

Dr Clays A-level Chemistry

UNIT 1 TOPIC 4
ENERGETICS

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Unit 1 Topic 4 – ENERGETICS

Exercise 1 – Enthalpy Changes

The chemical potential energy of a substance is known as its **ENTHALPY** and has the symbol H.

During chemical reactions, the enthalpy can increase or decrease. The change in enthalpy during chemical reactions is called the **ENTHALPY CHANGE** (ΔH). It usually has units of $kJmol^{-1}$.

Almost all reactions require an initial input of energy in order to break the bonds in the reactants. This energy is called the **ACTIVATION ENERGY** (E_a).

1. What is meant by the term 'exothermic reaction'? Describe the energy changes which take place in an exothermic chemical reaction.

2. The combustion of methane is an exothermic reaction:
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ $\Delta H = -890\ kJmol^{-1}$
Draw an enthalpy profile diagram for the combustion of methane. Label the reactants and products, enthalpy change and activation energy.
Explain why the enthalpy increases before it decreases.

3. What will be the enthalpy change for the following reaction?
$CO_2 + 2H_2O \rightarrow CH_4 + 2O_2$

4. a) Calculate the heat energy released when 100 g of methane is burned
b) Calculate the heat energy released when 500 cm^3 of methane is burned at 298 K and 300 kPa
c) Calculate the mass of methane required to produce 50,000 kJ of heat energy.

5. What is meant by the term 'endothermic reaction'? Describe the energy changes which take place in an endothermic chemical reaction.

6. Photosynthesis is an endothermic reaction:
$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ $\Delta H = +2802\ kJmol^{-1}$
Draw an enthalpy profile diagram for photosynthesis. Label the reactants and products, enthalpy change and activation energy.

7. What will be the enthalpy change for the following reaction?
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

8. a) Calculate the amount of light energy required to make 1000 g of glucose.

b) Calculate the amount of light energy required to absorb 500 cm^3 of carbon dioxide is at 298 K and 100 kPa

c) Calculate the mass of glucose which can be made when a tree absorbs 10,000 kJ of light energy.

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Exercise 2 - bond dissociation energies

1. Define the term 'bond dissociation energy'

bond	ΔH_b/kJmol^{-1}	bond	ΔH_b/kJmol^{-1}	bond	ΔH_b/kJmol^{-1}
C-H	+413	H-F	+565	C=C	+611
C-Br	+280	N≡N	+945	H-H	+435
H-Br	+366	F-F	+158	N-H	+391
Br-Br	+193	C=O	+805	O=O	+498
C-C	+347	O-H	+464	I-I	+151

2. Use the information in the table above to calculate approximate energy changes for the following reactions:

a) $CH_4(g) + Br_2(g) \rightarrow CH_3Br(g) + HBr(g)$

b) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

c) $H_2(g) + F_2(g) \rightarrow 2HF(g)$

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

3. The enthalpy change for the following reaction:
$H_2(g) + I_2(g) \rightarrow 2HI(g)$ is -9 kJmol^{-1}

   Use this information and the values in the above table to calculate the bond dissociation energy for the H-I bond

4. Explain why using bond dissociation energies only give you an approximate value for the overall energy change

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Exercise 3 – measuring enthalpy changes

In all the following questions, assume that the densities and specific heat capacities of the solutions are the same as pure water

i.e. $\rho = 1.0\ gcm^{-3}$ and $c = 4.18\ Jg^{-1}K^{-1}$

1. Zinc will displace copper from copper (II) sulphate solution according to the following equation:

   $CuSO_4(aq) + Zn(s) \rightarrow Cu(s) + ZnSO_4(aq)$

   If an excess of zinc powder is added to 50 cm^3 of 1.0 $moldm^{-3}$ copper(II) sulphate, the temperature increases by 6.3 °C. Calculate the enthalpy change for the reaction.

2. Magnesium will also displace copper from copper (II) sulphate solution. If an excess of magnesium is added to 100 cm^3 of 1.0 $moldm^{-3}$ copper(II) sulphate, the temperature increases by 46.3 °C. Calculate the molar enthalpy change for the reaction

3. When 5.73 g of sodium chloride (NaCl) dissolves in 100 cm^3 of water, the temperature of the water fell from 22.4 °C to 19.8 °C. Calculate the enthalpy change of the reaction.

4. When 2.3 g of magnesium chloride dissolves in 200 cm^3 of water, the temperature rose by 3.4 °C. Calculate the enthalpy change for the reaction.

5. If 50 cm^3 of 0.1 $moldm^{-3}$ HCl and 50 cm^3 of 0.1 $moldm^{-3}$ NaOH are mixed, the temperature of the solution rises by 0.68 °C. Calculate the enthalpy change of the reaction in $kJmol^{-1}$.

6. If 50 cm^3 of 1.0 $moldm^{-3}$ NaOH is added to 25 cm^3 of 2.0 $moldm^{-3}$ CH_3COOH, the temperature rose by 8.3 °C. Calculate the molar enthalpy change for the reaction.

7. A spirit burner containing ethanol (C_2H_5OH) was used to heat 100 cm^3 of water in a copper can by 30 °C. As a result, the mass of the spirit burner decreased by 0.62 g. Calculate the enthalpy of combustion of ethanol.

8. A spirit burner containing butan-1-ol (C_4H_9OH) was used to heat 200 cm^3 of water in a copper can by 20 °C. As a result, the mass of the spirit burner decreased by 0.81 g. Calculate the enthalpy of combustion of butan-1-ol.

9. Explain why measuring energy changes tend to result in an underestimate of the actual energy change in the reaction.

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Exercise 4 – Formation and Combustion Equations

1. Define the term "standard enthalpy of formation"

2. Write equations which represent the standard enthalpy of formation of the following substances:

   a) MgO

   b) CO_2

   c) C_4H_{10}

   d) C_2H_6O

   e) Al_2O_3

3. Explain why the enthalpy of formation of all elements is always zero.

4. Define the term "standard enthalpy of combustion"

5. Write equations which represent the standard enthalpy of combustion of the following substances:

   a) CH_4

   b) C_6H_6

   c) C_2H_6O

   d) H_2

   e) Al

6. Identify three substances for which the enthalpy of combustion is zero.

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Exercise 5 - Hess' Law

Using standard enthalpies of formation

1. Given the following data:

Substance	$H_2O(l)$	$CO_2(g)$	Ethane $C_2H_6(g)$	Ethene $C_2H_4(g)$
ΔH_f/kJmol^{-1}	-286	-393	-84	+52

a) Write equations for the complete combustion of
   i) ethane
   ii) ethene

b) Calculate the enthalpy of combustion in each case using the above data.

2. Given the following data: $\Delta H_f(CH_4)$ = -74.8 kJmol^{-1}, $\Delta H_f(CH_3Cl)$ = -134.5 kJmol^{-1}, $\Delta H_f(HCl)$ = -92.3 kJmol^{-1};
   Calculate ΔH for the reaction $CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$

3. Given the data:

Substance	$H_2O(l)$	$NH_3(g)$
ΔH_f/kJmol^{-1}	-286	-46

   Calculate the enthalpy change of the following reaction:

   $4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(l)$

4. Given the data:

Substance	$B_2H_6(g)$	$B_2O_3(s)$	$C_6H_6(g)$	$CO_2(g)$	$H_2O(g)$
ΔH_f/kJmol^{-1}	+31.4	-1270	+83.9	-393	-242

Calculate the enthalpy of combustion of gaseous diborane and gaseous benzene given that they burn according to the following equations:

$B_2H_6(g) + 3O_2(g) \rightarrow B_2O_3(s) + 3H_2O(g)$, $C_6H_6(g) + 7.5O_2(g) \rightarrow 6CO_2(g) + 3H_2O(g)$

5. The enthalpy of combustion of ethanol is -1380 kJmol^{-1}. Calculate the enthalpy of formation of ethanol, given that the enthalpies of formation of carbon dioxide and water are -393.7 and -285.9 kJmol^{-1} respectively.

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Using standard enthalpies of combustion

6. Calculate the enthalpy of formation of butane (C_4H_{10}) from the following data:
   Enthalpy of combustion of graphite = -393.6 $kJmol^{-1}$

   Enthalpy of combustion of hydrogen = -285.9 $kJmol^{-1}$

   Enthalpy of combustion of butane = -2877.1 $kJmol^{-1}$

7. Given the following data:

Substance	$CH_3CH_2CH_2CH_3$	$CH_3CH_2CH=CH_2$	H_2
$\Delta H_c/kJmol^{-1}$	-2877	-2717	-286

Calculate ΔH for the following reaction: $CH_3CH_2CH=CH_2 + H_2 \rightarrow CH_3CH_2CH_2CH_3$

8. Given the following data:

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H = -890\ kJmol^{-1}$

$CO(g) + 1/2O_2(g) \rightarrow CO_2(g)$ $\Delta H = -284\ kJmol^{-1}$

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -393\ kJmol^{-1}$

$H_2(g) + 1/2O_2(g) \rightarrow H_2O(l)$ $\Delta H = -286\ kJmol^{-1}$

Calculate:

a) The enthalpy of formation of methane
b) The enthalpy of formation of carbon monoxide
c) The enthalpy change when methane is burned in limited oxygen to form carbon monoxide and water.