II. CHEMICAL BONDING

One of the major studies in chemistry is concerned with how atoms group together. Why do atoms combine at all? What makes them stick together once they have formed? What forces cause NaCl to stay in a cubic form? This section will help to answer these questions.

SECTION OBJECTIVES

Review these objectives. When you have completed this section, you should be able to:

2. Define and use the concept of electronegativity.
3. Predict percent ionic and covalent character of bonds.
4. Describe and explain the nature of ionic, covalent, and metallic bonds.

VOCABULARY

Study these words to enhance your learning success in this section.

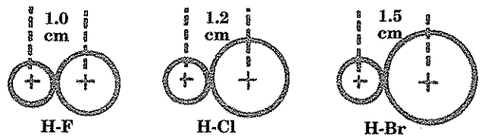
covalent bond ionic bond metallic bond
electronegativity

ELECTRONEGATIVITY

Scientists found that all atoms in the combined state show varying degrees of attraction for the electrons of the other member(s) of the compound. For example, the fluorine atom in HF has a very strong attraction for the electron of the hydrogen. In HCl is found a similar but weaker attraction, and in HBr an even weaker attraction is observed. Look at the Periodic Table of the Elements that you found as an insert to Science LIFEPAC 1101. Notice that the atomic size increases as you go down a vertical column. This increase can be represented in this way:

$$F < Cl < Br$$

The molecules of HF, HCl, and HBr could be represented in this way:



Do these activities.

2.1 Measure the distance between nuclei in each molecule.

a. HCl molecular distance between nuclei = _____

b. HF molecular distance between nuclei = _____

c. HBr molecular distance between nuclei = _____

2.2 Remember that each nucleus attracts the electrons of the other atom to hold the molecule together. Which atom has the greatest distance to overcome to attract the hydrogen electron (Circle the greatest one)?

fluorine chlorine bromine

2.3 If two opposite charges get farther apart, does their attraction for each other increase, decrease, or remain the same? _____

2.4 Which element then has the least attraction for the hydrogen atom, fluorine, chlorine, or bromine?

_____

2.5 Explain why HF is a more strongly bonded molecule than HBr.

_____

_____

_____

_____

Ionization energy. Review Science LIFEPAC 1104 concerning ionization energy. Remember that ionization energy is the energy necessary to remove valence electrons from atoms. Look carefully at the Periodic Table. Notice that there is a general increase in ionization energy, E_I, from left to right across a periodic row and general decrease in the ionization energy when going down a periodic column.

Increasing ionization energy means that generally *more energy* is required to remove an electron from the elements going *across a row*, and it takes progressively *less energy* to remove an electron when going *down a column*. This progression can be represented in general as in Figure 1.

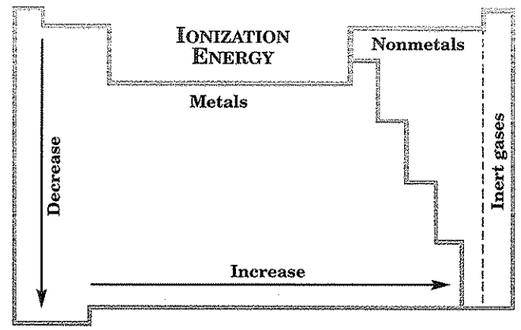


FIGURE 1

Another idea might be drawn from these observations. An atom that gives up an electron easily is less likely to take on another electron. This fact means that the atoms with less ability to hold any given electron (ones with low ionization energy) will not be very likely to want or to get another electron. Atoms with high ionization potential will be able to hold another electron more easily. Therefore, in general, greater ionization energy indicates a greater ability to attract additional electrons; the lower the ionization energy, the less the desire for additional electrons.

Do this activity.

2.6 On the basis of the preceding reasoning, answer these questions.

a. Do metals or nonmetals have the greatest chance to lose electrons and become positive ions?

_____

b. Which group, metals or nonmetals, has the greatest chance to gain electrons and to become negative ions? _____

c. Which group of elements has very little desire to gain or to lose electrons?

_____

Adult check _____
Initial Date

Definition. Refer to the Periodic Table, which shows the electron *attracting ability*, or **electronegativity** as it is more commonly called. Pauling developed a scale of relative values with fluorine being assigned a value of 4 and all other elements rated on that basis. Complete Figure 2 in 2.7 by putting in the corresponding electronegativities for each element listed.

Complete these activities.

2.7 Complete Figure 2 by putting the electronegativities of each element on the line in the box.

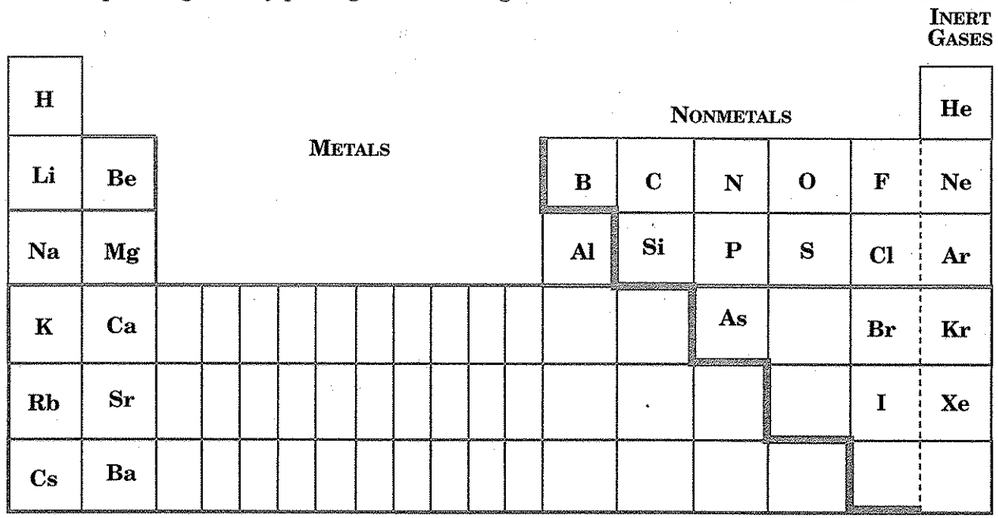


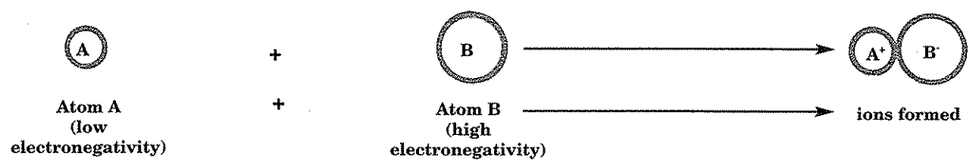
FIGURE 2

2.8 In relationship to Figure 1 for ionization energy, compare in general how ionization energy and electronegativity are related to the Periodic Table.

IONIC BONDS

When elements with different abilities to attract the electrons of another element are put together, a bond will result. If one element can completely take a valence electron away from some other atom, ions will form.

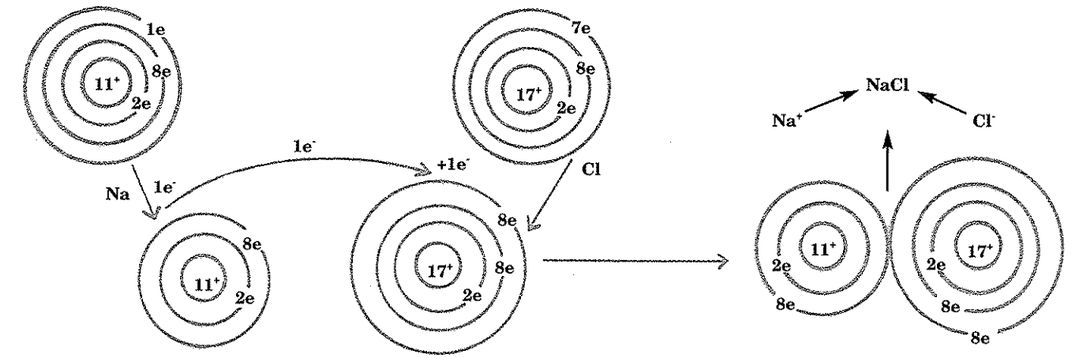
Definition. An **ionic bond** is *any bond that is made from ions*. This relationship is shown in this diagram.



Complete this question.

2.9 Why does an ionic bond stay together? (Hint: Opposite electrical charges.)

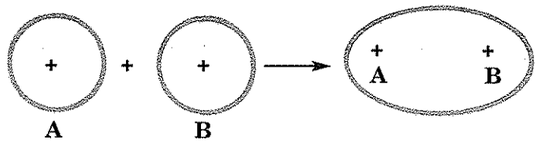
Characteristics. Ionic bonds are the most common bonds in the minerals of the earth. Most crystals are ionic in nature. Some common ionic compounds include table salt (NaCl), lithium chloride (LiCl), and calcium chloride ($CaCl_2$). The ionic bond involves a transfer of a valence electron from one atom to another. This transfer is shown in this diagram.



COVALENT BONDS

Most ionic bonds occur between metals and nonmetals. Nearly all inorganic substances are ionic in nature. A few notable exceptions are water (H_2O), carbon dioxide (CO_2), and atmospheric gases like oxygen (O_2), hydrogen (H_2), and nitrogen (N_2). These exceptions are a part of a second class of bonds called **covalent bonds**.

Definition. Sometimes a bond will form between two or more atoms that have similar electronegativities. In this case, Atom A has no more attraction for the electrons of Atom B than Atom B has for the electrons of Atom A. Each has a mutual attraction for the other's valence electrons. When this sharing bond occurs, the resulting bond is called a covalent bond. This *covalent bond* is shown in this diagram.



In a covalent bond, two or more electrons are located in the region between the nuclei. This bond is a highly directed bond because the bonding electrons are located only in specific places.

Percent ionic character. Chemists find that most bonds are partly ionic and partly covalent. The amount of ionic and covalent character is determined by the difference in the electronegativities of the atoms making up the compound. The mathematics resulting in a prediction device for determining the degree of ionic character of any bond was studied by several men. We will use the chart as developed by Linus Pauling, a two time Nobel Prize winner. Refer to the Periodic Table found in Science LIFEPAC 1101. In the upper center of the Periodic Table is a chart that displays the *Difference in electronegativity* and the *Percent ionic character*. This chart is based on fluorine, which has the greatest attraction for electrons and is given a value of 4. All of the other elements have a value relative to the value for fluorine.

You can determine the percent of ionic character of a single bond by this method:

1. Calculate the numerical difference in the electronegativity values of the two atoms involved in the bond.
2. Locate this value in the top row of the chart labeled "Difference in electronegativity."
3. Read the value directly below this electronegativity difference. This second value is the percent of ionic character.

Example. Determine the ionic character of the bond between H and F in the molecule HF.

	Element	Electronegativity
Step 1:	F	4.0
	H	2.1
	difference =	1.9

Step 2: Find 1.9 in the top row of the chart.

Step 3: Locate the percent directly below 1.9. The percent ionic character is equal to 59%.

The total percent ionic character and percent covalent character will equal 100% for each bond. The percent covalent character is determined by subtracting the percent ionic character from 100%.

Do these activities. Use the Periodic Table as necessary.

2.10 As the electronegativity differences between two elements gets greater, what happens to the amount of ionic character? _____

_____

2.11 Does this greater difference mean that the resulting bond is more ionic or covalent?

_____

2.12 Answer these questions about electronegativity difference.

a. If the bond were 50% ionic and 50% covalent, what would be the electronegativity difference?

_____

b. If the electronegativity difference were 1.0 what would be the percent ionic character?

_____

c. Does a 1.0 electronegativity difference represent a predominantly ionic or covalent type bond?

_____

2.13 a. Which compound would have a more ionic bond, NaCl or NaI? _____

b. Which compound has a greater difference in electronegativities of its members, NaCl or KCl?

_____

2.14 Refer to the first paragraph following the section title "COVALENT BONDS." List the three substances that are 100% covalent in nature. a. _____ b. _____ c. _____

2.15 Complete the following generalization about electronegativity difference and the degree of ionic character of a chemical bond. As electronegativity difference increases, the degree of ionic character _____ .

2.16 Find the approximate percent of ionic character of the following compounds. Consider that each is bonded only between two elements with a single bond. For example, the electronegativity difference for H_2S is 0.4, *not* (0.4) (2). Use a chemistry handbook to find whether each is a solid, liquid, or gas at room temperature.

NaCl	= a. _____ ;	b. _____
CsF	= c. _____ ;	d. _____
$MgCl_2$	= e. _____ ;	f. _____
BrF_5	= g. _____ ;	h. _____
CO_2	= i. _____ ;	i. _____
H_2O	= k. _____ ;	l. _____
O_2	= m. _____ ;	n. _____
NO_2	= o. _____ ;	p. _____
IF_5	= q. _____ ;	r. _____

2.17 Consider these questions.

a. Generally, how does the amount of ionic character relate to the state of matter?

_____

_____

b. How does bond strength relate to ionic character? _____

_____

c. How does melting point and boiling point relate to bond type? _____

_____

2.18 Bonding between metals and nonmetals is common in the minerals of the earth.

a. In general when a metal bonds with a nonmetal, does the bond type tend to be more ionic or covalent? _____

b. Predict what you think is the most ionic compound possible. The formula is _____ .

c. Why did you predict this combination? _____

_____

_____

_____

2.19 We found examples in 2.14 of 100% covalent bonds.

a. Can you ever have 100% ionic compound? _____

b. What is the basis of this prediction? _____

_____

_____

2.20 Which two columns of elements when combined with each other tend to form the most ionic compounds? _____

_____

METALLIC BONDS

The third type of bonding that we will study in some detail is that type which holds metals together. All metals except mercury are solids at room temperature. We also know that all metals are good conductors of electricity and heat.

Definition. Let us investigate conductivity and other metallic bonding characteristics to expand your ideas about metals. Look at the three areas generally outlined on the Periodic Table in Figure 3 as inert gases, metals, or nonmetals. **Metallic bonds** are bonds that hold metals together.

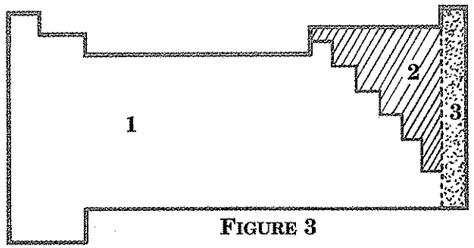


FIGURE 3

1. _____
2. _____
3. _____

Do these activities.

2.21 Label the three areas in Figure 3 as metals, inert gases, or nonmetals.

2.22 Consider these questions.

a. Generally, which of the three families of elements listed in 2.21 has the greatest ionization energy? _____

b. Which family generally has the valence electrons which are the easiest to remove from the atom? _____

c. Therefore, which family of elements will have the most mobile electrons? _____

Characteristics. You have already investigated several properties of metals. They are good conductors of heat and electricity, are generally solids at room temperature, and are usually shiny in color. Most metals are malleable (capable of being shaped or hammered) and do not come in a pure form in their natural state. Gold and silver are exceptions to the pure-form rule.

The metallic bond is different from the ionic or covalent bond. The ionic bonds and covalent bonds are both *directed bonds*. Directed bonds means the bonding electrons are located between the two atoms of the bond which causes the bonding electrons to be "locked" into a fixed location. Metallic bonds are made from a "sea" of electrons and the bonding electrons are free to roam among any of the atoms in the metal piece. A diagram of a metallic bond is shown in Figure 4.

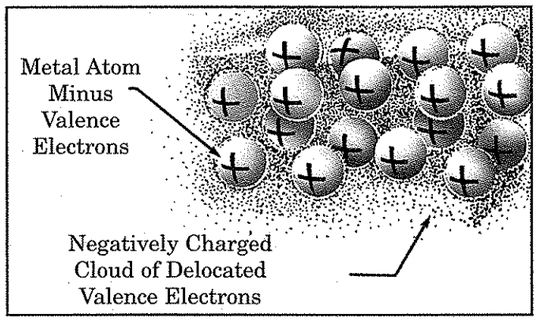


FIGURE 4: METALLIC BOND

Do these activities.

2.23 Using Figure 4 as a model for metallic bonding, try to explain why metals are such good conductors of heat and electricity.

_____

_____

_____

_____

_____

_____

2.24 List the predominant type of bonding as ionic, covalent, or metallic for each of the following chemicals.

a. NaCl - _____
b. Al rod - _____
c. H_2O - _____
d. CsF - _____
e. $FeCl_3$ - _____
f. AgI - _____
g. SO_2 - _____
h. CO_2 - _____

Adult check _____
Initial Date

Review the material in this section in preparation for the Self Test. The Self Test will check your mastery of this particular section as well as your knowledge of the previous section.