ASSESSMENT and QUALIFICATIONS ALLIANCE

Mark scheme June 2003

GCE

Chemistry

Unit CHM3/W

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SECTION A

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

1 (a) Butane, C_4H_{10}, is a hydrocarbon which is used as a fuel.

(i) Explain what is meant by the term *hydrocarbon*.

A molecule / A compound / It consists / It is composed / It is made up of hydrogen and carbon only QoL (1)

(ii) Explain what is meant by the term *fuel*. accept heat ≡ energy

releases (heat) energy (when burned) (1)

OR provides (a useable form of) energy OR is a source of energy NOT burns exothermically

NOT: is energy / is heat

(iii) Write an equation for the complete combustion of butane.

$C_4H_{10} + 6\frac{1}{2}O_2 \longrightarrow 4CO_2 + 5H_2O$ (1)

OR $2C_4H_{10} + 13O_2 \longrightarrow 8CO_2 + 10H_2O$ ignore state symbols

If not C_4H_{10} = CE

(iv) Write an equation for the incomplete combustion of butane to produce carbon monoxide and water.

$C_4H_{10} + 4\frac{1}{2}O_2 \longrightarrow 4CO + 5H_2O$ (1)

OR $2C_4H_{10} + 9O_2 \longrightarrow 8CO + 10H_2O$ ignore state symbols

(v) Under what conditions would you expect incomplete combustion to occur?

limited or reduced supply of [air / oxygen]

OR low temperature OR poor mixing

OR insufficient oxygen/air OR shortage of O_2 (1)

NOT: no oxygen / lack of oxygen / not in excess

(5 marks)

(b) Three different carbocations are formed by breaking C – C bonds in separate molecules of butane during catalytic cracking. One of these structures is shown below. Give the structures of the other two carbocations.

Structure 1	*Structure 2*	*Structure 3*
$CH_3CH_2\overset{+}{C}H_2$	NOT $C_2H_5^+$ $CH_3\overset{+}{C}H_2$ (1)	$\overset{+}{C}H_3$ (1)

either order

(2 marks)

- allow credit for positive charge around C atom
- no alternative carbocations allowed

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(c) Ethane can be cracked in the presence of a catalyst to produce ethene and hydrogen.

(i) Write an equation for this reaction.

C_2H_6 / CH_3CH_3 $\longrightarrow$ C_2H_4 / CH_2CH_2 + H_2 (1)

$CH_2=CH_2$ / $H_2C=CH_2$ NOT $CH_2 \cdot CH_2$

(ii) Give a suitable catalyst for this reaction.

Al_2O_3 OR zeolite OR aluminosilicate (1)

NOT bauxite

ignore SiO_2

(iii) State **one** reason why cracking is important.

needed / more useful [fuels / products] OR implied

OR more valuable products

(3 marks)

NOT aluminium silicate
NOT porous pot NOT SiO_2 alone

OR qualified demand exceeds supply

OR to produce motor fuels OR petrol OR cycloalkanes OR aromatic hydrocarbons OR branched alkanes OR smaller molecules OR alkenes

10

TURN OVER FOR THE NEXT QUESTION

2 When chlorine reacts with trichloromethane, tetrachloromethane, CCl_4, is formed.

(a) (i) Write the overall equation for this reaction.

$CHCl_3 + Cl_2 \longrightarrow CCl_4 + HCl$ ①

(ii) State **one** essential condition for this reaction.

max T = 1000°C

Condition could be on first equation arrow

uv light OR high T OR T ≥ 500°C ①

Sunlight

NOT [heat / light] ignore pressure

(2 marks)

(b) The mechanism for the chlorination of trichloromethane is free-radical substitution, which proceeds by a series of steps. Write equations for the steps named below in this chlorination.

penalise absence of dot once only

Initiation step

$Cl_2 \longrightarrow 2Cl\cdot$ ①

First propagation step

$CHCl_3 + Cl\cdot \longrightarrow \dot{C}Cl_3 + HCl$ ①

Second propagation step

$\dot{C}Cl_3 + Cl_2 \longrightarrow CCl_4 + Cl\cdot$ ①

A termination step

NOT $2Cl\cdot \rightarrow Cl_2$ $\dot{C}Cl_3 + Cl\cdot \longrightarrow CCl_4$ ①

OR $2\,\dot{C}Cl_3 \longrightarrow C_2Cl_6$

(4 marks)

ignore additional termination steps

(c) (i) A chloroalkane, **W**, was shown to contain 37.2% carbon and 55.0% chlorine by mass. The remainder of the compound was hydrogen. Calculate the empirical formula of compound **W**.

M1 % mass H = 7.8(0)% ① (can appear in calculation)

M2 Use of Ar with Cl and C: mol C = $\frac{55.0}{35.5}$; mol C = $\frac{37.2}{12}$; mol H = $\frac{7.80}{1}$ ①

[CH_3CH_2Cl alone = 2 marks]

Ratio 1.55 : 3.10 : 7.80

1 : 2 : 5

[correct answer = 3 marks]

∴ C_2H_5Cl ① NOT CH_3CH_2Cl alone

(ii) What additional information would be needed to calculate the molecular formula of compound **W**?

M_r ①

OR relative [formula / molecular] mass

OR molar mass

OR the mass of one mole

(4 marks)

3 (a) Compounds with double bonds between carbon atoms can exhibit geometrical isomerism.

(i) Draw structures for the two geometrical isomers of 1,2-dichloroethene.

Isomer 1 either order *Isomer 2*

[credit $H-\overset{Cl}{\overset{|}{C}}=\overset{Cl}{\overset{|}{C}}-H$ and $H-\overset{Cl}{\overset{|}{C}}=C(Cl)-H$]

(ii) What feature of the double bond prevents isomer 1 from changing into isomer 2?

restricted rotation OR no rotation (1)

OR cannot rotate

(3 marks)

(b) When 2-chloropropane reacts with sodium hydroxide, two different reactions occur. Each reaction produces a different organic product.

Reaction 1 $CH_3-\underset{\displaystyle Cl}{\underset{|}{CH}}-CH_3 + NaOH \rightarrow CH_3-\underset{\displaystyle OH}{\underset{|}{CH}}-CH_3 + NaCl$

Reaction 2 $CH_3-\underset{\displaystyle Cl}{\underset{|}{CH}}-CH_3 + NaOH \rightarrow CH_3-CH=CH_2 + NaCl + H_2O$

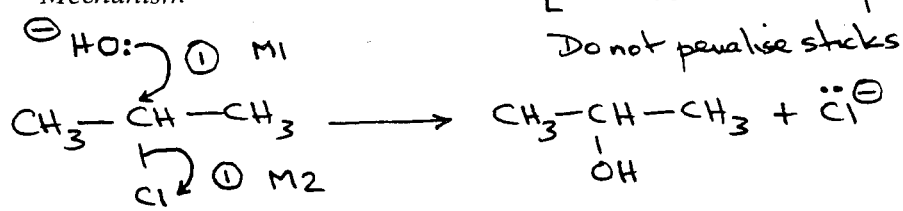
(i) Outline a mechanism for **Reaction 1** and state the role of the hydroxide ion in this reaction.

M1 and M2 independent

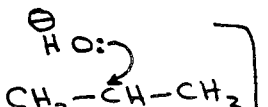
[curly arrows must be from a bond or a lone pair]

Mechanism

penalise M1 if Na–OH precedes (penalise this once)



Do not penalise sticks.

[Credit M1 for ]

penalise incorrect δ+ for M2

penalise + on C atom for M2

only allow M1 for incorrect haloalkane

Role of the hydroxide ion ..... nucleophile (1)

electron pair donor

lone pair donor

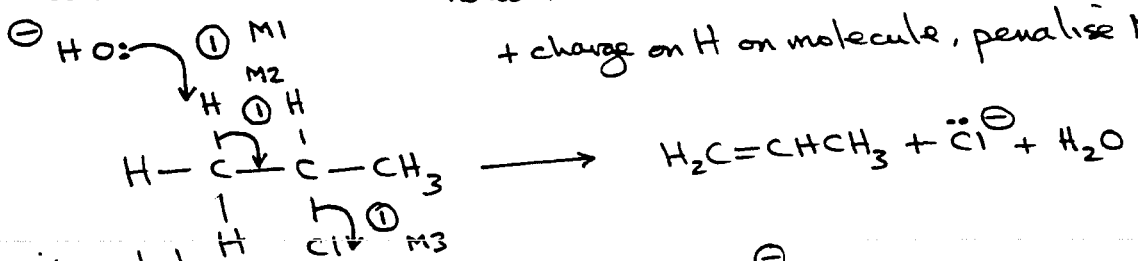
NOT nucleophilic

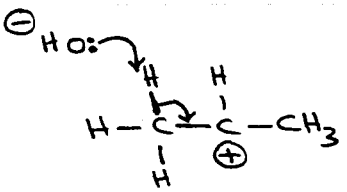
(ii) Outline a mechanism for **Reaction 2** and state the role of the hydroxide ion in this reaction.

only allow M1 and M2 for incorrect haloalkane unless RE on (i)

+ charge on H on molecule, penalise M1

Mechanism





M3 independent
M2 must be to correct C–C
M1 must be to correct H atom
Credit M1 and M2 via carbocation mechanism
[No marks after any attack of C⊕ by OH^-]

Role of the hydroxide ion ..... base (1)

proton acceptor
accepts H^+

(7 marks)

10

TURN OVER FOR THE NEXT QUESTION

4 (a) Four isomers with the formula C_4H_9OH are given below.

Isomer	Name
$CH_3CH_2CH_2CH_2OH$	butan-1-ol
$CH_3-\underset{\displaystyle OH}{\overset{\displaystyle CH_3}{\underset{|}{\overset{|}{C}}}}-CH_3$	2-methylpropan-2-ol
$CH_3-\underset{\displaystyle CH_3}{CH}-CH_2OH$	(2-)methylpropan-1-ol ①
$CH_3CH_2-\underset{\displaystyle OH}{CH}-CH_3$	OR 2-butanol butan-2-ol ①

NOT prop-1-ol

NOT but-2-ol

NOT hydroxy

No RE

(allow e in the names)

(i) Complete the naming of the isomers in the table above.

(ii) Name the type of isomerism shown by these four isomers.

structural ①

OR chain and position(al)

(3 marks)

(b) One of the isomers in part (a) is resistant to oxidation by acidified potassium dichromate(VI).

If b(i) is blank, b(ii) equation must be full for credit NOT C_4H_9OH]

(i) Identify this isomer.

2-methylpropan-2-ol OR the second one ①

(ii) This isomer can be dehydrated. Give a suitable dehydrating agent and write an equation for this dehydration reaction. ignore additional eqn

Dehydrating agent conc H_2SO_4 OR conc H_3PO_4 OR Al_2O_3 ①

Mark consequential on b(i)

Equation $CH_3-\underset{\displaystyle OH}{\overset{\displaystyle CH_3}{\underset{|}{\overset{|}{C}}}}-CH_3 \longrightarrow CH_3-\overset{\displaystyle CH_3}{\overset{|}{C}}=CH_2 + H_2O$ ①

(3 marks)

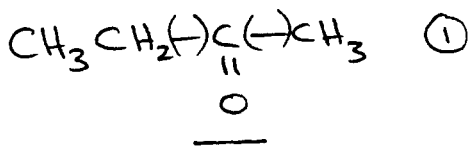
allow C_4H_9OH in equation provided RHS is correct

(c) (i) Identify the isomer in part (a) which can be oxidised to a ketone. Give the structure of the ketone formed. [Look at name in Table]

wrong isomer = CE

Isomer butan-2-ol OR the fourth one (1)

Structure of the ketone



(1)

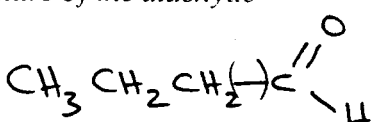
(ii) Identify **one** of the isomers in part (a) which can be oxidised to an aldehyde. Give the structure of the aldehyde formed. [Look at name in Table]

wrong isomer = CE

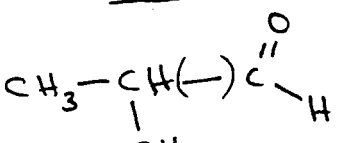
Isomer butan-1-ol OR the first one OR 2-methylpropan-1-ol OR the third one

Structure of the aldehyde

Either



NOT C_3H_7

OR 

(iii) Give a reagent that can be used in a test to distinguish between a ketone and an aldehyde. State what you would observe in the test.

Wrong reagent = No reagent = CE

Penalise $AgNO_3$ $[Ag(NH_3)_2]^+$ but allow M2 and M3 - consequential

	Reagent M1 (1)	Observation with ketone M2 (1)	Observation with aldehyde M3 (1)
	$AgNO_3/NH_3$ Tollens'	stays colourless / no change	silver mirror / black ppt.
	Fehling's	stays blue / no change	red solid / orange/red brown/red ppt/solid
*	Others include $K_2Cr_2O_7/H_2SO_4$		Schiff's
	$KMnO_4/H_2SO_4$		Benedict's

(7 marks)

(d) Butan-1-ol can be oxidised to form a carboxylic acid. Using [O] to represent the oxidising agent, write an equation for this reaction and name the product.

C_4H_9OH C_3H_7COOH

$$CH_3CH_2CH_2CH_2OH + 2[O] \longrightarrow CH_3CH_2CH_2COOH + H_2O \quad (1)$$

Equation

Name of product butanoic acid (1) [accept butaneoic acid]

(2 marks)

* $K_2Cr_2O_7/H_2SO_4$ (acidified): ketone — orange, no change; aldehyde — green

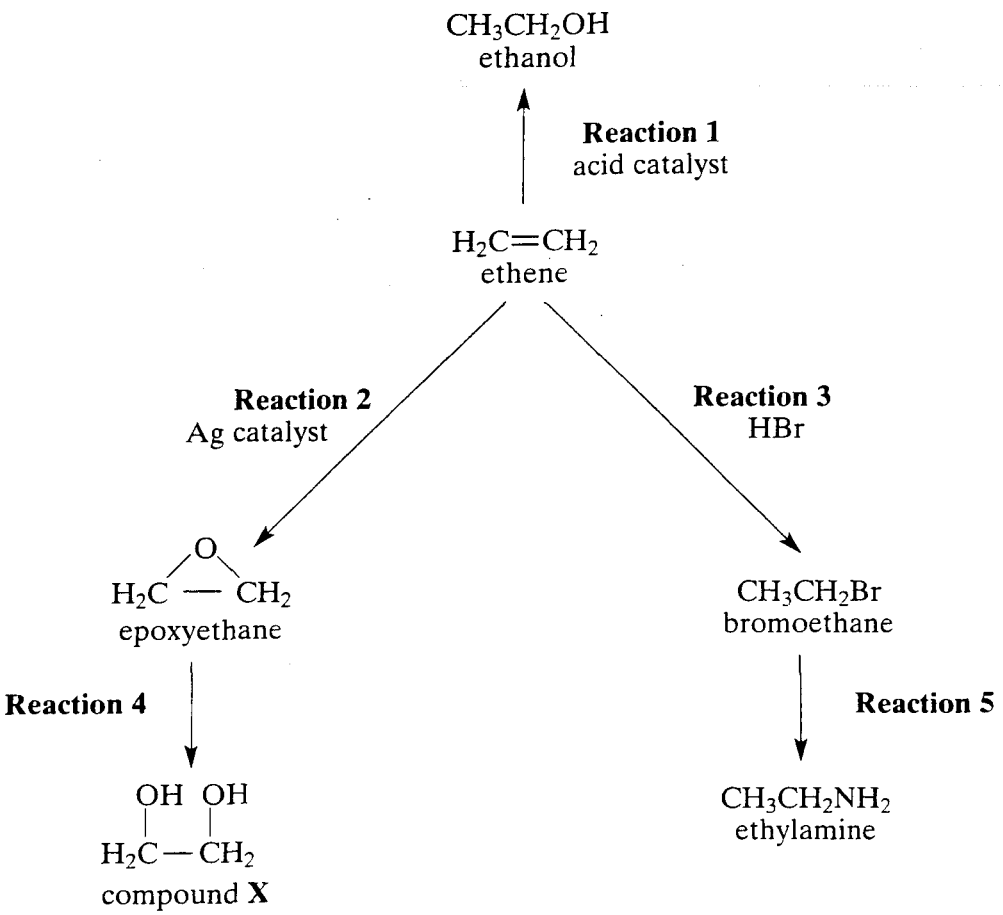
$KMnO_4/H_2SO_4$ (acidified): purple, no change; colourless (v. pale pink)

15

SECTION B

Answer the question below in the space provided on pages 13 to 16 of this booklet.

5 Ethene can be converted into a variety of useful products as illustrated below.



(a) Name and give a use for compound **X**. *(2 marks)*

(b) Give a reagent for each of **Reactions 1, 2, 4** and **5**. *(4 marks)*

(c) Outline a mechanism for **Reaction 3**. *(4 marks)*

(d) Ethanol can be manufactured from ethene as shown in **Reaction 1** or by the fermentation of sugars. Outline the essential conditions and give an equation for the fermentation reaction. Compare the relative rates and the purity of the product obtained in each case by these two manufacturing processes. *(5 marks)*

END OF QUESTIONS

Question 5

(a) ethan(e)-1,2-diol OR 1,2-ethan(e)diol ①

antifreeze ① OR production of Terylene / polyester

feedstock for polyester / PET

NOT surfactant NOT plasticiser NOT solvent NOT de-icer

2

(b) Reaction 1 H_2O or steam ① [Check page 12 to see if these have been included in the scheme]

Reaction 2 O_2 NOT air ①

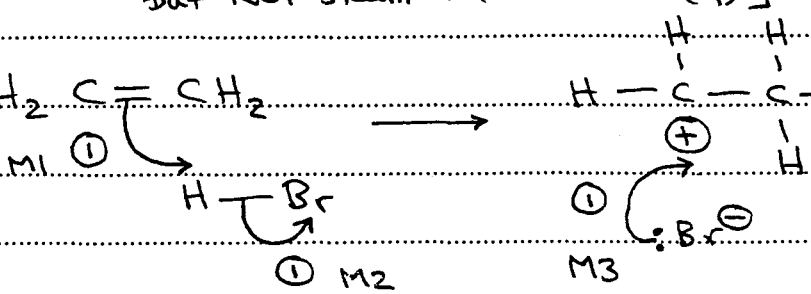
Reaction 4 H_2O ①

ignore Reaction 3 Reaction 5 NH_3 ①

4

[For Reaction 4; Credit dil H_2SO_4 or $H_2SO_4(aq)$ or $HCl(aq)$ but NOT steam and NOT $NaOH(aq)$]

(c)



penalise M2 incorrect δ+/δ−

penalise δ− on alkene (M1)

penalise dots on bonds once

Penalise M4 (structure) for use of wrong alkene

Penalise M1 for use of Br_2

4

(d) [water OR aqueous solution] OR (aq) in equation ① M1

yeast OR [enzyme / zymase] OR T ≤ 45°C but T not below 20°C and allow warm M2

NB yeast and T=60°C ✗ con

ignore pH, ignore pressure, ignore [anaerobic / oxygen], ignore time

$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$ M3

(CH_3CH_2OH)

[allow $C_{12}H_{22}O_{11}$ if balanced equation]

Turn over ▶

part (d) continued

M4 OR M5 needs the use of good English and correct chemistry to gain credit

(1) M4 The rate of fermentation is slower

OR The rate of hydration is faster

QoL OR (The rate of) fermentation is slow and (the rate of) hydration is fast.

[Reference correctly to time rather than rate gains credit]

(1) M5 The product of fermentation is less pure or lower purity

OR The product of hydration is more pure or higher purity

OR QoL The product of fermentation is impure and that of hydration is pure

OR specific reference to 10-15% versus 90-100%

OR correct reference to higher or lower yield.