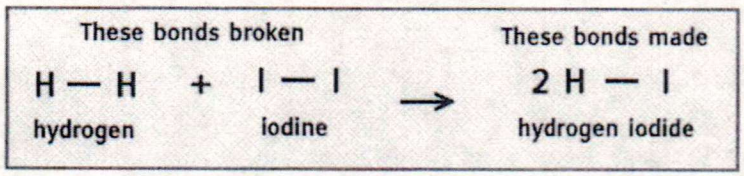
Lesson 8: The origins of heat of reaction

Why are some reactions exothermic and some endothermic? How can we explain why the heat content of reactants in some reactions is more than the heat content of the products, but sometimes the reverse is true?

We need to recall that for a chemical reaction to occur bonds in the reactants must be broken and bonds in the products must form. We know that breaking bonds requires an input of energy and making bonds releases energy. So as bonds break, energy is absorbed and as they form energy is released. The heat of the reaction will depend on which of these two processes has the greatest energy value.

Lets use the reaction between hydrogen gas and iodine gas as an example:



The bond energies involved in the reaction between hydrogen and iodine are shown in the table below.

Bond	Bond energy in kJ/mole
H - H	436
I - I	151
H - I	298

1. So the energy required to break the bonds , the energy IN , is 436 + 151 kJ/mole = 587 kJ/mole
2. The energy released as bonds form, the energy OUT , is 2 x 298 kJ/mole = 596 kJ/mole
3. The energy change is therefore 587 - 596 = -9 kJ/mole

Since the energy change is negative, this is an exothermic reaction. More energy is given out as bonds form (products) than is taken in to break the bonds.(reactants)

Table of Average Bond Dissociation Energies

Bond	Energy (kJ/mol)	Bond	Energy (kJ/mol)
H - H	436	N - N	160
C - H	413	N = O	631
N - H	393	N triple N	941
O = O	498	N - O	201
C - C	347	C = O	805
C - O	358	O - H	464
Cl-Cl	242	H-Cl	433
C - Cl	397	O - Cl	269
C = C	607	O - O	204

Activity: Modelling bond making and breaking

In this activity, you will

- Build models to investigate bond breaking and making.
- Use your model making to help work out the enthalpy change in a reaction. You will need to use the table of bond enthalpies given on the previous page.

Procedure:

1. Build models of the reactants given

2. Analyse all of the bonds in the reactants. Write down each bond and look up the energy required to break that bond. This will determine the energy IN.

3. Build models of the products.

4. Analyse all of the bonds formed. Write down each bond and look up the energy released when the bond forms. This will determine the energy OUT.

5. Determine the total energy of the reaction .

REACTANTS			→	PRODUCTS		
Ethanol	Oxygen			Carbon dioxide	Water	
Bonds broken	Number broken	Energy IN		Bonds formed	Number formed	Energy OUT

Energy of the reaction = energy IN - energy OUT

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REACTANTS			→	PRODUCTS		
Ethene	Hydrogen			Ethane		
Bonds broken	Number broken	Energy IN		Bonds formed	Number formed	Energy OUT

Energy of the reaction = energy IN - energy OUT

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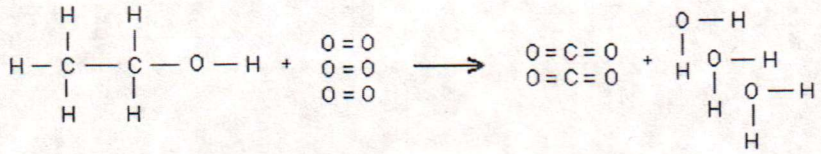
To do this without models, follow the following example:

First write out the balanced equation for the reaction showing full structural formulae.

Now simply add together the bond enthalpies involved for the reactants to obtain the total energy in

Do the same for the products to obtain a total energy out

Finally, subtract energy out from energy in to find ΔH for the reaction.



Bond	Number broken	Number formed	Average Bond Enthalpy kJ /mol
C-C	1	0	+347
C-H	5	0	+413
C-O	1	0	+358
O-H	1	6	+464
O=O	3	0	+498
C=O	0	4	+805

Bond breaking:

Total energy IN = (347 x 1) + (413 x 5) + (358 x 1) + (464 x 1) + (498 x 3) = 4728 kJ

Bond making:

Total energy OUT = (464 x 6) + (805 x 4) = 6004 kJ

Sum total of bond breaking and bond making=

energy IN – energy OUT = 4728kJ – 6004kJ = -1276 kJ

Exercises:

1.Use the table of bond enthalpies to determine the enthalpy of the following reactions:

a. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

b. $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$

c. $\frac{1}{2} H_2(g) + \frac{1}{2} Cl_2(g) \rightarrow HCl(g)$

d. $N_2H_4(g) + O_2(g) \rightarrow N_2(g) + 2 H_2O(l)$

2. Given that the enthalpy change for the reaction $N_2(g) + 3Cl_2(g) \rightarrow 2NCl_3(g)$ is 688 kJ/mol, calculate the bond enthalpy of the N-Cl bond.