ASSESSMENT and QUALIFICATIONS ALLIANCE

Mark scheme January 2002

GCE

Chemistry

Unit CHM2

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SECTION A

Answer **all** questions in the spaces provided.

1 (a) Define the term *standard molar enthalpy of formation*, ΔH_f°

Mark each point independently

Allow energy or heat. Ignore 'evolved or absorbed'

(Enthalpy change) when 1mol 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

$$CH_3COCH_3(l) + 4O_2(g) \longrightarrow 3H_2O(l) + 3CO_2(g)$$

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

	$CO_2(g)$	$H_2O(l)$	$CH_3COCH_3(l)$
ΔH_f°/kJ mol^{-1}	−394	−286	−248

Deduct one mark for each error to zero

$\Delta H_R = \Sigma \Delta H_f$ products $- \Sigma \Delta H_f$ reactants (1)

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

$= -1792$ (1) (kJmol^{-1})

(3 marks)

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

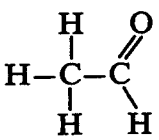
Penalise first-mark if 'energy' / 'enthalpy' evolved.

(Energy required) to break a given covalent bond (1)

averaged over a range of compounds (1)

(2 marks)

(b) Ethanal has the structure



Gaseous ethanal burns as shown by the equation

$$CH_3CHO(g) + 2\tfrac{1}{2}O_2(g) \longrightarrow 2H_2O(g) + 2CO_2(g)$$

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)

4 × C–H = 4 × 413 = + 1652

1 × C–C = 1 × 347 = 347

1 × C=O = 1 × 736 = 736

2½ × O=O = 2·5 × 498 = 1245

= 2735 + 1245

= + 3980 (1)

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

First mark for 4:4 (1) $4 \times H\text{-}O = -4 \times 464 = -1856$

$4 \times C\text{-}O = -4 \times 736 = -2944$

$= -4800$ (1)

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

$\Delta H_R = \Sigma$ Bonds broken $- \Sigma$ Bonds made

$= +3980 - 4800 = -820$ (1)

(5 marks)

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

(i) Answer + (ii) Answer =

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TURN OVER FOR THE NEXT QUESTION

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

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

(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.

If wrong allow max. 1 for a correct moles statement

Equilibrium yield Decreases (1)

Explanation More {moles} {molecules of product (or 2→4)} (1)

{Reaction} {Equilibrium moves to {left} {reduce constraint (1)

Allow one for "Reaction favours fewer molecules"

Not "volume" answers.

(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.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H_f^{\ominus} = -92\,kJ\,mol^{-1}$$

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)

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

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.)

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

Higher pressure gives a higher yield (1)

4moles of gaseous reactant form 2moles of gaseous product (1)

Higher pressure/expensive to produce (1)

(6 marks)

NB Not a safety answer.

'in equilibrium statement' required

cost factor

generation or equipment

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TURN OVER FOR THE NEXT QUESTION

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

$$2NO + 12H^+ + 10I^- \longrightarrow 2NH_4^+ + 2H_2O + 5I_2$$

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

loss (of electrons) (1)

(ii) Deduce the oxidation state of nitrogen in NO and of nitrogen in NH_4^+

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

Oxidation state of nitrogen in NH_4^+ −3 (1)

(iii) Identify the species formed by oxidation in this reaction I_2 (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.

Ignore state symbols in equations

$Cl_2 + 2e^{(-)} \rightarrow 2Cl^-$ (1)

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

Allow multiples of all equations

$SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$ (1)

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

$SO_2 + 2H_2O + Cl_2 \rightarrow SO_4^{2-} + 2Cl^- + 4H^+$ (1)

or $H_2SO_4 + 2HCl$ etc

(3 marks)

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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 mol dm^{-3} solution of sodium thiosulphate for complete reaction.

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

Moles = mv/1000 (1)

= 0·36×28·2/1000 = 0·0102 (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

$I_2 + 2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2I^-$ (1)

(1 mark)

(c) Calculate the number of moles of iodine which reacted with the sodium thiosulphate used in the titration. Answer from (a) ÷ 2 (1)

(Mole ratio = 1:2) = 0·0051 moles I_2

(1 mark)

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

Ignore state symbols and incorrect use of caps.

$2KI + Cl_2 \rightarrow 2KCl + I_2$ (1) or ionic or a multiple

(1 mark)

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

If A_r of chlorine used score max 1

If Mr chlorine = 70, penalise no AE

If moles not from (c) then max one if Mr chlorine given as 71

Mass Cl_2 = (Moles from (c) 0·0051 (1) × (35·5×2)) (1)

= 0·360 g (1) Allow 0·361 ± 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) (Not straw coloured)

Black

Blue/black

If an indicator given it must be correct for second mark to be awarded.

(2 marks)

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

$C + O_2 \rightarrow CO_2$ (1)

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

Allow oxides FeO; Fe_2O_3; Fe_3O_4

$Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$ etc (1)

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

$Mg + S \rightarrow MgS$ (1)

(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

Equation $TiO_2 + (2C) + 2Cl_2 \rightarrow TiCl_4 + (2CO)$ (1) (1) All species correct; Balanced equation

(CO₂)

Condition High temperature (1) or (700 – 1100 °C)

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)

Half-equation $Al^{3+} + 3e^- \rightarrow Al$ (1)

(2 marks)

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(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

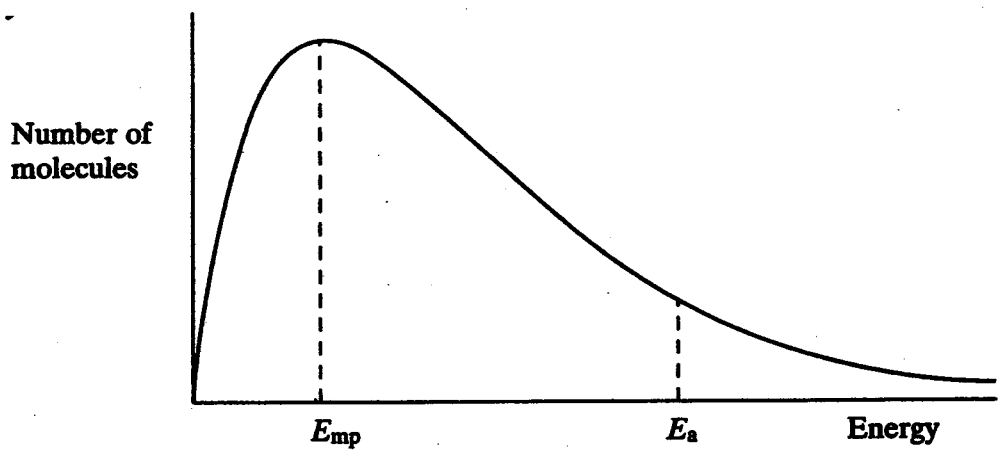
SECTION B

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)

8 (a) Samples of solid sodium fluoride, sodium chloride, sodium bromide and sodium iodide are each warmed separately with concentrated sulphuric acid. All four compounds react with concentrated sulphuric acid but only two can reduce it.

(i) Identify the **two** halides which do **not** reduce concentrated sulphuric acid. Write an equation for the reaction which does occur with **one** of these two halides.

(ii) Identify the **two** halides which reduce concentrated sulphuric acid to sulphur dioxide. Using half-equations for the oxidation and reduction processes, deduce an overall equation for the formation of sulphur dioxide when concentrated sulphuric acid reacts with **one** of these halides.

(iii) In addition to sulphur dioxide, two further reduction products are formed when one of these two halides reacts with concentrated sulphuric acid. Identify the two reduction products and write a half-equation to show the formation of **one** of them from concentrated sulphuric acid. *(9 marks)*

(b) How would you distinguish between separate solutions of sodium chloride, sodium bromide and sodium iodide using solutions of silver nitrate and ammonia? *(6 marks)*

END OF QUESTIONS

Jan 2002 Unit 2 Section B

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

Jan 2002 Unit 2 Question 8

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

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

Ignore State Symbols in equations

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

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

Equation:- $H_2SO_4 + 2H^+ + 2e^- \rightarrow SO_2 + 2H_2O$ (or $2H^+ + SO_4^{2-}$) (1)

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

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

Q of L mainly wrong symbols for fluoride or bromide once

(iii) Products: Sulphur or S_8 (not S_8) (1)
Hydrogen sulphide (1)

Equation:- $H_2SO_4 + 6H^+ + 6e^- \rightarrow S + 4H_2O$ (or $2H^+ + SO_4^{2-}$)

or $H_2SO_4 + 8H^+ + 8e^- \rightarrow H_2S + 4H_2O$ (or $2H^+ + SO_4^{2-}$) (1) 9

Ignore halide if given 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