Ionic Bonding

Ionic compounds are held together by coulombic attraction. There is a negatively charged ion next to a positively charged ion. The two will attract each other, Coulomb's Law.

$$E = 2.31 \times 10^{-19}\ \text{J} \bullet \text{nm}\ (Q_1Q_2)/r$$

Q is the numerical ion charge, r is the radius in nm.

$$E = 2.31 \times 10^{-19}\ \text{J} \bullet \text{nm}\ (-1)(1)/0.276\ \text{nm}$$

$$E = 8.37 \times 10^{-19}\ \text{J} \quad \text{for 1 interaction}$$

how about a mole of interactions in kJ

$$E = 8.37 \times 10^{-19}\ \text{J}\ (6.02 \times 10^{23}\ \text{interactions/mole})/1000$$

$$E = -504\ \text{kJ mol}^{-1}$$

The Coulombic attraction is very important!

Let's make NaCl from an Na atom and a Cl atom.

To remove and electron from a gaseous sodium atom 495 kJ/mol are required. This is just the molar ionization energy of Na.

When an electron is added to a gaseous chlorine atom 348 kJ/mol are released.

$$Na(g) \longrightarrow Na^+(g) + e^- \qquad \Delta H = 495\ \text{kJ}$$

$$e^- + Cl(g) \longrightarrow Cl^-(g) \qquad \Delta H = -348\ \text{kJ}$$

$$Na(g) + Cl(g) \longrightarrow Na^+(g) + Cl^-(g) \qquad \Delta H = 147\ \text{kJ}$$

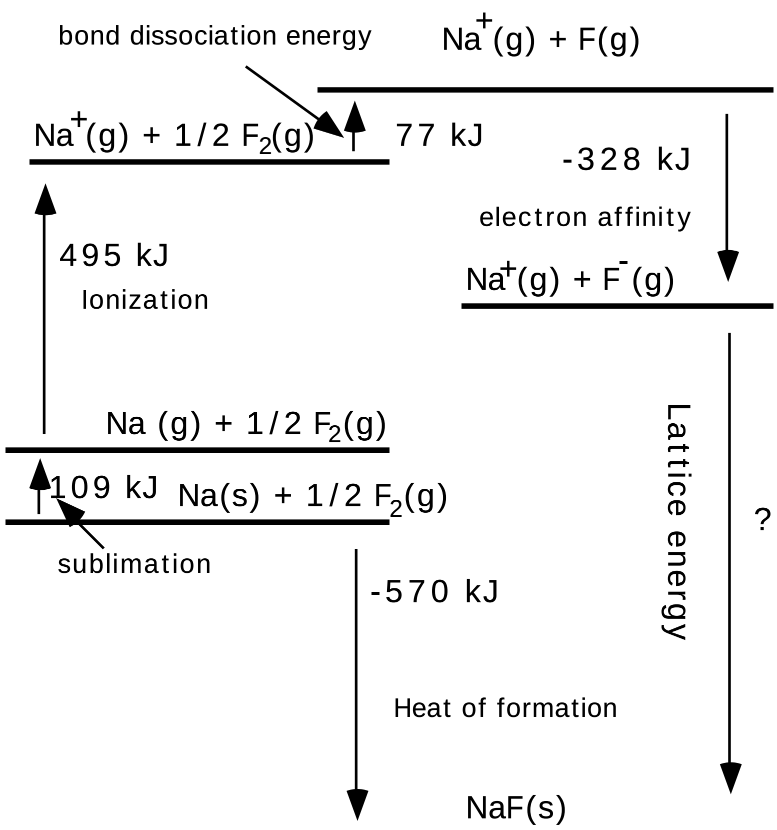
So, a chlorine atom cannot simply rip an electron of a Na atom. The attraction between the ions must make up for the uphill energy involved in abstracting the electron from the sodium atom. Afterall, the heat of formtaion of NaCl very large, $\Delta H_f° = -411$ kJ/mol.

The energy released by the attraction between the ions is called the Lattice Energy. The reaction is...

$$Na^+(g) + Cl^-(g) \longrightarrow NaCl(s)$$

Experimentally determining the ΔH for the reaction written above cannot be done; however, Hess's Law can be used to calculate the energy involved when an ionic crystal is formed from gaseous ions.

Let's determine the Lattice Energy for NaF. That is, determine ΔH for the following reaction:



one side must equal the other, so

$$-570 + -(109) + -(495) + -(77) = -328 + \Delta H_{lattice}$$

Additionally, all the arrows must point in the same direction since we are saying the energy required to go DOWN one side is the same as the amount of energy required to go DOWN the other side. Since some reactions are being reversed; the corresponding ΔH's must also be reversed.

$$\Delta H_{lattice} = -923 \text{ kJ/mol}$$

Essentially, lattice energy is the result of coulombic attraction; because of this, we can make predictions about lattice energies by examining Coulomb's Law.

$$E = 2.31 \times 10^{-19} \text{ J nm } (Q_1Q_2)/r$$

Which of the following two ionic solids will have a higher lattice energy?

MgF_2, or NaF?

MgF_2	NaF
Compare charges of the ions	
$Q_1 = +2$, $Q_2 = -1$	$Q_1 = +1$, $Q_2 = -1$
$Q_1Q_2 = -2$	$Q_1Q_2 = -1$

Compare r

Mg^{2+} will be slightly smaller than Na^+

Since the anions are the same,

the "r" for MgF_2 is slightly smaller than the "r" for NaF

Due to the charge of the ions the energy released by the coulombic attraction is more than twice as large for MgF_2 than it is for NaF. So, the lattice energy for MgF_2 should be more negative than the lattice energy for NaF.

Electron configuration of ions in the third period.

Na^+	Mg^{2+}	Al^{3+}	S^{2-}	Cl^-
$2s^2\ 2p^6$	$2s^2\ 2p^6$	$2s^2\ 2p^6$	$3s^2\ 3p^6$	$3s^2\ 3p^6$

Main group, s and p block, ions always resemble the nearest noble gas. Why doesn't Na form Na^{2+}?

The electrons which are removed from Na and Mg are 3s electrons. The electrons which are removed from Al are 3s and 3p electrons. The electrons in the 3rd shell are shielded from much of the charge of the nucleus by the 10 electrons in the 1st and 2nd shells.

By comparison, the electrons in the 2nd shell are shielded from the nucleus by the 2 electrons in the 1s shell. Therefore, the electrons in the second shell are MUCH more strongly attracted to the nucleus. Since the electrons are strongly attracted to the nucleus they are too difficult to remove.

Why doesn't Cl form Cl^{2-}?

When an electron is added to a Cl atom it is added to the third shell. The electron which is being added is shielded from the nucleus by the 10 electrons in the 1st and 2nd shells. If a second electron is added to a $Cl^–$ ion the electron must go into the 4s orbital. If the electron is put in the 4th shell it is shielded from the nucleus by 18 electrons. Essentially, the electron in the 4th shell cannot "see" any positive charge from the nucleus. Since there is little or no attraction between the nucleus and the 2nd additional electron the $Cl^{2–}$ ion releases the electron.