2.4 The Electronegativity Table: Partially Ionic Bonds

The periodic table gives a qualitative understanding of the preference of atoms to donate or to accept electrons. Thus, atoms have a varying degree of affinity to draw electrons to themselves. This nature of atoms was given a quantitative value, called electronegativity, by Pauling and is given in Table 2.3.

Table 2.3: Electronegativity of Elements

						H 2.1										
Li 1.0	Be 1.5	B 2.0											C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.2	Al 1.5											Si 1.8	P 2.1	S 2.5	Cl 3.0
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.9	Ni 1.9	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5
Cs 0.7	Ba 0.9	La-Lu 1.0-1.2	Hf 1.3	Ta 1.5	W 17	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.9	Bi 1.9	Po 2.0	At 2.2
Fr 0.7	Ra 0.9	Ac 1.1	Th 1.3	Pa 1.4	U 1.4	Np-No 1.4-1.3										

The values of electronegativity in Table 2.3 are consistent with the examples of chemical bonding discussed in Example 2.5. The metals yield electrons and oxygen accepts them. Thus oxygen has a higher electronegativity than metals—a value of 3.5 relative to those of the metals, which lies between 1 and 2. We now ask the significance of the difference between the electronegativity values between two different metals and oxygen. For instance, the difference between the electronegativities of Ca and O is 3.5-1.0 = 2.5 while the difference between Zr and O is 3.5-1.4 = 2.1. We will return to this question after reconsidering the discussion of ionic and covalent bonding.

In a purely ionic bond, the electron transfers completely from one atom to another. For example, if the Ca-O bond were to be purely ionic, then two electrons from Ca will move over entirely to the oxygen atom, giving a whole charge of +2 to the Ca atom and –2 to the oxygen atom. However, electrons are not stationary entities, which are either all in one place or the other. Rather, they are constantly orbiting the nucleus of the atom. When an ionic bond forms, the electrons can choose to spend a greater amount of time with one atom than the other. Thus, the transfer of electron is a probability rather than a certainty. This fact leads to the concept of the degree of ionicity of a bond. The electronegativity series gives a value to the ionic character via the following equation:

$$I_C = 1 - e^{-\left(\frac{\chi_A - x_B}{2}\right)^2} \tag{2.3}$$

where I_C is the amount of ionic character of the bond A-B, and where χ_A and χ_B are the electronegativity of atoms A and B. Note that I_C ranges from zero, when $\chi_A = \chi_B$ (the bonds between like atoms are entirely non–ionic), to one when the difference ($\chi_A - \chi_B$) becomes very large. Note that ($\chi_A - \chi_B$) is always calculated in such a way that it is always a positive quantity, that is, x_A always has the higher value of electronegativity. Equation 2.3

is highly non—linear, that is, small changes in the electronegativity can have a large effect on ionicity. Therefore, it is useful to have a numerical table of the predictions, which are given in Table 2.4.

Table 2.4: The relationship between the difference in the electronegativity between two atoms A and B, and the ionic character of the bond between then.

$x_A - x_B$	Amount of ionic Character (%)	$x_A - x_B$	Amount of ionic Character (%)
0.2	1	1.8	55
.4	4	2.0	63
.6	9	2.2	70
.8	15	2.4	76
1.0	22	2.6	82
1.2	30	2.8	86
1.4	39	3.0	89
1.6	47	3.2	92

We are now able to say that the bond between Zr and O is about 67% ionic while that between Ca and O is nearly 80% ionic. In general, bonds are more than 50% ionic if the difference in the electronegativity between the atoms is greater than 1.7.

There is a pattern to x value of elements in the periodic table. The metals generally have $x < 2.0$,while atoms with nearly complete outermost shells have $x > 2.0$. The values for the transition metals are less than but close to 2.0. The values for x generally increase from the left to the right, and from the higher row numbers, near the bottom of the table to the upper rows. Thus, the elements in the lower left corner have the lowest and those in the diagonally opposite corner have the highest values of x.