5.4 Bond Enthalpies

Bond breaking is endothermic and bond making is exothermic. Bond making produces greater stability because the resulting products have a lower energy state.

bond making **bond breaking**

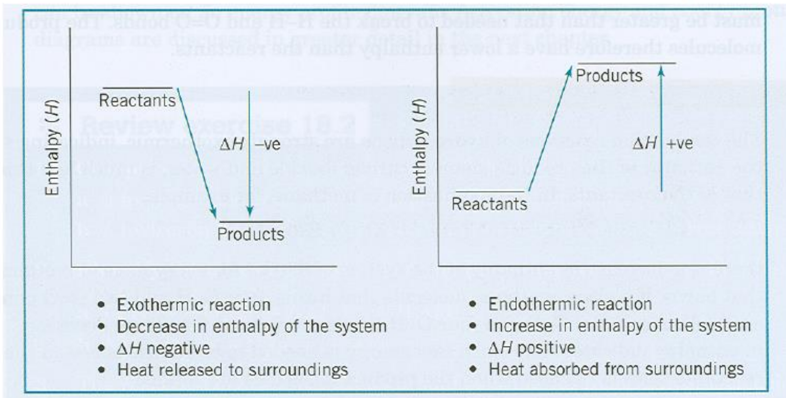


Figure 18.5 Enthalpy changes for exothermic and endothermic reactions

$$CH_{4(g)} + O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$$

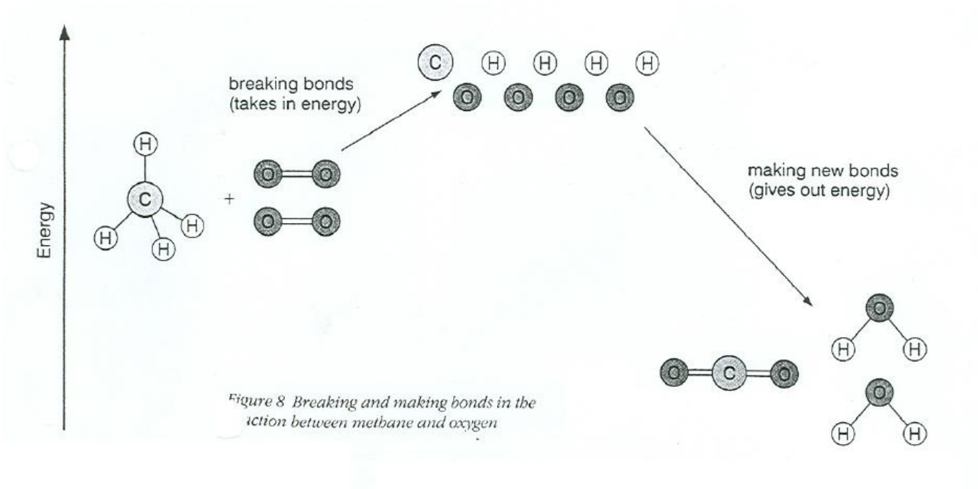


Figure 8 Breaking and making bonds in the action between methane and oxygen

During every chemical reaction sufficient energy needs to first be absorbed (endothermic) to break the bonds. This energy is called the activation energy and is defined as the minimum amount of energy required by the reactants before products will form.

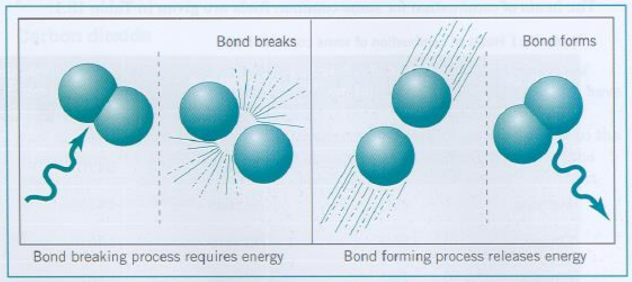
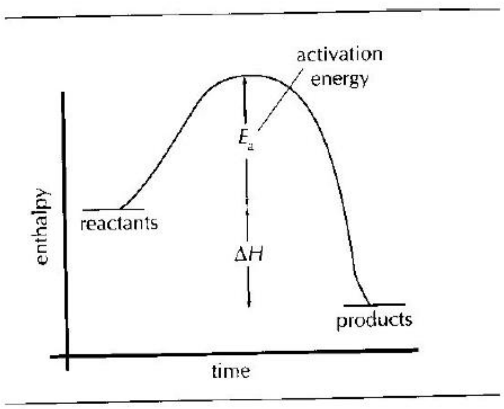


Figure 18.6 The energy required to break a chemical bond equals the energy released when the bond forms.



Some reactions have small activation energies, because there is enough energy in the surroundings at room temperature to get them started. Other reactions have higher activation energies and need to absorb much more heat energy in order to break the bonds. Burning / combusting a fuel is an example. Not all the bonds of the reactants need to break at the same time before products form. Once one or two bonds have broken new bonds can start to form and this usually releases enough energy to keep the reaction going.

Recall that a covalent bond is an electrostatic attraction between positive protons in the nucleus (called the positive nuclear charge) of the bonded atoms and the negative shared electrons in the bond. To break this bond sufficient energy needs to be absorbed by the bond to overcome the attraction between the protons and electrons. The stronger the bond the greater the amount of energy required to break it.

The factors that affect the strength of a bond are:

1. When the number of shared electrons in the bond increases the attraction between them and the protons in the nuclei of the bonded atoms increases. Triple bonds are stronger than double which are stronger than single bonds. (C-C, ΔH = 348 $kJmol^{-1}$; C=C, ΔH = 612 $kJmol^{-1}$ and C≡C, ΔH = 837 $kJmol^{-1}$)
2. When the radius of the bonded atoms decreases, the protons and electrons of the bond are closer to each other so the attraction between them increases, making the bond weaker.
3. When the number of protons in the nuclei of the bonded atoms increases the attraction between them and the bonding electrons increases, increasing the strength of the bond.

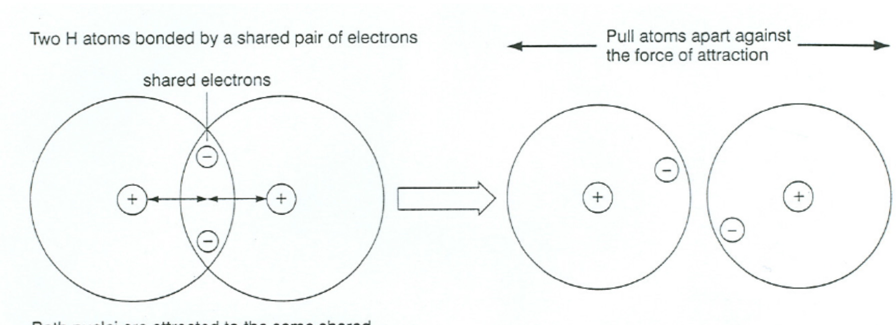
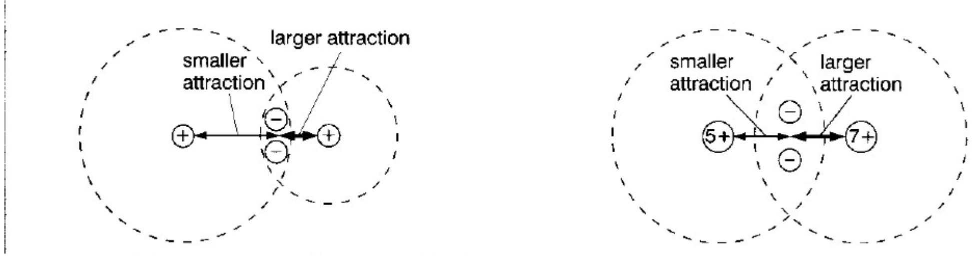


Figure 6 Breaking a bond involves using energy to overcome the force of attraction



So far we have calculated enthalpy changes the following ways:

1. ΔH = (m x c x ΔT) ÷ n
2. Hess's Law

Another way to calculate enthalpy changes is using average bond enthalpies. ***Average bond enthalpy*** is defined as *the average energy required to break <u>one mole</u> of gaseous covalent bonds*. They are calculated by taking the average of the enthalpies for that specific bond obtained from a number of similar compounds. The average bond enthalpy provides an indication of the strength of a chemical bond.

Average bond enthalpies values are not particularly accurate because they are average values. They are most accurate and most useful when only a few bonds are made and broken, when specific bond energies are used instead of averages and when the reactants and products are gases.

Calculating Enthalpy Changes from Average Bond Enthalpies

$$\Delta H = \sum \Delta H_{\text{(bonds broken in reactants)}} - \sum \Delta H_{\text{(bonds made in products)}} \ (\text{kJ mol}^{-1})$$

Tables of average bond enthalpies are found in the Chemistry data booklet.

Average bond enthalpies at 298K

Bond	ΔH / kJ mol^{-1}	Bond	ΔH / kJ mol^{-1}
H - H	436	C - H	412
D - D	442	Si - H	318
C - C	348	N - H	388
C = C	612	P - H	322
C ≡ C	837	O - H	463
C - C (benzene)	518	S - H	338
Si - Si	226	F - H	562
Ge - Ge	188	Cl - H	431
Sn - Sn	151	Br - H	366
N - N	163	I - H	299
N = N	409		
N ≡ N	944	C - O	360
P - P	172	C = O	743
O - O	146	C - N	305
O = O	496	C = N	613
S - S	264	C ≡ N	890
F - F	158	C - F	484
Cl - Cl	242	C - Cl	338
Br - Br	193	C - Br	276
I - I	151	C - I	238
		Si - O	374

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