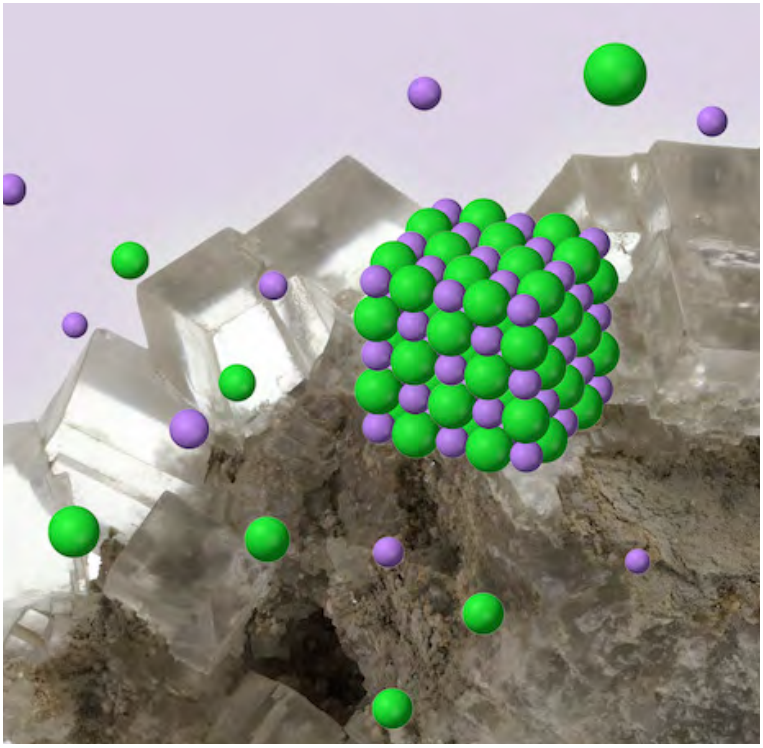


Chapter 6

How Atoms Bond

THE MAIN IDEA

Atoms bond by exchanging or sharing electrons

6.7 Polar Covalent Bonds

If the two atoms in a covalent bond are identical, as shown below, their nuclei have the same positive charge. The electrons shared between these two identical atoms are shared evenly. We can represent these electrons being shared evenly using an electron-dot structure with the electrons situated exactly halfway between the two atomic symbols. Alternatively, we can draw a cloud in which the positions of the two bonding electrons over time are shown as a series of dots. Where the dots are most concentrated is where the electrons have the greatest probability of being located:

In a covalent bond between nonidentical atoms, the nuclear charges are different, and consequently, the bonding electrons may be shared *unevenly*. This occurs in a hydrogen–fluorine bond, in which electrons are more attracted to fluorine's greater nuclear charge:

The bonding electrons spend more time around the fluorine atom. For this reason, the fluorine side of the bond is slightly negative, and because the bonding electrons have been drawn away from the hydrogen atom, the hydrogen side of the bond is slightly positive. This separation of charges is called a **dipole** (pronounced die-pole) and is represented either by the characters $\partial-$ and $\partial+$ (read "slightly negative" and "slightly positive," respectively) or by a crossed arrow pointing to the negative side of the bond:

$$\overset{\delta+}{\mathrm{H}}\!-\!\overset{\delta-}{\mathrm{F}} \qquad \mathrm{H}\!-\!\mathrm{F}$$

READING CHECK
What is an atom with great electronegativity able to do?

So, atoms forming a chemical bond engage in a tug-of-war for electrons. How strongly an atom is able to tug on bonding electrons has been measured experimentally and quantified as the atom's **electronegativity**. The range of electronegativities runs from 0.7 to 3.98, as **Figure 6.28** shows. The greater an atom's electronegativity, the greater its ability to pull electrons toward itself when bonded. Thus, in hydrogen fluoride, fluorine has a greater electronegativity, or pulling power, than hydrogen.

Electronegativity is greatest for elements at the upper right of the periodic table and lowest for elements at the lower left. Noble gases are not considered in electronegativity discussions because, as previously mentioned, they rarely participate in chemical bonding.

When the two atoms in a covalent bond have the same electronegativity, no dipole is formed (as is the case with H_2) and the bond is classified as a **nonpolar bond**. When the electronegativities of the atoms differ, a dipole may form (as with HF) and the bond is classified as a **polar bond**. Just how polar a bond is depends on the difference between the electronegativity values of the two atoms—the greater the difference, the more polar the bond. An electronegativity difference between two atoms greater than about 1.7 indicates an ionic bond. A difference of less than 1.7 but greater than about 0.4 indicates a polar covalent bond. Nonpolar covalent bonds have electronegativity differences of less than 0.4.

As can be seen in Figure 6.28, the greater the distance between two atoms in the periodic table, the greater the difference in their electronegativities, and hence the greater the polarity of the bond between them. So, a

H 2.2																He —
Li 0.98	Be 1.57											B 2.04	C 2.55	N 3.04	O 3.44	F 3.98	Ne —
Na 0.93	Mg 1.31											Al 1.61	Si 1.9	P 2.19	S 2.58	Cl 3.16	Ar —
K 0.82	Ca 1.0	Sc 1.36	Ti 1.54	V 1.63	Cr 1.66	Mn 1.55	Fe 1.83	Co 1.88	Ni 1.91	Cu 1.90	Zn 1.65	Ga 1.81	Ge 2.01	As 2.18	Se 2.55	Br 2.96	Kr —
Rb 0.82	Sr 0.95	Y 1.22	Zr 1.33	Nb 1.6	Mo 2.16	Tc 1.9	Ru 2.2	Rh 2.28	Pd 2.20	Ag 1.93	Cd 1.69	In 1.78	Sn 1.96	Sb 2.05	Te 2.1	I 2.66	Xe —
Cs 0.79	Ba 0.89	La 1.10	Hf 1.3	Ta 1.5	W 2.36	Re 1.9	Os 2.2	Ir 2.20	Pt 2.8	Au 2.54	Hg 2.00	Tl 2.04	Pb 2.33	Bi 2.02	Po 2.0	At 2.2	Rn —
Fr 0.7	Ra 0.9	Ac 1.1	Rf —	Db —	Sg —	Bh —	Hs —	Mt —	Ds —	Rg —	Cn —	Nh —	Fl —	Mc —	Lv —	Ts —	Og —

Λ Figure 6.28

The experimentally measured electronegativities of elements.

chemist can predict which bonds are more polar than others without reading the electronegativities. Bond polarity can usually be inferred by looking at the relative positions of the atoms in the periodic table—the farther apart they are, especially when one is at the lower left and one is at the upper right, the greater the polarity of the bond between them.

The magnitude of bond polarity is sometimes indicated by the size of the crossed arrow or the ∂− and ∂+ symbols used to depict a dipole, as shown in **Figure 6.29**. Note that the electronegativity difference between atoms in an ionic bond is relatively large. For example, the bond in NaCl has an electronegativity difference of 2.23, far greater than the difference of 1.43 shown for the C–F bond.

What is important to understand here is that there is no black-and-white distinction between ionic and covalent bonds. Rather, there is a gradual change from one to the other as the atoms that bond are located farther and farther apart in the periodic table. This continuum is illustrated in **Figure 6.30**. Atoms on opposite sides of the periodic table have great differences in electronegativity, and hence the bonds between them are highly polar—in other words, ionic. Nonmetallic atoms of the same element have the same electronegativities, so their bonds are nonpolar covalent. The polar covalent bond, with its uneven sharing of electrons and slightly charged atoms, lies between these two extremes.

FOR YOUR INFORMATION

The term electronegativity was coined by Linus Pauling in his famous 1932 publications "The Nature of the Chemical Bond, Parts I–IV." Through these articles, Pauling was the first to formally describe the periodic trends of ionic, polar covalent, and nonpolar covalent bonding. The term electronegativity refers to the negative charge that an atom in a molecule picks up due to the electrons it may attract. There are other electronegativity scales, but Pauling's original scale has remained the most commonly used.

Figure 6.29 >

These bonds are in order of increasing polarity from left to right, a trend indicated by the larger and larger crossed arrows and ∂–/∂+ symbols. Which of these pairs of elements are farthest apart in the periodic table?

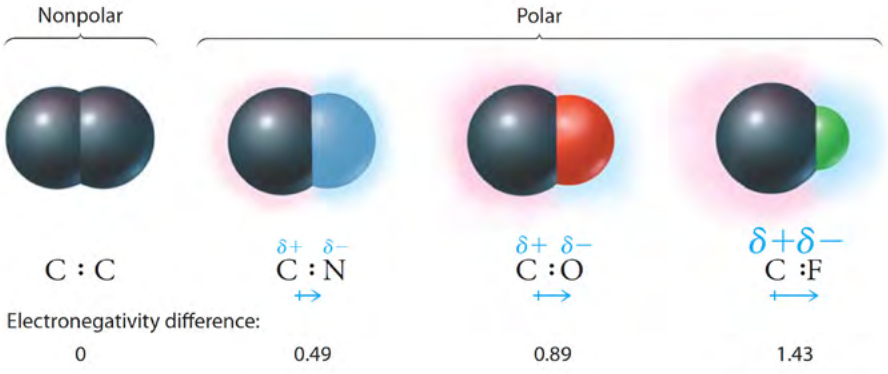
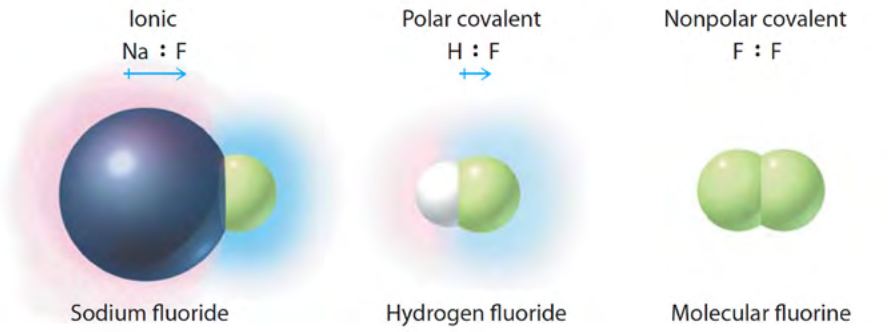


Figure 6.30 >

The ionic bond and the nonpolar covalent bond represent the two extremes of chemical bonding. The ionic bond involves a transfer of one or more electrons, and the nonpolar covalent bond involves the equitable sharing of electrons. The character of a polar covalent bond falls between these two extremes



CONCEPT **CHECK**

List these bonds in order of increasing polarity: P–F, S–F, Ga–F, Ge–F.

(least polar) _____,_____,_____,_____. (most polar)

CHECK YOUR ANSWER

If you answered the question, or attempted to, before reading this answer, hooray for you! You're doing more than reading the text—you're learning chemistry. The greater the difference in electronegativities between two bonded atoms, the greater the polarity of the bond; so, the order of increasing polarity is S–F, P–F, Ge–F, Ga–F.

Note that this answer can be obtained merely by looking at the relative positions of these elements in the periodic table rather than by calculating the differences in their electronegativities.