AQA

ASSESSMENT and QUALIFICATIONS ALLIANCE

Mark scheme June 2002

GCE

Chemistry

Unit CHM2

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SECTION A

Answer all questions in the spaces provided.

1 (a) What is the meaning of the term *enthalpy change*?

Heat energy change (NOT energy on its own) (1)

Measured at constant pressure (1)

Mark separately

Ignore constant temperature statements

(2 marks)

(b) (i) Define the term *standard enthalpy of formation* of a compound.

(Enthalpy change when) 1 mol of a (compound / substance / product) (1) is formed

Mark separately

from its constituent elements (1) in their standard states (1)

under standard conditions

(ii) Write an equation, including state symbols, for the formation from its elements of solid sodium sulphate, Na_2SO_4.

Balanced (1)

State symbols (1) – but only if all species correct

$2Na(s) + S(s) + 2O_2(g) \rightarrow Na_2SO_4(s)$

Allow $\frac{1}{8}S_8(s)$

(3 marks)

(c) State Hess's Law.

Enthalpy change is independent of reaction route (1)

(Penalise incorrect additional statements)

(1 mark)

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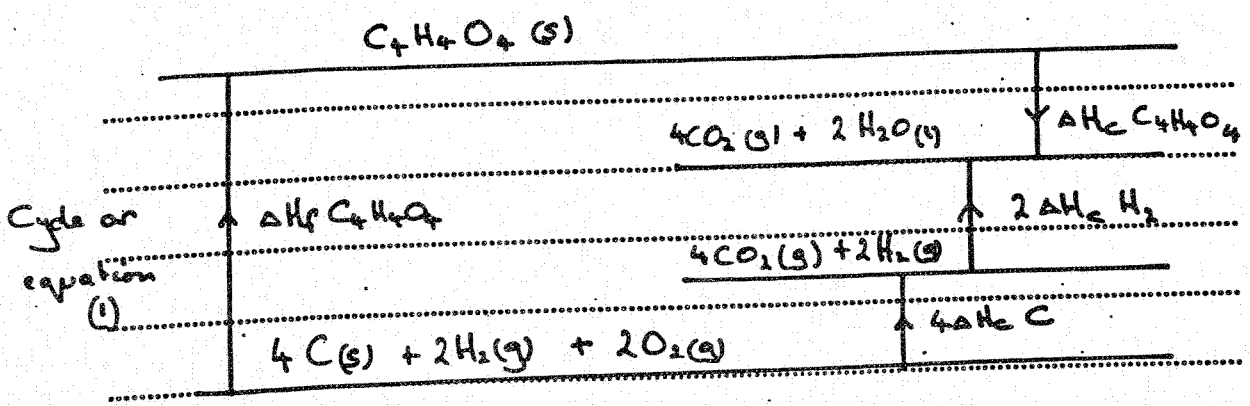
(d) Some standard enthalpy changes are difficult to measure directly but can be determined from standard enthalpies of combustion.
Maleic acid, $C_4H_4O_4$, reacts with oxygen to form carbon dioxide and water as shown by the following equation.

$$C_4H_4O_4(s) + 3O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l)$$

Use the standard enthalpy of combustion data given below to calculate a value for the standard enthalpy change for the following reaction.

$$4C(s) + 2H_2(g) + 2O_2(g) \rightarrow C_4H_4O_4(s)$$

	$C_4H_4O_4(s)$	$C(s)$	$H_2(g)$
$\Delta H_c^{\ominus}$ /kJ mol^{-1}	−1356	−393.5	−285.8



$-1356 + (2 \times 285.8) + (4 \times 393.5) + \Delta H_f\, C_4H_4O_4 = 0$ (1)

$\Delta H_f = -789.6$ kJ mol^{-1} (1)

(3 marks)

If answer incorrect:-

Score +789.6 two marks

Score (×1); (×2) and (×4) for species - one mark

If an incorrect negative answer given check for AE for loss of one mark

11

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2 A 50.0 cm^3 sample of a 0.200 mol dm^{-3} solution of silver nitrate was placed in a polystyrene beaker. An excess of powdered zinc was added to this solution and the mixture stirred. Zinc nitrate, $Zn(NO_3)_2$, and silver were formed and a rise in temperature of 3.20 °C was recorded.

(a) Write an equation for the reaction between silver nitrate and zinc.

$2AgNO_3 + Zn \longrightarrow Zn(NO_3)_2 + 2Ag$ (1)

accept an ionic equation ie $2Ag^+ + Zn \rightarrow 2Ag + Zn^{2+}$ (1 mark)

(b) Calculate the number of moles of silver nitrate used in the experiment.

Moles = mv/1000 (1) = $0.20 \times 50/1000$

$= 1.00 \times 10^{-2}$ (1)

(2 marks)

(c) Calculate the heat energy evolved by the reaction in this experiment assuming that all the energy evolved is used to heat only the 50.0 g of water in the mixture.
(Specific heat capacity of water is 4.18 J g^{-1} K^{-1})

Heat energy change = $mc\Delta T$ (1) = $50 \times 4.18 \times 3.2$ J

= 669 J (ignore signs) (1)

(2 marks)

Allow 668. 670 0.67kJ Penalise wrong units if given.

(d) Calculate the heat energy change for the reaction per mole of zinc reacted.

$2 \times 669 / 1 \times 10^{-2}$ Mark one = 2 × answer to (c)

$= 134$ kJ mol^{-1} Mark two - Dividing by answer to (b) penalise incorrect units. (2 marks)

Allow 133 - 134

Also credit to Mark correct equation in (a) for full marks IF No working shown and answer incorrect - zero. mark in (c)

(e) Explain why the experimental value for the heat energy evolved in this experiment is less than the correct value.

Incomplete reaction or

Heat loss (1)

(1 mark)

8

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3 (a) Concentrated sulphuric acid can be reduced by some solid sodium halides to H_2S

(i) Give the oxidation state of sulphur in H_2S

-2 or 2- (1)

(ii) Give **one** solid sodium halide which will reduce concentrated sulphuric acid, forming H_2S NOT atoms or molecules

NaI or NaAt or I^- or Iodide or At^- or astatide (1)

(iii) State **one** way in which the presence of H_2S could be recognised.

Smell of bad eggs Allow $PbAc_2$ goes black and $K_2Cr_2O_7/H^+$ goes cloudy green (1)

(iv) Write a half-equation for the formation of H_2S from sulphuric acid.

$8e^- + 8H^+ + H_2SO_4 \rightarrow H_2S + 4H_2O$ (1)

or $10H^+ + SO_4^{2-}$

(4 marks)

(b) A different solid sodium halide reacts with concentrated sulphuric acid without reduction forming a halogen-containing product **X**.

(i) Suggest an identity for **X**. CE=0 if redox answer given If wrong halide given allow max one in b(iii)

HF or HCl If NaF or NaCl, or F^- or Cl^- given (1)

lose mark in (i) but mark on

(ii) Identify the solid sodium halide which produces **X**. also if X is a "reasonable" mark on eg HF_2 or H_2F

NaF or NaCl or F^- or Cl^- or names (1)

Allow if X is a hydrogen halide in (i)

(iii) State the role of sulphuric acid in the formation of **X**.

A proton donor or an acid (1)

(iv) Write an equation for the reaction with concentrated sulphuric acid in which **X** is formed.

$H^+ + F^- \rightarrow HF$ or (1)

(4 marks)

$H_2SO_4 + NaF \rightarrow NaHSO_4 + HF$ or

$H_2SO_4 + 2NaF \rightarrow Na_2SO_4 + 2HF$

(or for chloride)

8

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4 (a) When using silver nitrate to test for the presence of chloride ions in an aqueous solution, it is important to add another reagent to prevent interference by any carbonate ions which would form a white precipitate of Ag_2CO_3.

(i) Identify this other reagent.

HNO_3 or CH_3COOH CE in (a) if incorrect acid given (1)

(ii) Write an equation to show how this other reagent reacts with sodium carbonate.

$2HNO_3 + Na_2CO_3 \rightarrow 2NaNO_3 + CO_2 + H_2O$ (1)

(2 marks)

OR $2H^+ + CO_3^{2-} \rightarrow H_2O + CO_2$ NOT H_2CO_3

(b) The presence of some halide ions in solution can be detected using aqueous silver nitrate and aqueous ammonia.

(i) Identify a halide ion which, on addition of aqueous silver nitrate, forms a precipitate that is insoluble in concentrated aqueous ammonia.

I^- or At^- Not elements, atoms or molecules (1)

(ii) Identify a halide ion which cannot be detected using these reagents.

F^- Not element, atoms or molecules (1)

(2 marks)

(c) A mixture of two precipitates, **P** and **Q**, was formed by adding aqueous silver nitrate to a solution containing two different halide ions. Precipitate **P** dissolved on addition of an excess of dilute aqueous ammonia. The remaining precipitate, **Q**, was filtered off.

(i) Identify the halide ion in **P**.

Cl^- Allow AgCl Not element, atoms or molecules (1)

(ii) Precipitate **Q** was soluble in concentrated aqueous ammonia. Identify the halide ion in **Q**.

Br^- Allow AgBr Not element, atoms or molecules (1)

(2 marks)

6

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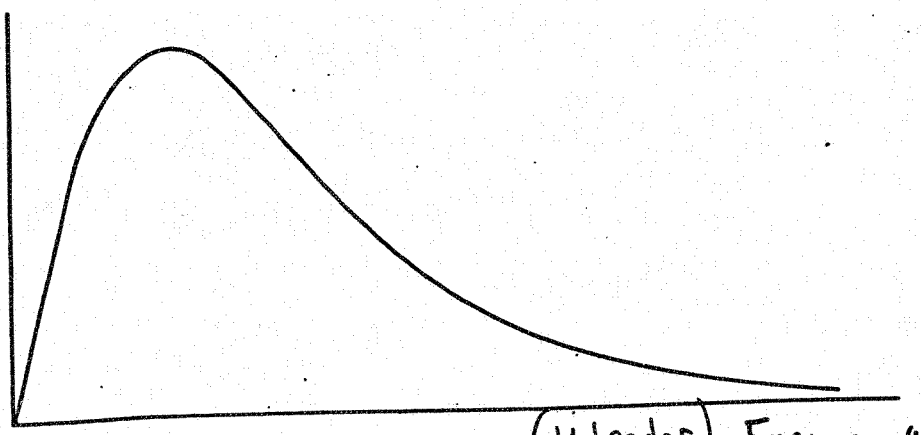
5 (a) Below is a Maxwell-Boltzmann curve showing the distribution of molecular energies for a sample of gas at a temperature *T*.



Number of molecules or particles (1)

NOT moles or mols or atoms

Not fraction or proportion

(Molecular) Energy (1)

Not velocity

(i) Label the axes on the diagram above.

(ii) What does the area under the curve represent?

The total number of {particles / molecules} in the sample (1)

or the number of molecules present.

(iii) State why this curve starts at the origin.

No molecules have no energy OR All molecules have some energy (1)

(4 marks)

Do not allow "If there are no molecules there is no energy"

(b) (i) State what is meant by the term *activation energy*.

The minimum energy required (1)

for a reaction to occur or to start reaction (1)

or for a successful collision

(ii) The rate of a chemical reaction may be increased by an increase in reactant concentration, by an increase in temperature and by the addition of a catalyst.

State which, if any, of these changes involves a different activation energy. Explain your answer.

If change incorrect CE = 0

Change(s) Catalyst (1)

Explanation Alternative route (1)

with a lower activation energy (1)

(5 marks)

Allow answers anywhere in (b)(ii)

OR a lower activation energy (1)

so {more molecules can react (1) / more molecules have this energy.

9

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6 (a) In terms of electron transfer, what does the reducing agent do in a redox reaction?

A reducing agent gives electrons (1)

Not electron pairs

(1 mark)

(b) What is the oxidation state of an atom in an uncombined element?

Zero (1)

(1 mark)

(c) Deduce the oxidation state of nitrogen in each of the following compounds.

(i) NCl_3 (+)3 Allow answers in roman (1)

(ii) Mg_3N_2 -3 (1)

(iii) NH_2OH -1 (1)

(3 marks)

(d) Lead(IV) oxide, PbO_2, reacts with concentrated hydrochloric acid to produce chlorine, lead(II) ions, Pb^{2+}, and water.

(i) Write a half-equation for the formation of Pb^{2+} and water from PbO_2 in the presence of H^+ ions.

$PbO_2 + 4H^+ + 2e^{(-)} \rightarrow Pb^{2+} + 2H_2O$ (1)

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

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

(iii) Hence deduce an equation for the reaction which occurs when concentrated hydrochloric acid is added to lead(IV) oxide, PbO_2

$PbO_2 + 4H^+ + 2Cl^- \rightarrow Pb^{2+} + Cl_2 + 2H_2O$ (1)

Or molecular

(3 marks)

8

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7 (a) State why chlorine is added to drinking water.

To kill bacteria (or micro-organisms or microbes or germs) or to sterilize water (or disinfect water or as a germicide) (1)

NOT – to purify water
NOT – to kill organisms

(1 mark)

(b) Write an equation for the reaction which occurs when chlorine is bubbled into water. Identify the substance which causes the resulting solution to be pale green.

Allow ionic products

Equation $Cl_2 + H_2O \rightleftharpoons HClO + HCl$ (1)

Identity of substance (Free) chlorine or Cl_2 (1)

(2 marks)

(c) Write an equation for the reaction which occurs when chlorine is bubbled into an excess of cold aqueous sodium hydroxide. Both products MUST be salts

$2NaOH + Cl_2 \longrightarrow NaCl + NaClO + H_2O$ (1)

OR $2OH^- + Cl_2 \rightarrow Cl^- + ClO^- + H_2O$ (or OCl^-)

(1 mark)

(d) The amount of chlorine which has been added to water can be determined by treating a measured volume of the solution with an excess of potassium iodide and titrating the liberated iodine against a standard solution of sodium thiosulphate.

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

$Cl_2 + 2KI \longrightarrow 2KCl + I_2$ or ionic equation (1)

(ii) Write an equation for the reaction between iodine and sodium thiosulphate.

$I_2 + 2Na_2S_2O_3 \longrightarrow 2NaI + Na_2S_4O_6$ (1)

or ionic equation

(iii) An excess of potassium iodide was added to 1.00 dm^3 of water from a swimming pool. The liberated iodine reacted with 7.20 cm^3 of a 0.0150 mol dm^{-3} solution of sodium thiosulphate. Calculate the mass of chlorine which had been added to each 1.00 dm^3 of swimming pool water.

Penalise missing 1000 as AE – 1

(1)

Moles thio = $mv/1000 = 0.0150 \times 7.20/1000 = 1.08 \times 10^{-4}$

Moles I_2 : moles Cl_2 = $1.08 \times 10^{-4}/2$ (1) = 5.4×10^{-5} (1)

Mass Cl_2 = moles $Cl_2 \times M_r = 5.4 \times 10^{-5} \times 71$ (1)

$= 3.834 \times 10^{-3}$ g dm^{-3} (1)

allow $3.80 - 3.85 \times 10^{-3}$ g dm^{-3}

(6 marks)

10

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SECTION B

Answer **both** the questions below in the space provided on pages 10 to 16 of this booklet.

8 (a) In a blast furnace, iron can be extracted from an oxide ore which also contains silicon dioxide as an impurity. Identify the additional raw materials needed in the extraction process, state why they are needed and write equations for the reactions occurring. *(10 marks)*

(b) Iron produced in a blast furnace is impure. The iron contains carbon, sulphur and phosphorus. State how each of these impurities is removed. Explain why sulphur is removed before carbon and phosphorus. *(6 marks)*

(c) Although there are large reserves of iron and aluminium ores in the world, both metals are recycled.

(i) State **one** social benefit of recycling iron and state why it is particularly easy to separate iron from other scrap metal.

(ii) Give **one** main reason why it is much cheaper to recycle aluminium than it is to extract the metal from its ore. Give **one** major factor in the cost of recycling aluminium cans. *(4 marks)*

9 Hydrogen is produced by the reaction between steam and methane when the following dynamic equilibrium is established.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \quad \Delta H = +206\,kJ\,mol^{-1}$$

(a) Use Le Chatelier's principle to predict the separate effects of an increase in temperature and of an increase in pressure on the yield of hydrogen obtained in the above reaction. In each case, explain your answer. *(6 marks)*

(b) State how, and explain why, the use of a catalyst might or might not change the equilibrium yield of hydrogen, and also the amount of hydrogen produced, in a given time. *(4 marks)*

END OF QUESTIONS

Question 8

(a) *Essential steps:-*

Four equations	*4 marks*
Three stated raw materials	*3 marks*
Three statements of use	*3 marks*

Raw materials- These must be stated by name or formula
Formula MUST be correct if name not given
Ignore incorrect formula if name correct
Apply list principle if more than three materials given **but**
Ignore any oxide of iron even if wrong
Do NOT allow reagents which are only given in equations

Carbon or coke but NOT coal (1)
Limestone but NOT lime (1)
Air/oxygen but NOT "O" on its own (1)

Role:-

Oxygen (reacts with carbon) to produce {high temperature heat or energy / or exothermic} (1)
but NOT oxygen is an oxidising agent (1)
$C + O_2 \rightarrow CO_2$
NOT $C + CO_2 \rightarrow 2CO$ NOT $2C + O_2 \rightarrow 2CO$

Carbon {or CO} is a reducing agent (or makes CO) (1)
$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$ etc. (1)
Allow equation with FeO; Fe_2O_3 or Fe_3O_4 **OR**
$C + CO_2 \rightarrow 2CO$

Limestone forms {calcium silicate slag} or reacts with {sand SiO_2} or with impurities (1)
$CaCO_3 \rightarrow CaO + CO_2$ (1)
$CaO + SiO_2 \rightarrow CaSiO_3$ (1)
OR $CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$ scores (2) or zero if wrong **10**
Ignore incorrect equations in THIS section

(b) Removal:-

Sulphur; {or Calcium Magnesium (powder) added or in an equation (even if incorrect)} (1)
Carbon; Oxygen but NOT air blown into {or over} molten iron Allow if air penalised above (1)
Phosphorus; CaO or lime added ~~but NOT~~ or limestone (1)
Ignore incorrect oxides formed by P with Oxygen

Sulphur:-

Removed before C as oxygen would form SO_2 (1)
SO_2 is toxic or causes acid rain or a stated effect (1)
OR S cannot be removed by oxygen (1)
as iron is oxidised in preference (1)
~~so S not removed~~ (1) **6**

(c)(i) Iron:-

Less ore extracted, **OR** less holes in ground **OR** less unsightly landfill, **OR** less greenhouse gas formed
OR less acidic/toxic gas evolved **OR** less energy needed (1)
Only allow "by-product answers" if qualified by a "problem"

Iron is magnetic (1)

(c)(ii) Aluminium-

Extraction needs a large {cost amount of electricity or electrolysis (1)
Collection of cans **OR** cost of melting, **OR** cost of sorting,
OR cost of transport (1) **4**
NOT cost of removing "other substances: from cans

Question 9

(a) **Increase in temperature**

Yield is increased (Allow if for $H_2(g)$ or products) (1)

Reaction endothermic (1)

Equilibrium moves to the right **OR** or forward

Equilibrium moves to oppose change or to absorb heat (1)

If "Yield statement" incorrect allow max one if reaction stated to be endothermic

Increase in pressure:-

Yield is decreased (Allow if for $H_2(g)$ or products) (1)

Increase in moles of gas or 2 moles increased to 4 moles or more moles on right (1)

Equilibrium moves to the left **OR** or backwards

Equilibrium moves to oppose change or to reduce pressure (1) **6**

If "yield statement" incorrect allow max one if number moles change correct

(b) **Equilibrium yield:-**

Unaffected or equilibrium unchanged (1)

Rate or speed increased (1)

Forward and backward reactions equally or by same amount (1)

Amount of hydrogen produced:-

More hydrogen produced (1) **4**