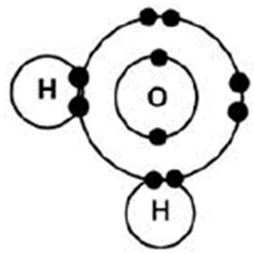
8.5 - 8.8 - Bond Energy



Water: 2 hydrogen atoms sharing electrons with 1 oxygen atom

Bond Energy

Forming and breaking chemical bonds involves the transfer of energy.

There are different situations wherein bonds are altered, but the process of computing energy is roughly the same.

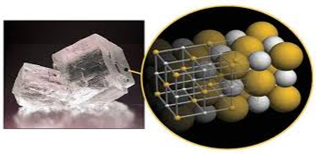
It relies on data gathered over time relating to energy transfers that occur during each step of the chemical reaction.

Ionic Compound Structure

Ionic compounds form a repeating system of ions called a crystal lattice.

They tend to have relatively high melting and boiling points, and are hard, rigid, brittle solids.

Solutions of ionic solids conduct electricity – called electrolytes.



Salt Crystals

Lattice Energy

Measure of cohesive forces in an ionic solid.

Definition: the change in energy that takes place when separated gaseous ions are packed together to form an ionic solid.

Lattice energy can't be measured empirically, instead, it must be determined through a process of steps.

Consider the example of the formation of solid lithium fluoride:

$$Li_{(s)} + \frac{1}{2}F_{2(g)} \rightarrow LiF_{(s)}$$

1. Lithium Fluoride Guided Ex.

$$Li_{(s)} + \frac{1}{2}F_{2(g)} \rightarrow LiF_{(s)}$$

This reaction is quite involved, and must be broken down into a sequence of steps, each of which contributes to the energy of formation (ΔH_f^o) for LiF.

1. Sublimation of solid lithium:
$Li_{(s)}$ --> $Li_{(g)}$ = 161 kJ/mole
2. Ionization of lithium:
$Li_{(g)}$ --> $Li^+_{(g)}$ + e^- = 520 kJ/mol
3. Fluorine dissociation:
1/2 $F_{2(g)}$ --> $F_{(g)}$ = 154 kJ/mol / 2 = 77 kJ/mol
4. Formation of F^- ions:
$F_{(g)}$ + e^- --> $F^-_{(g)}$ = -328 kJ/mol
5. Formation of solid LiF from gaseous ions:
$Li^+_{(g)}$ + $F^-_{(g)}$ --> $LiF_{(s)}$ = -1047 kJ/mol

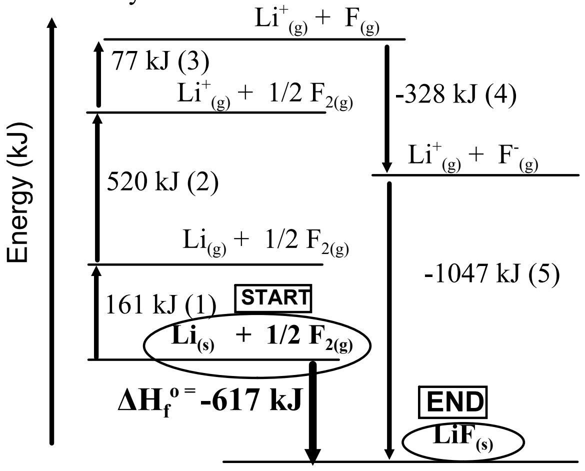
1. Lithium Fluoride Guided Ex.

The sum of these 5 processes yields the overall reaction and energy change:

$Li_{(s)}$ --> $Li_{(g)}$	161 kJ/mol
$Li_{(g)}$ --> $Li^+_{(g)}$ + e^-	520 kJ/mol
1/2 $F_{2(g)}$ --> $F_{(g)}$	77 kJ/mol
$F_{(g)}$ + e^- --> $F^-_{(g)}$	-328 kJ/mol
+ $Li^+_{(g)}$ + $F^-_{(g)}$ --> $LiF_{(s)}$	+ -1047 kJ/mol
$Li_{(s)}$ + 1/2 $F_{2(g)}$ --> $LiF_{(s)}$	-617 kJ/mol

1. Lithium Fluoride Guided Ex.

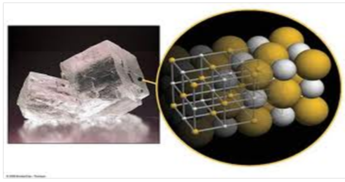
Pictorially:



Lattice Energy vs. Heating

One application is to predict the relative amount of energy required to break the bonds of a mole of an ionic compound during melting (or boiling).

Lattice Energy depends on size and charge of ions:
- The smaller the ion, and/or the larger the ionic charge, the greater the lattice energy. Smaller ions have their nuclei closer to neighboring ions, thus increasing their attraction to their neighbor's electrons.
- The larger the ion and/or smaller the charge, the lower the lattice energy.



2. Lattice Energy Example

Which compound has greater lattice energy, potassium fluoride (KF) or potassium iodide (KI)?

Compare ions: K is in both formulas - same size.

Fluoride is smaller than iodide, so KF has a greater lattice energy.

3. Ranking Example

Rank the following compounds melting points from least to greatest:

NaCl NaF

KCl LiF

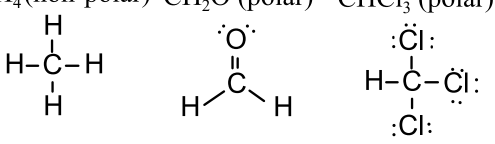
Answer: KCl NaCl NaF LiF

Covalent Bond Energies & Reactions

The length of a chemical bond depends on the chemical environment and electronic interactions within the molecule.

For example, the single bond between hydrogen and carbon in the following three compounds requires different amounts of energy to sever due to electronegativity differences:

CH_4(non-polar) CH_2O (polar) $CHCl_3$ (polar)



Covalent Bond Energies & Reactions

This bond energy table averages empirical data and renders a 'first approximation' of the energy associated with chemical reactions involving breaking and forming bonds:

Bond	kJ/mol	Bond	kJ/mol
H-H	432	Cl-Cl	239
H-F	565	F-F	154
H-Cl	427	O=O	495
C-H	413	C-C	347
C-F	485	N-N	160
C-Cl	339	C-O	358

For more data, consult table 8.4 on Page 374 of your book.

Covalent Bond Energies & Reactions

To calculate the enthalpy of a reaction (ΔH), determine the difference between energy required to break the bonds of the reactants, and energy released during the bond formation of the products.

$$\Delta H = \Sigma\, n \times D\ (bonds\ broken) - \Sigma\, n \times D\ (bonds\ formed)$$

Energy Required **Energy Released**

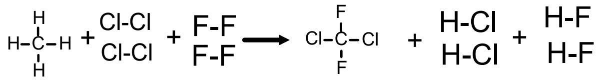
n = the moles of a particular type of bond,
D = bond energy of each particular type of bond.

4. ΔH From Bond Energies

Calculate ΔH for the following reaction.
Assme that all bonds between atoms are single bonds, and that carbon is the central atom.

CH_4 + 2 Cl_2 + 2 F_2 --> CF_2Cl_2 + 2 HCl + 2 HF

Just to be sure you get it:



4. ΔH From Bond Energies Answer

CH_4 + 2 Cl_2 + 2 F_2 --> CF_2Cl_2 + 2 HCl + 2 HF
Calculate the energy required to break bonds first:

4 mol C-H x 413 kJ/mol = 1652 kJ

2 mol Cl-Cl x 239 kJ/mol = 478 kJ

2 mol F-F x 154 kJ/mol = 308 kJ

Sum total = 2438 kJ

4. ΔH From Bond Energies Answer

CH_4 + 2 Cl_2 + 2 F_2 --> CF_2Cl_2 + 2 HCl + 2 HF
Calculate the energy released during bond formation next:

2 mol C-F x 485 kJ/mol = 970 kJ

2 mol C-Cl x 339 kJ/mol = 678 kJ

2 mol H-F x 565 kJ/mol = 1130 kJ

2 mol H-Cl x 427 kJ/mol = 854 kJ

Sum total = 3,632 kJ

The total for the process:
2,438 kJ - 3,632 kJ = -1,194 kJ

This is an exothermic process: more energy is released than required to allow the reaction to progress.

Homework

Preview 8.9 - 8.12

8.5 - 8.8 Problems in your Booklet
Due: Next Class