4.4

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.

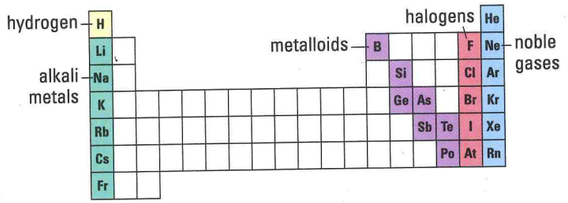

Figure 1
Location of noble gases, alkali metals, halogens, hydrogen, and metalloids on the periodic table. Hydrogen is a unique element.

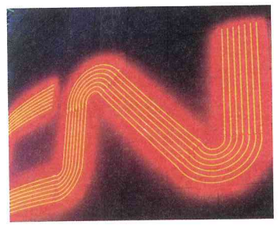

Figure 2
Noble gases have many applications.

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

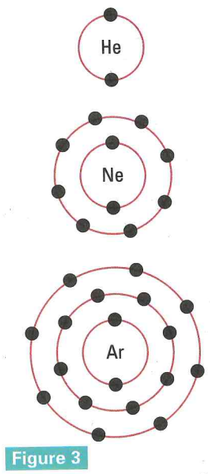

Figure 3
Electron arrangements for three noble gases

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.

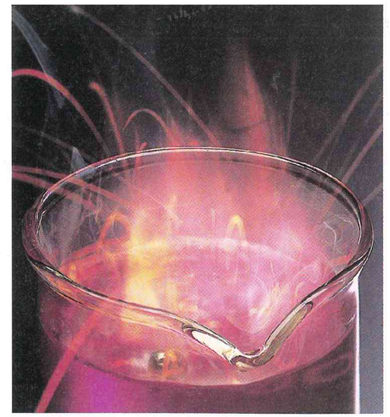

Figure 4
Like all alkali metals, sodium reacts vigorously with water. The reaction releases heat and produces pure hydrogen gas. Why could this reaction be dangerous?

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.

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 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.

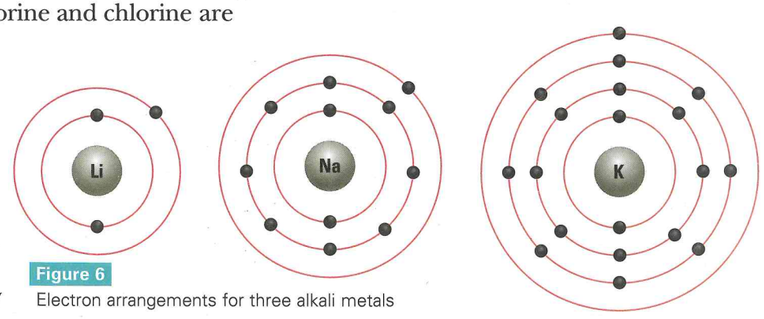

Figure 6
Electron arrangements for three alkali metals

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

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.

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.

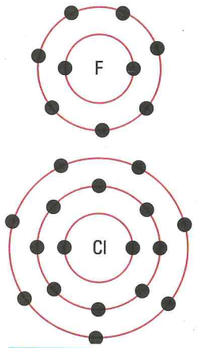

Figure 8
Electron arrangements for two halogens

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?

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.