ASSESSMENT and QUALIFICATIONS ALLIANCE

Mark scheme January 2004

GCE

Chemistry

Unit CHM3/W

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales 3644723 and a registered charity number 1073334.
Registered address AQA, Devas Street, Manchester M15 6EX.
Dr Michael Cresswell Director General

LEAVE MARGIN BLANK

SECTION A

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

1 (a) Crude oil is composed mainly of alkanes, which are saturated hydrocarbons.

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

(or clearly implied)

A molecule / A compound / Consists / Composed of hydrogen and carbon only (1)

(ii) State what is meant by the term *saturated*, as applied to a hydrocarbon.

only single bonds (or clearly implied) (1)

OR has no double bond

(2 marks)

NOT has maximum number of hydrogen atoms

(b) Crude oil can be separated into the fractions listed in the table below.

Name of fraction	Number of carbon atoms
LPG (liquefied petroleum gas)	1 – 4
Petrol (gasoline)	4 – 12
Naphtha	7 – 14
* Kerosine OR Kerosene OR Paraffin (1)	11 – 15
Gas oil (diesel) (ignore uses)	15 – 19
Mineral oil (lubricating oil)	20 – 30
Fuel oil	30 – 40

(i) Name the process used to obtain these fractions from crude oil.

fractional distillation OR fractionation (1)

(ii) Complete the table by naming the missing fraction.

(2 marks)

* Answer may occur here.

(c) Some of the naphtha fraction is thermally cracked to produce more useful products.

(i) Give the molecular formula of an alkane with ten carbon atoms.

$C_{10}H_{22}$ only (1)

NOT $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

(ii) Write an equation to illustrate the thermal cracking of one molecule of tetradecane, $C_{14}H_{30}$, in which the products are ethene and propene, in the ratio of 2:1, and one other product. (1) alkene formulas (1) balanced

$C_{14}H_{30} \longrightarrow 2C_2H_4 + C_3H_6 + C_7H_{16}$

OR $C_{14}H_{30} \longrightarrow 4C_2H_4 + 2C_3H_6 + H_2$

(iii) Name the mechanism involved in thermal cracking.

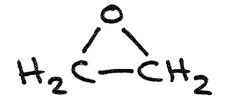
(free) radical OR homolysis OR homolytic fission (1)

(4 marks)

NOT radical substitution
NOT thermal decomposition

(d) Ethene can react with oxygen to produce epoxyethane. If the reaction is not controlled carefully, the ethene can undergo complete combustion.

(i) Write an equation for the partial oxidation of ethene to form epoxyethane.

C_2H_4 or CH_2CH_2 or $H_2C{=}CH_2$ $+ \frac{1}{2}O_2 \longrightarrow$  (1)

(ii) Write an equation for the complete combustion of ethene in oxygen.

$C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O$ (1)

(2 marks)

10

TURN OVER FOR THE NEXT QUESTION

2 The burning of fossil fuels can produce atmospheric pollutants.

(a) The combustion of petrol in an internal combustion engine can lead to the formation of carbon monoxide, CO, and nitrogen monoxide, NO.

(i) Write an equation for the incomplete combustion of octane, C_8H_{18}, to produce CO and water only.

$C_8H_{18} + 8\frac{1}{2}O_2 \longrightarrow 8CO + 9H_2O$ (1)

OR double this equation

(ii) State **one** essential condition for the formation of NO in an engine. Write an equation for the reaction in which NO is formed.

Condition spark OR high T OR T = 2500 – 4000°C (1)

Equation $N_2 + O_2 \longrightarrow 2NO$ (1)

OR half this equation *(3 marks)*

(b) All new petrol-engined cars must be fitted with a catalytic converter.

(i) Name **one** of the metals used as a catalyst in a catalytic converter.

platinum OR rhodium OR palladium (1)

(ii) Write an equation to show how CO and NO react with each other in a catalytic converter.

$2CO + 2NO \longrightarrow N_2 + 2CO_2$ (1)

OR half this equation *(2 marks)*

(c) State why sulphur dioxide gas is sometimes found in the exhaust gases of petrol-engined cars. Give **one** adverse effect of sulphur dioxide on the environment.

Reason for SO_2 in exhaust gases fraction/petrol/fuels contain sulphur or sulphur-containing impurities (which burn to give SO_2) (1)

Environmental effect of SO_2 acid rain OR a specific effect (1)

NOT greenhouse effect *(2 marks)*
NOT damages ozone layer

7

3 The table below gives the names and structures of three isomeric alkenes.

Name	Structure
but-1-ene	$CH_3CH_2CH=CH_2$
but-2-ene	$CH_3CH=CHCH_3$
methylpropene	$H_3C-C(CH_3)=CH_2$

(a) Give the molecular formula and the empirical formula of but-2-ene.

Molecular formula ..... C_4H_8 (1) .....

Empirical formula ..... CH_2 (1) .....

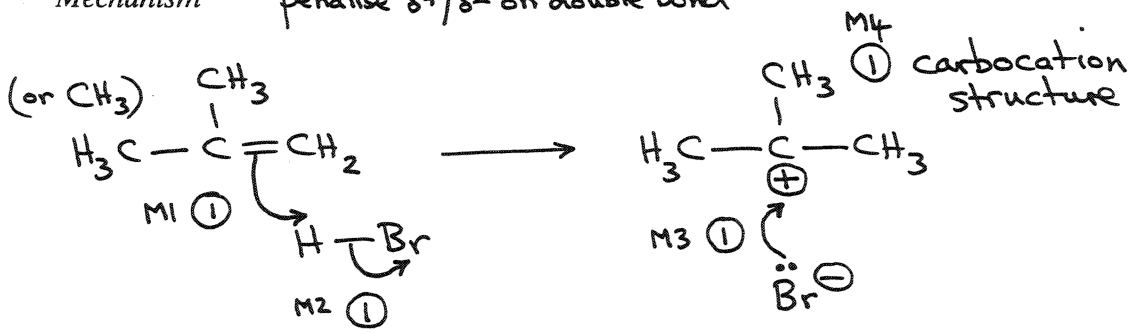
(2 marks)

(b) Methylpropene reacts with hydrogen bromide to produce 2-bromo-2-methylpropane as the major product.

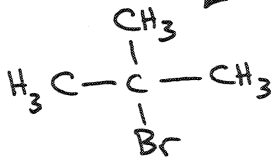
(i) Name and outline the mechanism for this reaction.

Name of mechanism ..... electrophilic addition (1) .....

Mechanism penalise δ+/δ− on double bond



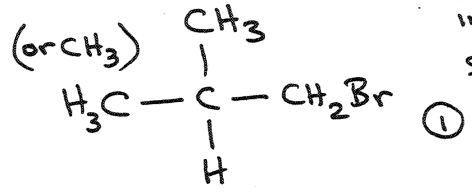
Award M1 for arrow to H⊕
penalise H ÷ Br once only
ignore δ+/δ− on HBr unless wrong



wrong alkene loses carbocation mark only (M4)

(ii) Draw the structure of another product of this reaction and explain why it is formed in smaller amounts.

Structure



If wrong asymmetric alkene in b(i) allow consequential structure and explanation

M1 major product formed via tertiary carbocation (1)

Explanation OR minor product formed via primary carbocation

M2 primary carbocation less stable than tertiary carbocation

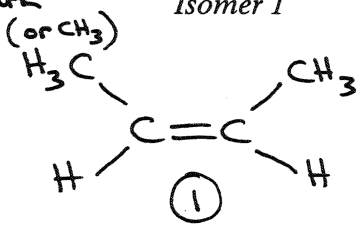
OR converse statement (1)

(8 marks)

(c) Draw the structures and give the names of the two geometrical isomers of but-2-ene.

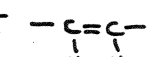
Award one mark for two correct structures and wrong or no name

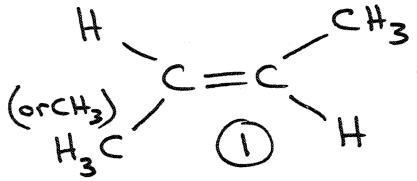
Isomer 1



mark vertically either order

Isomer 2

accept  structures



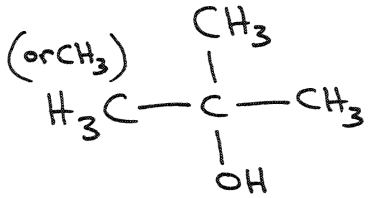
Name cis but-2-ene *Name* trans but-2-ene

Award both marks for two correct structures and only the words cis and trans correctly placed. *(2 marks)*

(d) One of the isomers shown in the table can be hydrated to form a tertiary alcohol.

(i) Draw the structure and give the name of this tertiary alcohol.

Structure



Insist on C–O bond clearly shown

NOT "hydroxy"

Name (2-) methylpropan-2-ol (1)

(ii) Suggest a reason why tertiary alcohols are resistant to oxidation.

central carbon atom has no H atom (1)

(3 marks)

LEAVE MARGIN BLANK

4 (a) Chloromethane can be made by the reaction of chlorine with methane.

(i) Give **one** essential condition for this reaction. NOT high T

uv light OR sunlight OR T ⩾ 450°C ①

(ii) Name the mechanism for this reaction.

(free) radical substitution ①

(iii) Further substitution can occur during this reaction. Identify the main organic product when a large excess of chlorine is used in this reaction.

CCl_4 ① OR named

(3 marks)

(b) Ethanenitrile can be made by reacting chloromethane with potassium cyanide.

(i) Write an equation for this reaction.

$CH_3Cl + KCN \longrightarrow CH_3CN + KCl$ ①

$CN^\ominus$ $Cl^\ominus$

(ii) Name the mechanism for this reaction.

nucleophilic substitution ①

(iii) Explain, in terms of bond enthalpies, why bromomethane reacts faster than chloromethane with potassium cyanide.

C—Br bond is weaker (than C—Cl bond)

OR C—Br bond enthalpy is less than C—Cl ①

ignore electronegativity

(3 marks)

(c) Ethanenitrile can be hydrolysed to a carboxylic acid by heating it under reflux with a dilute acid. Identify the carboxylic acid formed in this reaction.

CH_3COOH OR ethanoic acid ①

(1 mark)

(d) Chloromethane can react with ammonia to produce a primary amine.

(i) What feature of the chloromethane molecule makes it susceptible to attack by an ammonia molecule?

$\overset{\delta+}{C}-\overset{\delta-}{Cl}$ OR C–Cl is polar ① OR C atom is [electron deficient $\delta+$]

NOT chloromethane is polar

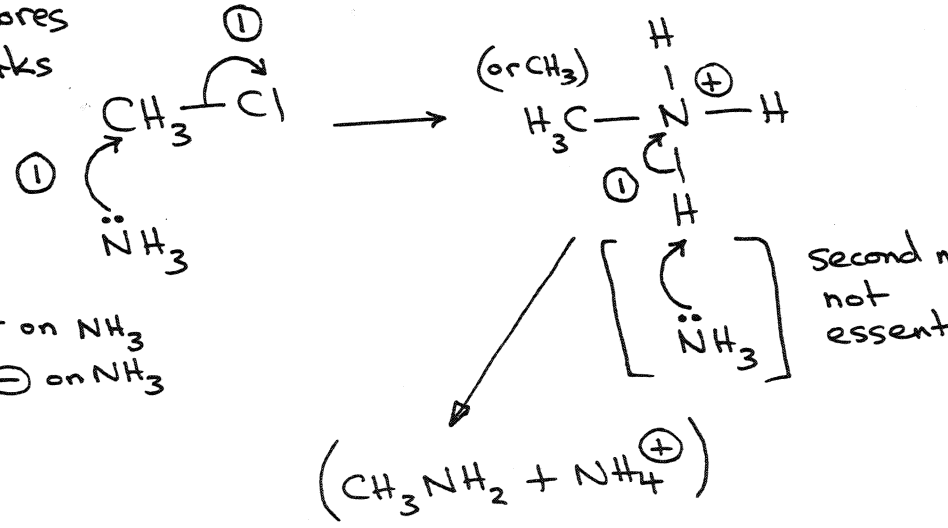
(ii) Name the amine produced in this reaction.

methylamine ① only

(iii) Outline a mechanism for this reaction.

① structure

S_N1 scores full marks



Allow $\delta-$ on NH_3
penalise $\ominus$ on NH_3

$(CH_3NH_2 + NH_4^{\oplus})$

(6 marks)

13

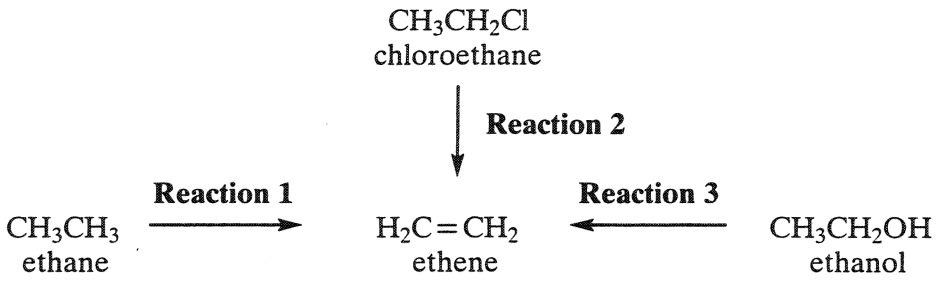
LEAVE MARGIN BLANK

SECTION B

JANUARY 2004
CHM3/W

Answer the question below in the space provided on pages 12 to 14 of this booklet.

5 Ethene is an important starting point for the manufacture of plastics and pharmaceutical chemicals. Most of the ethene used by industry is produced by the thermal cracking of ethane obtained from North Sea gas (**Reaction 1**). It is also possible to make ethene either from chloroethane (**Reaction 2**) or from ethanol (**Reaction 3**).



(a) Give essential conditions and reagents for each of **Reactions 2** and **3**. *(4 marks)*

(b) Name and outline a mechanism for **Reaction 2**. Suggest a reason why chloroethane is **not** chosen by industry as a starting material to make ethene commercially. *(5 marks)*

(c) Name and outline a mechanism for **Reaction 3**. Suggest why this route to ethene may become used more commonly in the future as supplies of North Sea gas begin to run out. *(6 marks)*

END OF QUESTIONS

(a) Reaction 2 [NaOH (1) M1 alcohol(ic) (1) M2 ignore heat
OR [KOH ethanol(ic)

Condition mark linked to correct reagent but award M2 if $OH^{\ominus}$ or base or alkali mentioned

Reaction 3 concentrated [H_2SO_4 (1) M1 heat (1) M2
[H_3PO_4 OR 150°C - 200°C

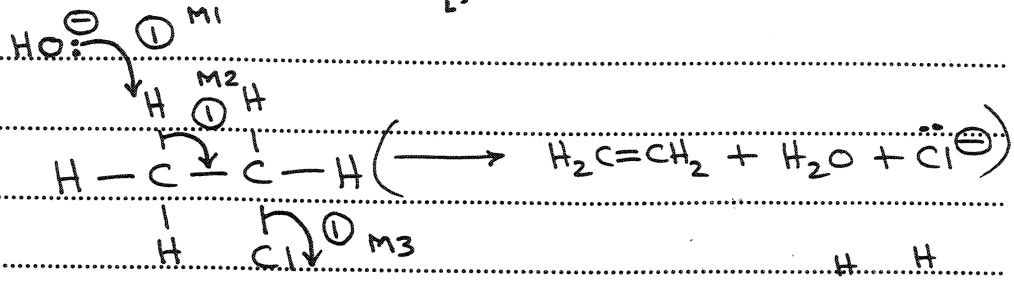
Condition mark linked to correct reagent but award M2 if H_2SO_4 or H_3PO_4, but not concentrated.

Penalise reagent and condition if dilute H_2SO_4 | H_3PO_4 4

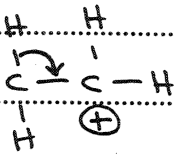
LEAVE MARGIN BLANK

(b) Award M3 (C—Cl) independently

Mechanism M1 and M2 must be to correct places from



E1 mechanism possible in which M2



Name of mechanism = elimination (1)

NOT dehydrohalogenation

Ignore "base" or "nucleophilic" before elimination

Reason

Reaction 2 has (very) low yield (1)

QoL OR Chloroethane has to be made (from ethene)

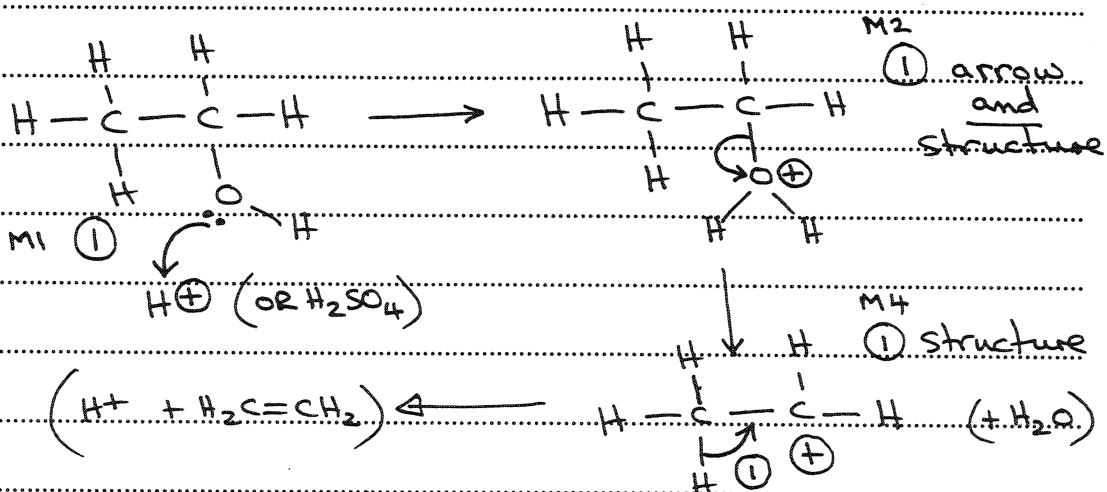
OR chloroethane is expensive.

OR chloroethane is not readily available.

5

(c)

Mechanism



(M3 could be awarded on protonated alcohol)

Name of mechanism = elimination (1) NOT dehydration alone.

Reason QoL Ethanol could come from (fermentation of) renewable sugars/glucose/carbohydrates/sources (1)

6

Turn over ▶

(15)