



ASSESSMENT and
QUALIFICATIONS
ALLIANCE

Mark scheme January 2002

GCE

Chemistry

Unit CHM2

SECTION A

Answer all questions in the spaces provided.

- 1 (a) Define the term
- standard molar enthalpy of formation*
- ,
- ΔH_f^\ominus
- Mark each point independently

Allow
energy or
heat. Ignore
'evolved or
absorbed'

(Enthalpy change) when 1 mol^o of a compound is formed
from its constituent elements (1) in their standard states (1)

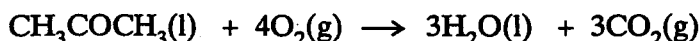
(3 marks)

- (b) State Hess's law.

(The enthalpy change for a reaction is) independent of
the route (1)

(1 mark)

- (c) Propanone,
- CH_3COCH_3
- , burns in oxygen as shown by the equation



Use the data given below to calculate the standard enthalpy of combustion of propanone.

	$\text{CO}_2(\text{g})$	$\text{H}_2\text{O}(\text{l})$	$\text{CH}_3\text{COCH}_3(\text{l})$
$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	-394	-286	-248

Deduct one
mark for
each
error
to zero

$$\Delta H_c = \sum \Delta H_f \text{ products} - \sum \Delta H_f \text{ reactants} \quad (1)$$

$$= [(3 \times -286) + (3 \times -394)] - (-248) \quad (1)$$

$$= -1792 \quad (1) \quad (\text{kJ mol}^{-1})$$

(3 marks)

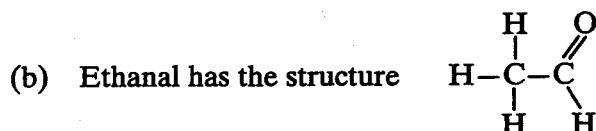
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Turn over ▶

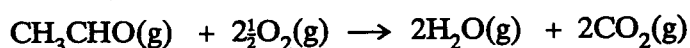
2 (a) State what is meant by the term *mean bond enthalpy*.

Penalise first mark if 'energy' evolved.
 (Energy required) to break a given covalent bond (1)
 averaged over a range of compounds (1)

(2 marks)



Gaseous ethanal burns as shown by the equation



Use the mean bond enthalpy data given below to answer the following questions.

Bond	Mean bond enthalpy/kJ mol ⁻¹
C-H	+413
C-C	+347
C=O	+736
O=O	+498
O-H	+464

(i) Calculate the enthalpy change which occurs when all the bonds in the reactants shown in the above equation are broken.

First mark for 4:1:1 or 2735 (1) (ignore sign)

$$\left. \begin{array}{l} 4 \times \text{C-H} = 4 \times 413 = +1652 \\ 1 \times \text{C-C} = 1 \times 347 = 347 \\ 1 \times \text{C=O} = 1 \times 736 = 736 \\ 2\frac{1}{2} \times \text{O=O} = 2.5 \times 498 = 1245 \end{array} \right\} = 2735 + 1245 = +3980 \text{ (1)}$$

- (ii) Calculate the enthalpy change which occurs when all the bonds in the products shown in the above equation are formed.

$$\begin{array}{l} \text{First mark} \quad 4 \times \text{H-O} = -4 \times 464 = -1856 \\ \text{for 4:4 (i)} \quad 4 \times \text{C-O} = -4 \times 736 = -2944 \\ \qquad \qquad \qquad = -4800 \quad (1) \end{array}$$

- (iii) Hence, calculate the enthalpy change for the complete combustion of ethanal as shown in the equation above.

$$\begin{array}{l} \Delta H_r = \sum \text{Bonds broken} - \sum \text{Bonds made} \\ = +3980 - 4800 = -820 \quad (1) \end{array}$$

Conseq. Mark for incorrect answers in (i) and (ii) as

(5 marks)

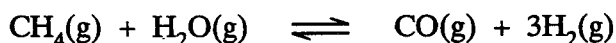
$$(i) \text{ Answer} + (ii) \text{ Answer} =$$

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TURN OVER FOR THE NEXT QUESTION

Turn over ►

- 3 (a) Hydrogen used in the Haber Process is produced in the following dynamic equilibrium reaction.



- (i) In terms of rates and of concentrations, what does the term *dynamic equilibrium* mean?

Rates Rates are equal, forward and backward (1)

Q of 1 mark. Concentrations Concentrations are constant (1)

- (ii) State how an increase in pressure will affect the equilibrium yield of hydrogen. Explain your answer.

Equilibrium yield Decreases (1) If wrong allow max. 1 for a correct moles statement

Explanation More ^{moles} molecules of product (or 2 → 4) (1) Not "volume" answer.
 { Reaction Equilibrium moves to { ^{left} reduce constraint (1)
 Allow one for "Reaction favours fewer molecules"

- (iii) The equilibrium yield of hydrogen is reduced when the reaction is carried out at a lower temperature. What can be deduced about the enthalpy change in this reaction?

Enthalpy of Reaction is { ^{positive} endothermic (1)

- (iv) Explain why the equilibrium yield is unchanged when a catalyst is introduced.

Both forward and backward rates { ^{changed} increase (1)
 by { ^{same proportion} equal amount (1)

Allow one for "Ea of forward and backward reactions reduced by an equal amount (8 marks)

- (b) Ammonia is produced in the Haber Process according to the following equation.



Typical operating conditions are 450 °C and 20 MPa (200 bar).

- (i) Explain why 450 °C is a compromise temperature.

The reaction is exothermic (1)

High temperature gives a low equilibrium yield (1)

Rate of reaction higher at higher temperature (1)

(Do not allow answers based on cost of higher temp. etc.)

An "equilibrium statement" needed →
 eg low temp favours the reaction

(ii) Explain why 20 MPa is a compromise pressure.

Higher pressure gives a higher yield (1)

4 moles of gaseous reactant form 2 moles of

gaseous product (1)

Higher pressure ^{generation of equipment} expensive to produce (1)

(6 marks)

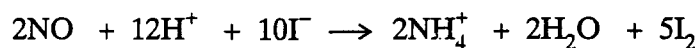
NB Not a safety answer.

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TURN OVER FOR THE NEXT QUESTION

Turn over ►

- 4 (a) The following is an equation for a redox reaction.



- (i) Define *oxidation* in terms of electrons.

Loss (of electrons) (1)

- (ii) Deduce the oxidation state of nitrogen in NO and of nitrogen in NH₄⁺

Oxidation state of nitrogen in NO ... (+2) (1)

Oxidation state of nitrogen in NH₄⁺ ... -3 (1)

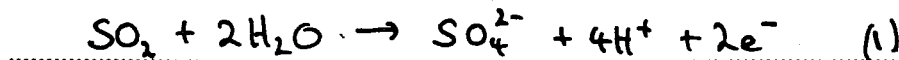
- (iii) Identify the species formed by oxidation in this reaction... I₂ (1)
(4 marks)

- (b) When chlorine gas is bubbled into an aqueous solution of sulphur dioxide, hydrogen ions, sulphate ions and chloride ions are formed.

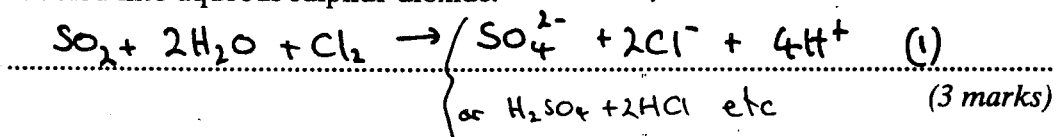
- (i) Write a half-equation for the formation of chloride ions from chlorine.



- (ii) Write a half-equation for the formation of hydrogen ions and sulphate ions from sulphur dioxide and water.



- (iii) Hence, deduce an overall equation for the reaction which occurs when chlorine is bubbled into aqueous sulphur dioxide.



Ignore state symbols in equations

Allow multiples of all equations

- 5 An excess of potassium iodide was added to an aqueous solution of chlorine. In a titration the liberated iodine required 28.2 cm^3 of a $0.360 \text{ mol dm}^{-3}$ solution of sodium thiosulphate for complete reaction.

- (a) Calculate the number of moles of sodium thiosulphate used in the titration.

$$n_{\text{dca}} = mv/1000 \quad (1)$$

$$= 0.36 \times 28.2 / 1000 = 0.0102 \quad (1)$$

NB An answer of 0.01 scores one (2 marks)

- (b) Write an equation for the reaction between thiosulphate ions and iodine.



Allow multiples

(1 mark)

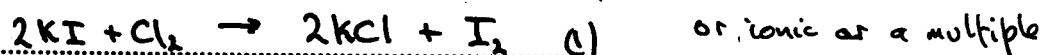
- (c) Calculate the number of moles of iodine which reacted with the sodium thiosulphate used in the titration.

Answer from (a) $\div 2$ (1)

$$\left(\text{Mole ratio} = 1:2 \right) \Big|_h = 0.005 \quad (1) \text{ moles } \text{I}_2$$

(1 mark)

- (d) Write an equation for the reaction between potassium iodide and chlorine.



Ignore state symbols and incorrect use of caps.

(1 mark)

- (e) Calculate the mass of chlorine in the original solution which reacted with potassium iodide.

In A_r of chlorine

used score max 1

If M_r chlorine = 70, pending note

$$\text{Mass } \text{Cl}_2 = \left(\begin{array}{l} \text{Moles from (c)} \\ 0.005 \end{array} \right) \times (35.5 \times 2) \quad (1)$$

$$= 0.360 \text{ g} \quad (1) \quad \text{Allow } 0.36 \pm 0.005$$

(3 marks)

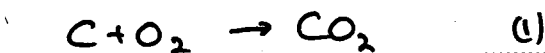
- (f) Name an indicator which could be used when a solution of iodine is titrated with sodium thiosulphate solution from a burette. State the colour change at the end-point.

Indicator Starch (1)

Colour change (Blue to colourless) (1)
 { Black (Not straw) coloured
 { Blue/black

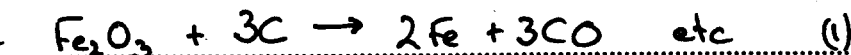
If an indicator given it must be correct for second mark to (2 marks) be awarded.

- 6 (a) (i) Write an equation for the reaction which is mainly responsible for the high temperature in the Blast Furnace.

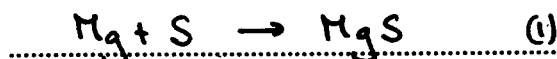


- (ii) Write an equation for a reaction in which iron is formed from its oxide in the Blast Furnace.

Allow oxides
FeO; Fe₂O₃; Fe₃O₄



- (iii) Iron from the Blast Furnace can contain sulphur. Write an equation to show how this impurity is removed.



- (iv) Iron from the Blast Furnace contains carbon. State how most of this carbon is removed. Give one reason why this removal is necessary.

Removal of carbon Oxygen (1)

blown through / ^{liquid} molten iron (1)
or bubbled through

Reason Carbon makes iron brittle (1)

(6 marks)

- (b) (i) State why carbon cannot be used to reduce titanium(IV) oxide directly to titanium.

Allow C bonds / reacts

(Titanium) carbide is formed (1) with Ti

- (ii) Carbon is used in one of the steps in the batch process for titanium extraction. Write an equation for the reaction which occurs in this step and state a condition under which this reaction is carried out.

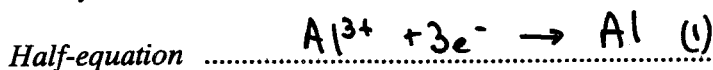
Mark
Independently



Condition High temperature (1) or (700-1100 °C) ^{Balanced equation}
Not "heat" (4 marks)

- (c) Aluminium is not usually extracted by heating aluminium oxide with carbon, but carbon does have a use in the extraction of aluminium from aluminium oxide. State how carbon is used during the extraction process and write a half-equation showing how aluminium is produced.

Use of carbon As ^{Cathode} / ^{Anode} electrodes (1)



(2 marks)

- (d) State **three** factors which determine the choice of reduction method used for the extraction of metals from their ores.

Factor 1 Cost of reductant (1)

Factor 2 Cost of energy (1)

Factor 3 Purity of metal (1) Max 3
or Reactivity of metal (1) (3 marks)

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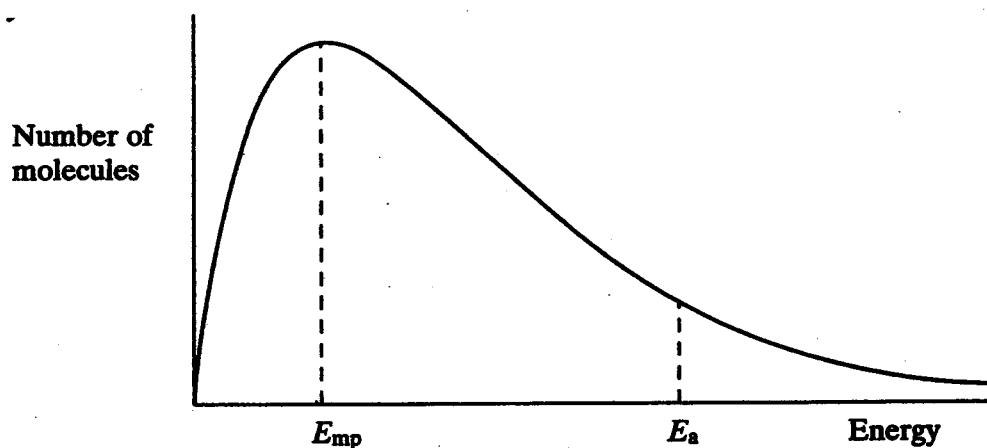
TURN OVER FOR THE NEXT QUESTION

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SECTION B

Answer **both** questions in the space provided on pages 13 to 16 of this booklet.

- 7 (a) State what is meant by the term *activation energy* of a reaction. (1 mark)
- (b) State in general terms how a catalyst increases the rate of a chemical reaction. (2 marks)
- (c) The curve below shows the Maxwell–Boltzmann distribution of molecular energies, at a constant temperature, in a gas at the start of a reaction. On this diagram the most probable molecular energy at this temperature is indicated by the symbol E_{mp} and the activation energy by the symbol E_a .



Consider the following changes.

- (i) The number of molecules is increased at constant temperature.
- (ii) The temperature is decreased without changing the number of molecules.
- (iii) A catalyst is introduced without changing the temperature or the number of molecules.

For **each** of these changes state how, if at all, the following would vary:

- the value of the most probable energy, E_{mp}
 - the number of molecules with the most probable energy, E_{mp}
 - the area under the molecular energy distribution curve
 - the number of molecules with energy greater than the activation energy, E_a
- (12 marks)

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Section B

Q7	(a)	Activation energy;- The minimum energy needed for a reaction to occur	(1)	1
	(b)	Catalyst effect:- Alternative route or more molecules have E_a Lower activation energy	(1) (1)	2
	(c)	Increase in moles of gas:- Position of E_{mp} unchanged More molecules with E_{mp}	(1) (1)	
		Area under curve increase Molecules with $E \geq E_a$ increased	(1) (1)	4
		Temperature decreased:- Position of E_{mp} moves to left More molecules with E_{mp}	(1) (1)	
		Area under curve unchanged Molecules with $E \geq E_a$ decreased	(1) (1)	4
		Catalyst introduced:- Position of E_{mp} unchanged Molecules with E_{mp} unchanged	(1) (1)	
		Area under curve unchanged Molecules with $E \geq E_a$ increased	(1) (1)	4
			Total 15	

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Question 8

Do not allow elements, molecules or atoms in part (a)

Q8 (a)(i) Halides:- Fluoride } (1)
 Chloride }

Equation:- $H^+ + F^- \rightarrow HF$ (or molecular) for a correct halide (1)

(ii) Halides:- Bromide and Iodide (1)

Equation:- $H_2SO_4 + 2H^+ + 2e^- \rightarrow SO_2 + 2H_2O$ (1)

Must be for correct halide { $2Br^- \rightarrow Br_2 + 2e^-$ (1)

{ $H_2SO_4 + 2H^+ + 2Br^- \rightarrow Br_2 + SO_2 + 2H_2O$ (1)
 or $2HBr$

(iii) Products Sulphur or S_8 (not S_6) } Ignore halide (1)
 Hydrogen sulphide } if given (1)

Equation:- $H_2SO_4 + 6H^+ + 6e^- \rightarrow S + 4H_2O$ (1)

or $H_2SO_4 + 8H^+ + 8e^- \rightarrow H_2S + 4H_2O$ (1) 9
 even if incorrect

(b) Addition of silver nitrate

Chloride gives white precipitate | solid (1)

Bromide gives cream precipitate | solid (1)

Iodide give yellow precipitate | solid (1)

Addition of ammonia

Do not allow halogen or sodium halide { Chloride precipitate soluble in dilute (1)
 Bromide precipitate soluble in concentrated (1)
 Iodide precipitate insoluble (1)

6

Total 15

of h
 realise wrong
 symbols for
 fluoride or
 bromide once

Ignore
 State
 Symbols
 in
 equations