Bond Energies

The bond energy is the amount of energy (enthalpy) required to break or form a bond in 1 mole of gaseous molecules, which is expressed as kJ/mol.

Enthalpy (*enthalpien*, Greek word, to warm) also known as "heat content" is a thermodynamic quantity that is nothing but the heat at constant pressure. In other words, it is a fancy word for heat content at constant pressure. Why constant pressure? Well, most of the experiments are carried out under atmospheric condition. Under this condition, the pressure is pretty much constant throughout our planet and due to that the constant pressure concept is introduced.

Some of the bond energies are listed in the following table.

Single Bonds					
Bond	Bond Energy (kJ/mole)	Bond	Bond Energy (kJ/mole	Bond	Bond Energy (kJ/mole
H- H	436.4	C-H	414	O-O	142
H-N	393	C-C	347	O-P	502
H-O	460	C-N	276	P-P	197
H-S	368	C-O	351	S-S	268
H-P	326	C-P	263	F-F	156.9
H-F	568.2	C-S	255	Cl-Cl	242.7
H-Cl	431.9	N-N	193	Br-Br	192.5
H-Br	366.1	N-O	176	I-I	151
H-I	298.3	N-P	209	O-O	142
Double Bonds					
C=C	620	C=S	477	O=S	469
C=N	615	N=N	418	P=P	489
C=O	745	O=O	498.7	S=S	352
Triple Bonds					
C≡C	812	C≡N	891	N≡N	941.4

What is the use of bond energies?

Bond energies can be used:

- To understand the strength of a bond
- To estimate the enthalpy changes in chemical reactions and to predict whether the reactions are exothermic (liberation of heat) or endothermic (absorption of heat)

Strength of a bond

Compare, for e.g. the bond energies of C- C, C=C, and C≡C bonds. The C-C bond energy (347 kJ/mol) is smaller than C=C bond energy (620 kJ/mol), which is in turn smaller than C≡C bond energy (812 kJ/mol). This means that triple bond is stronger than double bond, which in turn stronger than single bond. This is due to the fact six electrons are involved in triple bond, four electrons in double bond, and two electrons in single bond. Thus, bond energy is correlated with number of electrons engaged in bonding. It makes sense because more number of electrons in bonding means stronger the attraction between these electrons and nuclei. In general,

Strength of triple bond > Strength of double bond > Strength of Single bond

Enthalpy Changes in Chemical Reactions

Energy is supplied to break the chemical bonds and energy is always released when the chemical bonds are formed. Therefore, the change in enthalpy of any chemical reactions in terms of bond energies is given by

$$\Delta H^0 = \sum \text{Bond energies of reactants} - \sum \text{Bond energies of products}$$
$$= \text{Total input energy} - \text{Total output energy}$$

Let us consider the following chemical reaction for decomposition of water molecule in gaseous phase:

$$2\ H_2O\ (g) \rightarrow 2H_2\ (g) + O_2\ (g)$$

Let us represent this reaction with detail bonding as

2 (H - O - H) --> 2(H - H) + O = O

There are 4 O-H bonds in water molecule, 2 H-H bonds in H_2 molecule, and 1 O=O bond in O_2 molecule. First, four O-H bonds in water molecules have to be broken up and then two H-H and one O=O bonds have to be formed. Thus,

- Energy required to break 4 O-H bonds = 4 x 460 kJ/mol = 1840 kJ/mol
- Energy required to form 2 H-H bonds = 2 x 436.4 kJ/mol = 872.8 kJ/mol

- Energy required to form 1 O=O bond = 1 x 498.7 kJ/mil = 498.7 kJ/mol

Total input energy = 1840 kJ/mol
Total output (released) energy = 872.8 kJ/mol + 498.7 kJ/mol = 1371.5 kJ/mol

Now ΔH^0 = $\sum$ Bond energies of reactants - $\sum$ Bond energies of products
= 1840 kJ/mol – 1371.5 kJ/mol = 469 kJ/mol

This indicates that the reaction is endothermic because of the positive value of ΔH^0. Also it means that 469 kJ of heat need to be supplied in order to carry out this reaction.