6.4

Patterns in the Periodic Table

The periodic table is arranged in a particular way. All the elements in the same column have similar physical and chemical properties (Figure 1). If your classroom seating plan were organized in this way, everyone sitting in the same column would look similar and have similar personalities. Each student would still be an individual and different from all the other students. However, if there were an empty seat, you would be able to guess the absent student's appearance and temperament. In this way, we can predict the properties of any element simply by its assigned location in the periodic table. That is the power of the periodic table of the elements.

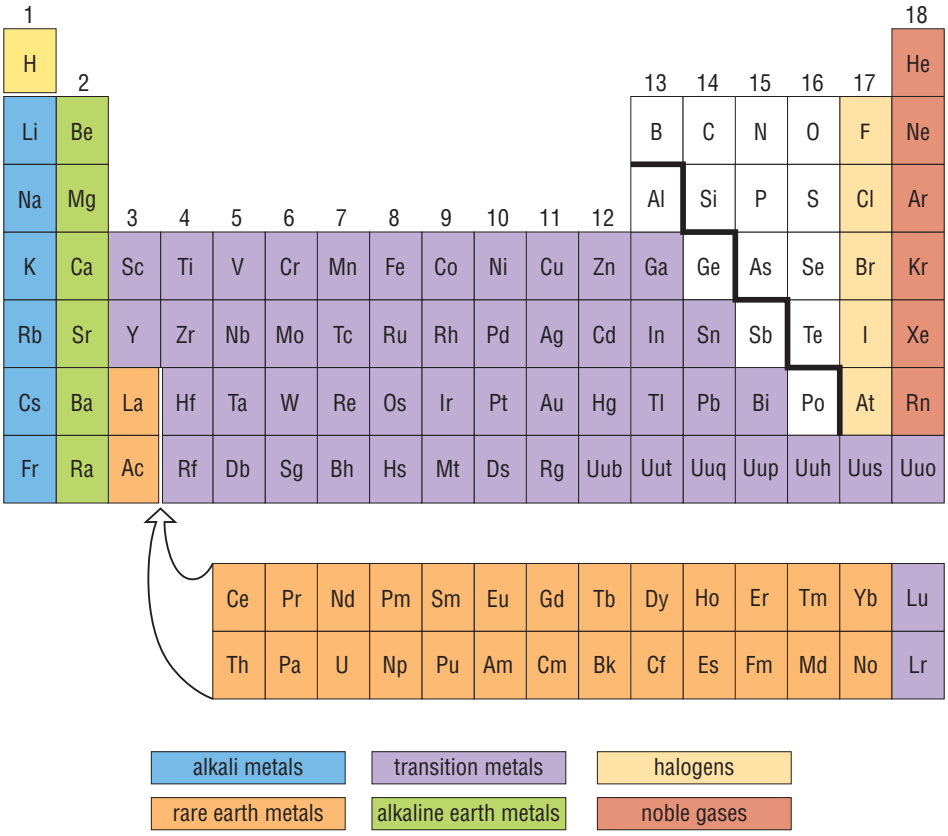

Figure 1 Elements in the same group (column) of the periodic table have similar physical and chemical properties.

Chemical Families

chemical family a column of elements with similar properties on the periodic table

alkali metal an element in Group 1 of the periodic table

Elements in the same column of the periodic table belong to the same group, or **chemical family**. Families with distinctive properties have been given identifying names. The elements in the first column from the left are called **alkali metals**. They are called Group 1 elements. All columns are numbered from left to right.

The alkali metals lithium (Li), sodium (Na), and potassium (K) are shiny, silvery, and soft, but highly reactive (Figure 2). These three elements have relatively low densities and they can float on water. We do not often encounter these elements on their own because they combine readily with other elements and compounds. They are present in many everyday substances such as table salt (NaCl) and baking soda ($NaHCO_3$). Many athletes know that plant foods like oranges and bananas are good sources of potassium. Potassium is important to the function of all living cells.

Elements in the next family, the Group 2 elements, are called **alkaline earth metals**. Beryllium, magnesium, calcium, strontium, barium, and radium are alkaline earth metals. These metals are shiny and silvery but are not as soft or reactive as the alkali metals. As every growing child has been told, calcium (Ca) helps to build strong bones and teeth (Figure 3). Similarly, strontium (Sr) builds a strong shell in coral. Many substances composed of alkaline earth metals burn with bright, colourful flames (Figure 4). As a result of this property, alkaline earth metals such as magnesium are used in fireworks.

Figure 2 The alkali metals are grouped together in Group 1 of the periodic table because they have similar properties.

alkaline earth metal an element in Group 2 of the periodic table

Figure 3 Calcium, in Group 2 of the periodic table, is an important dietary nutrient.

Figure 4 Magnesium, an alkaline earth metal (Group 2), burns with a bright flame.

The elements in the column on the far right of the periodic table are called **noble gases** (Group 18). This name reflects the stable nature or unreactivity of these elements. We have all experienced some of these noble gases. The low density of helium (He) makes it ideal for use in balloons. We use neon (Ne) and other noble gases in neon signs. Although noble gases are colourless, odourless, and tasteless, they glow brightly when an electrical current is passed through them (Figure 5). Argon (Ar) glows blue, krypton (Kr) glows pink, and xenon (Xe) glows purple. Bright red signs, which are the most common, are filled with neon. With the exception of radon, the Group 18 elements are also non-toxic.

noble gas an element in Group 18 of the periodic table

Figure 5 Each noble gas glows with its own distinctive colour when an electrical current is passed through it.

halogen an element in Group 17 of the periodic table

The **halogens**, also called Group 17 elements, are in the column to the left of the noble gases. The halogens fluorine (F) and chlorine (Cl) are gases at room temperature and atmospheric pressure. Bromine (Br) is a liquid, and iodine (I) and astatine (At) are solids (Figure 6).

All halogens are very reactive. Due to their reactive nature, the halogens are rarely found in elemental form. They often form compounds with alkali metals. Many of the halogens can be poisonous in large amounts. Some, such as chlorine, are poisonous even in small amounts. Chlorine gas was used as a chemical weapon during World War I. At much lower concentrations, chlorine is safely used to kill bacteria in swimming pools.

Iodine, usually dissolved in alcohol, is used to disinfect scrapes and cuts. Other halogens, such as bromine, can be added to light bulbs to increase the brightness and operating life of the bulb. Halogen lamps burn at extremely high temperatures, so care must be taken to keep halogen lamps away from flammable materials.

DID YOU KNOW?

Chlorine Warfare

Chlorine was used in chemical warfare for the first time in 1915, during World War I. French soldiers in the trenches in Ypres saw a yellow-green gas cloud approaching from the German side. Thinking it was a smoke screen, they took up positions in the front trenches—with fatal results. The soldiers suffocated as the poisonous gas destroyed their lungs. The Allies provided gas masks that offered limited protection. The soldiers were mistakenly advised that breathing through a urine-soaked cloth would delay the effects of the chlorine. Sadly, the combination of urine and gas produced additional toxic substances. Over 91 000 soldiers were killed by deadly gases during the war.

Figure 6 Samples of the halogens chlorine, bromine, and iodine

Periodic Trends

You have just learned that elements in the same column in the periodic table share some chemical and physical properties. Elements in the same horizontal row in the periodic table show some trends of increasing or decreasing reactivity. For example, Group 1 alkali metals are more reactive than their Group 2 neighbours. Group 17 halogens are more reactive than Group 16 elements in the same row. Therefore, sodium is more reactive than magnesium, and chlorine is more reactive than sulfur. Rows on the periodic table are called **periods**, signifying the recurring nature of these trends in reactivity. The word "period" refers to cycles, such as the classes that recur daily in your school schedule.

period a row on the periodic table

History of the Periodic Table

The current version of the periodic table evolved from the one developed in 1869 by Dmitri Mendeleev (Figure 7), a Russian chemistry professor. He gathered information about the properties of all known elements. At that time there were only 63. The masses of individual elements were known, and Mendeleev arranged the elements by increasing mass. He started with the lightest element, hydrogen, followed by the next lightest, helium, and so forth. He could have chosen to begin a new row after any number of elements. He could have filled rows of ten elements each to produce a perfectly rectangular table of elements, but he did not.

Mendeleev noticed that there were groups of elements with similar physical and chemical properties. In a brilliant move, he decided to arrange elements with similar properties under each other in the same column of the table. To do so, he had to force new rows of different lengths, resulting in the familiar irregular shape of his periodic table.

When he was finished with his table of elements, there were several empty spaces where no known element could fit (Figure 8). Mendeleev suggested that the missing elements did exist but had not yet been discovered. He boldly predicted the physical and chemical properties of the elements that would occupy each vacant spot. Doubters were convinced when new elements, such as gallium (Ga) and germanium (Ge), were discovered several years later with properties almost exactly as Mendeleev had predicted (Table 1).

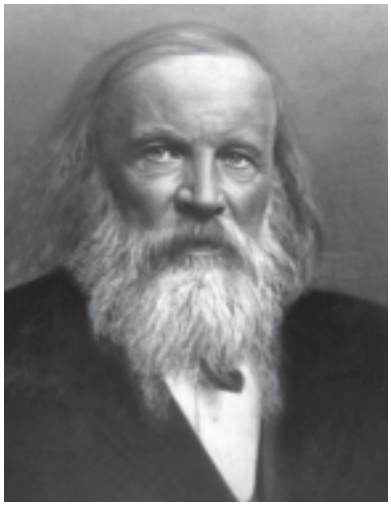

Figure 7 Dmitri Mendeleev is the father of the periodic table of the elements.

To learn more about becoming a historian of science,
GO TO NELSON SCIENCE

ROW	GROUP I	GROUP II	GROUP III	GROUP IV	GROUP V	GROUP VI	GROUP VII
1	H = 1						
2	Li = 7	Be = 9, 4	B = 11	C = 12	N = 14	O = 16	F = 19
3	Na = 23	Mg = 24	A1 = 27, 3	Si = 28	P = 31	S = 32	C1 = 35, 5
4	K = 39	Ca = 40	– = 44	Ti = 48	v = 51	Cr = 52	Mn = 55
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

Figure 8 Mendeleev left blank spaces in his periodic table for elements that had not yet been discovered. Note the blank spaces for gallium (Group III, mass = 68) and germanium (Group IV, mass = 72).

Table 1 Comparison of Mendeleev's Predictions to the Observed Properties of Germanium After Its Discovery

Property	Properties predicted by Mendeleev in 1871	Observed properties of germanium, discovered in 1886
colour	grey	grey
mass of element	72	72.6
density	5.5 g/cm^3	5.4 g/cm^3
melting point	high	947 °C
number of elemental oxygen particles it combines with	2	2
number of elemental chlorine particles it combines with	4	4

Decades later, scientific knowledge and theories about the structure of the elements led to a brilliant explanation of the periodic nature of the elements. You will be exploring these theories later in this chapter.

RESEARCH THIS THE PERIODIC TABLE IS EVOLVING!

SKILLS: Researching, Communicating, Evaluating

SKILLS HANDBOOK 4.B.

You may have noticed that period 7 of the periodic table is incomplete. The elements have strange, similar names, such as ununbium, and the information about them, such as atomic mass, is missing.

1. Choose one of the elements in period 7.
2. Perform research to find out what is known about this particular element.

GO TO NELSON SCIENCE

A. Write a short paragraph outlining what we know so far about this element. K/U C

B. Explain why the information on the periodic table about this element is incomplete. T/I

C. Who decides which elements get added to the periodic table? T/I

D. Do you think the process by which new elements are added to the periodic table is a good one? Explain why or why not. T/I

TRY THIS SOLVING THE PUZZLE, PERIODICALLY

SKILLS: Performing, Observing, Analyzing, Communicating

Mendeleev's first attempt at arranging elements into a table was much like trying to put together a puzzle that was missing pieces. In this activity, you will try to assemble the pieces of a puzzle to help you identify the properties of the missing piece.

Equipment and Materials: handouts of puzzles A and B from your teacher

1. Puzzle A shows 19 pieces from an original set of 20 (Figure 9). A single piece is missing. Your mission is to arrange the 19 pieces into rows and columns according to their properties, identifying as many trends as you can.

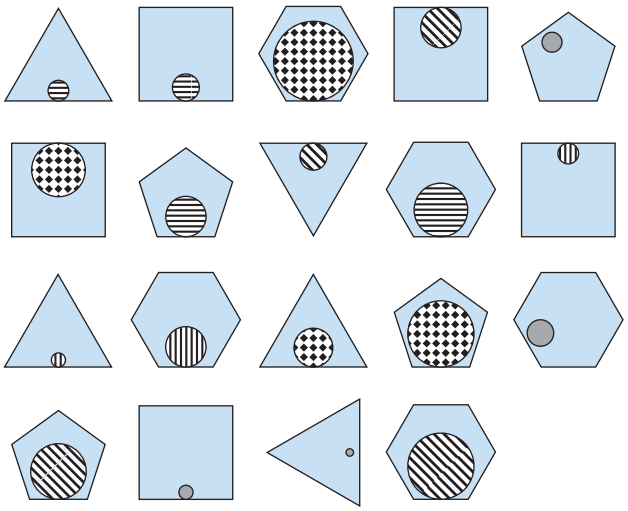

Figure 9 Puzzle A

2. When all the pieces are in place, the missing piece will become obvious to you, just as the missing elements were clear to Mendeleev. Sketch the missing piece, showing all its properties.
3. Puzzle B has more differentiating properties than does puzzle A, so it is a little more complex (Figure 10). If you enjoy a challenge, you will want to do this one too!

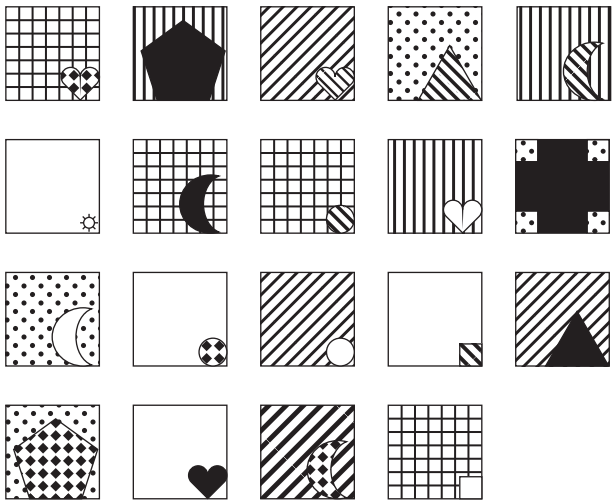

Figure 10 Puzzle B

A. There are many different possible arrangements. When you have finished, share your design with other students so that everyone can admire and learn from each other's thinking processes and ideas. That is how a real scientific community works. T/I

UNIT TASK Bookmark

You can apply what you learned about groups of elements on the periodic table to the Unit Task described on page 286.

IN SUMMARY

- A chemical family is a column of elements on the periodic table.
- Elements in the same chemical family have similar properties.
- The first two families on the periodic table are the alkali metals and the alkaline earth metals.
- The last two families on the periodic table are the halogens and the noble gases.
- A period is a row on the periodic table.
- Mendeleev grouped elements with similar physical and chemical properties in the same column in a periodic table.
- Mendeleev correctly predicted the properties of elements that had not yet been discovered.

CHECK YOUR LEARNING

1. Which of the following statements are correct? Rewrite each false statement to make it true. K/U
   (a) Elements listed in rows on the periodic table are in the same family.
   (b) Elements in the same column of the periodic table exhibit the same physical properties.
   (c) Elements in the same group are in the same family.
   (d) Elements that are side by side on the periodic table belong to the same period.
2. Name the chemical family to which each of the following elements belongs. K/U
   (a) chlorine, Cl
   (b) magnesium, Mg
   (c) potassium, K
   (d) helium, He
3. Read the names of each of the elements in the first and second columns on the periodic table. K/U
   (a) What do the names of these elements have in common?
   (b) Which element is the exception?
4. Sodium is a metal, like copper. Suggest reasons why sodium cannot be used in electrical wires. A
5. Identify which properties are common to each of the following chemical families. K/U
   (a) alkali metals
   (b) alkaline earth metals
   (c) halogens
   (d) noble gases
6. Hydrogen is a reactive gas under normal conditions. Based on this property alone, to which group of the periodic table should hydrogen belong? Why? (In Chapter 7, you will learn why hydrogen is placed in Group 1.) K/U
7. Sketch the periodic table and add the following labels: period, family, alkali metals, alkaline earth metals, halogens, noble gases, metals, non-metals, and metalloids. K/U C
8. Alkali metals are found in many common substances but are rarely found in pure form. Explain why this is the case. K/U
9. List three useful applications of halogens. K/U
10. List three useful applications of alkaline earth metals. K/U
11. Mendeleev chose to order the known elements by mass. Explain why he did not arrange the elements into rows and columns of equal length. T/I