13. Describe three observations that would help you decide that the burning of a fuel was a chemical change.

14. How is it possible that there are millions of pure substances, even though there are only about 100 different elements?

15. State the types of atoms and the numbers of each type that are present in the following molecules: sodium phosphate (Na_3PO_4) and lead IV sulfate $Pb(SO_4)_2$.

16. Compare the atomic models of (a) Dalton, (b) Rutherford, and (c) Bohr.

17. Describe the charge, mass, and location of the three fundamental particles that make up the modern atomic model of the atom.

18. Describe how the periodic table is organized. Include in your description similarities and differences observed across rows and down columns of the table.

19. Draw a sketch of the periodic table. Using patterns or colours, shade in the areas of the table that represent the locations of the (a) alkali metals, (b) halogens, (c) noble gases, (d) hydrogen, (e) metalloids, (f) metals, in general, and (g) nonmetals, in general.

Applying Skills

20. A substance is white, has a density of 1.2 g/mL, is very hard, has a melting point of 500°C, and fizzes when added to acid.

(a) Which properties could be described as quantitative? Explain.
(b) Which properties could be described as chemical? Explain.

21. A student is given the densities of types of wood in **Table 1**.

Table 1

Wood	Density (g/cm^3)
ironwood	1.24
birch	0.66
red cedar	0.37
balsa	0.12

(a) Which wood would sink when placed in water? Explain.

(b) Which wood would be the best choice to build a model airplane? Explain.

(c) The student is provided a rectangular block of wood that measures 8 cm × 8 cm × 8 cm. Its mass is 190 g. Use complete calculations to determine the identity of the wood.

22. Write chemical formulas for the following compounds:

(a) magnesium chloride

(b) silver iodide

(c) zinc oxide

23. Suppose someone tells you that a green object contains copper. You are not convinced because you have seen that copper wires and jewellery are reddish-brown.

(a) Is it possible that this green substance really does contain copper? Explain.

(b) With the assistance of a chemist, what test might you carry out to settle this question?

24. Copy **Table 2** into your notebook. Fill in the blanks with the missing numbers.

25. Write standard atomic notation for each of the elements in the previous question.

26. (a) What is the symbol and atomic number for the element, sulfur?

(b) Draw a Bohr diagram for this element.

(c) What noble gas has the closest atomic number?

(d) How many electrons will sulfur lose or gain to form a stable ion?

(e) What charge of ion will result?

27. A new element has been discovered, and all you know is that it is a halogen.

(a) Predict its state at room temperature.

(b) Predict the number of electrons in its outer orbit.

(c) Predict its possible atomic number.

(d) On what do you base your predictions?

28. (a) Magnesium forms a compound with fluorine called magnesium fluoride, MgF_2. What would be the name and formula of the compound formed when magnesium combined with iodine, another halogen atom?

(b) Aluminum forms a compound with chlorine called aluminum chloride, $AlCl_3$. What would be the name and formula of a compound it would make with bromine?

29. A chemist melts a sample of an unidentified mineral and then passes an electric current through the liquid. This produces a solid and a gas. The solid is shiny at first, but turns dull quickly. The gas has a strong, choking odour.

(a) Could the mineral be an element? State reasons for your answer.

(b) Suppose the new solid is an element. To which chemical family might it belong? State reasons for your answer.

(c) Suppose the new gas is an element. To which chemical family might it belong? State reasons for your answer.

Making Connections

30. The four Hazardous Household Product Symbols indicate products that are poisonous, flammable, explosive, and corrosive. Which labels would be on containers of (a) aerosol insect spray, (b) drain cleaner, (c) ant powder, and (d) furniture polish?

Table 2

Element	Symbol	Atomic Number	Mass Number	No. of Protons	No. of Electrons	No. of Neutrons
beryllium	Be	4	9	?	?	?
carbon	C	6	?	?	?	8
silicon	Si	?	?	?	14	14
potassium	K	?	?	19	?	20

31. You have read about two forms of paint. Research another product that comes in two or more comparable forms, with slightly different physical and chemical properties. Examples might include wood or plastic for dock-building, ceramic tile or linoleum for flooring, and wool or synthetic pile for clothing. Compare their properties, methods of production, and use.

32. You and your group are members of a "Think Tank" of concerned business people, environmentalists, and politicians. Your task is to suggest ways to reduce the money lost each year to corrosion of automobiles. These could include new technology, regulations, or changes to people's lifestyles. Write a brief report of your findings, suitable for newspaper publication.

(a) Brainstorm as many ways as possible to reduce the amount of corrosion that occurs.

(b) Record all your ideas in a table. Be sure to include benefits, drawbacks, and cost.

33. Problems have been caused in the past when elements and compounds have been released into the environment. Research and report on such problems, using a CD-ROM database or the Internet. Some possible key words and combinations are: groundwater + contamination, chemical + effluent, water + pollution.

34. As advisors to the Minister of the Environment, your group must suggest ways to reduce the amount of air pollution.

(a) Brainstorm as many ways as possible to reduce the amount of air pollution from vehicles, industries, and power plants.

(b) Record all your ideas in a table. Be sure to include benefits, drawbacks, and cost.

35. "Radioactivity is more helpful than harmful." Do you agree or disagree with this statement? Give some possible arguments both for and against the statement, and then explain your opinion.

36. Visit a garden supply centre, and note the information and instructions on the packaging for (a) at least three kinds of fertilizer that are not labelled "organic," and (b) at least one fertilizer that is labelled "organic." Select a label that has a high percentage of nitrogen and note what the label says the fertilizer is for. Repeat this step, looking for a fertilizer high in phosphorus. Note what other nutrients besides nitrogen (nitrate), phosphorus (phosphate), and potassium are mentioned on the labels. Note what the organic fertilizers were made from.

37. Think of a group of objects (e.g., leaves, food, animals, children's toys, or drug store products, etc.) and devise a way to categorize them so that, if a new one were to be discovered, it could be included in your system. Create a computer or poster display of your organization system, and explain your decisions.

38. Elements have been named for many reasons. Using your library resources, research the following:

(a) Germanium, lutetium, and polonium were named to honour the geographic origin of their discoverers. Who were the discoverers and where did they come from?

(b) Which heavenly bodies were the following named after: mercury, uranium, neptunium, plutonium, tellurium, selenium, palladium, cerium? (Some are very easy, while others are not so obvious.)

(c) Some elements are named to honour people. Which people were honoured by the following: gadolinium, curium, einsteinium, fermium, mendelevium, lawrencium, nobelium, seaborgium? State their full names, and write a couple of sentences about each person.

(d) Some elements were named after places. What places are the following named after: europium, hafnium, americium, berkellium, californium?

39. An inventor is trying to sell an idea to protect people from ultraviolet radiation: a headband that releases a cloud of ozone around a person's head. Write a letter to this inventor explaining whether it is a good idea or not.

40. Design a "mini-poster," approximately 20 cm × 20 cm, to represent an element. The design of the poster should reflect the properties of the element, and its use or significance to society. The symbol for the element, its atomic number, and its name should be found somewhere in the box. Your teacher may decide to have a number of students produce these posters in order to build a "Great Wall of Chemistry" on a display board or in the hall at school.