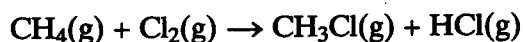# AQA

Mark scheme

January 2002

GCE

Chemistry

Unit CHM3

SECTION A

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

1   The equation below represents a reaction between methane and chlorine.

$$CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$$

(a)   State an essential condition required for this reaction to occur.   Explain why this condition is essential.

Condition .....UV light or sunlight or 450°C or high temp.........   (1)

Explanation ...UV light etc. provides energy to break (Cl-Cl) bond (1)

Do not accept ref. to E_A or wrong bond or 'to make Cl radicals

(2 marks)

(b)   (i)   State the type of mechanism involved in the above reaction.

(Free) radical substitution   (1)

(ii)   Name the three types of step involved in this mechanism.

Step 1 .....initiation.............   (1)   (Any order)

Step 2 .....propagation............   (1)   (Don't be too harsh on spelling)

Step 3 .....termination............   (1)

(4 marks)

(c)   In addition to CH_3Cl, compounds such as CH_2Cl_2 and CH_3CH_2Cl may also be formed when chlorine reacts with methane.

(i)   Write equations for the two steps in the mechanism by which CH_2Cl_2 is formed from CH_3Cl

mark equ.   Equation 1 .....$CH_3Cl + Cl\cdot \rightarrow CH_2Cl\cdot + HCl$ (1)

independently   Equation 2 .....$CH_2Cl\cdot + Cl_2 \rightarrow CH_2Cl_2 + Cl\cdot$ (1)
- any order
or $CH_2Cl\cdot + Cl\cdot \rightarrow CH_2Cl_2$

(ii)   Write an equation to represent a step in the mechanism in which CH_3CH_2Cl is formed. $CH_2Cl\cdot + CH_3\cdot \rightarrow CH_3CH_2Cl$

or $CH_3CH_2\cdot + Cl_2 \rightarrow CH_3CH_2Cl + Cl\cdot$ (1)

or $CH_3CH_2\cdot + Cl\cdot \rightarrow CH_3CH_2Cl$ *(3 marks)*

(eg must have CH_3CH_2Cl as product)

(Accept C_2H_5Cl)

Penalise absence of • once only

Turn over ▶

9

2 (a) In the manufacture of margarine, unsaturated vegetable oils such as sunflower oil are hardened.

(i) State the reagent and conditions used in this process.

M1 = 0
if M2 ✓
M3 if max

Reagent ...... Hydrogen or H_2 ...... (1)

Conditions ...... Ni (catalyst) ...... (1)   Ignore (Pt)

if M2 = 0 then = > 0   M3 tied to 100-200 °C or heat (1)   Not 'high temp.' Not 'warm'
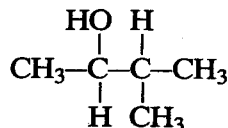M1. Only award M3 if M1 earned

(ii) Soft and hard margarines are obtained from the same vegetable oil. How does the structure and the melting point of a soft margarine differ from that of a hard one?

not the comparison

Difference in structure ...... Soft margarine less hydrogenated or has more C=C bonds or is more unsaturated than hard margarine (1)

Difference in melting point ...... soft has lower melting point (1)

(5 marks)

(b) In the presence of reagent **X**, the alcohol shown below undergoes a reaction to form two isomeric alkenes.

$$\text{CH}_3\!-\!\overset{\overset{\displaystyle HO}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}\!-\!\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{C}}\!-\!\text{CH}_3$$

(i) Name this alcohol.

...... 3-methylbutan-2-ol ...... (1)   No alternatives

(ii) Give the name of the type of reaction involved in the formation of the two alkenes.

...... elimination or dehydration ...... (1)

(iii) Suggest the identity of reagent **X**.

...... (c) H_2SO_4 or (c) H_3PO_4 — Name or correct formula (1)

(iv) Give the structural formulae of the two isomeric alkenes.

Alkene 1

$$\text{CH}_2\!=\!\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}\!-\!\overset{\overset{\displaystyle \,}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{C}}\!-\!\text{CH}_3$$

(1)

Alkene 2

$$\text{CH}_3\!-\!\overset{\overset{\displaystyle \,}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}\!=\!\overset{\overset{\displaystyle \,}{|}}{\underset{\underset{\displaystyle CH_3}{|}}{C}}\!-\!\text{CH}_3$$

(1)

(double bond must be shown)
(Accept any correct unambiguous structures)   *(5 marks)*
if but-1-ene and but-2-ene offered, allow M2

10

3 Propene reacts with bromine by a mechanism known as electrophilic addition.

(a) Explain what is meant by the term *electrophile* and by the term *addition*.

*for 'species'
accept atom,
molecule, ion*

Electrophile e⁻ pair acceptor or e⁻ deficient species lane pair or e⁻ seeking species (1)   Not '+' ion   Not 'attracted to '-' charge

Addition reaction which increases number of substituents or converts double bond to single bond or where two molecules form one molecule (1)

(2 marks)

(b) Explain why bromine, a non-polar molecule, is able to react with propene.
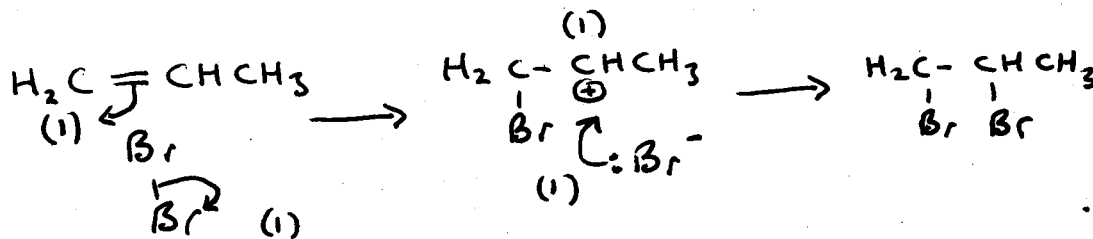
*Not just
'c=c'*

(high) e⁻ dense or e⁻ rich c=c or e⁻ rich π bond or 4e⁻ between the c's. (1)

causes induced dipole in Br₂ (1)

(2 marks)

*Ignore refs. to 'temporary'
Can score M2 from δ+/δ- on Br₂ in (c) unless a contradicting error in (b)*

(c) Outline the mechanism for the electrophilic addition of bromine to propene. Give the name of the product formed.

Mechanism   if incorrect alkene, Lose M3 (wrong cation)

*If all curly
arrows c=c
allow*

$H_2C \rightleftharpoons CHCH_3$ (1)
Br
Br (1)

$\rightarrow$

(1)
$H_2C - \overset{\oplus}{CHCH_3}$
Br :Br⁻ (1)

$\rightarrow$

$H_2C - CHCH_3$
Br Br

Mark M4 conseq on M3

Name of product 1,2-dibromopropane (1)

(5 marks)

(d) The polymerisation of propene to form poly(propene) is an important industrial process. Name the type of polymerisation involved.

addition (1)

(1 mark)

Not 'additional'

10

Turn over ▶

4 Two reactions of compound **A** are shown in the reaction scheme below.

$$CH_3CH_2CH_2CHO \quad \text{A}$$

Reagent **Y** → $CH_3CH_2CH_2CH_2OH$ **B**
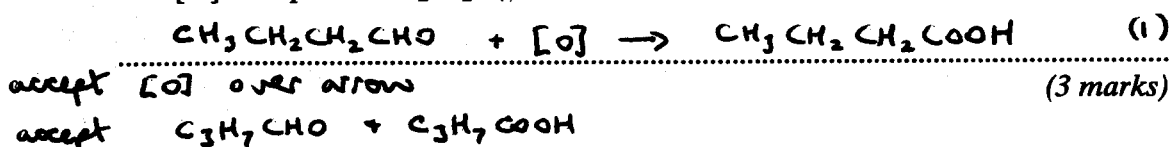
$K_2Cr_2O_7/H^+$ → Compound **C**
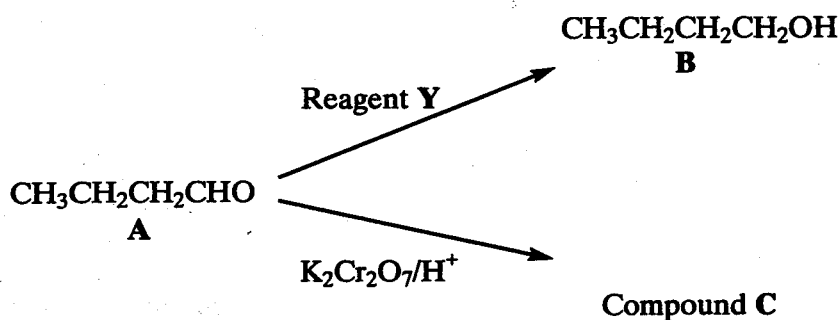
(a) (i) State the type of reaction occurring in the conversion of compound **A** into compound **B**. Identify a suitable reagent **Y**.

Type of reaction reduction or (nucleophilic) addition or hydrogenation (1)

Reagent **Y** Sodium borohydride or $NaBH_4$ or H_2 (1)
(Not $NaBH_4$ for hydrogenation)

(ii) Write an equation for the conversion of compound **A** into compound **C**.
Use [O] to represent $K_2Cr_2O_7/H^+$

$CH_3CH_2CH_2CHO + [O] \longrightarrow CH_3CH_2CH_2COOH$ (1)

accept [O] over arrow   *(3 marks)*

accept $C_3H_7CHO + C_3H_7COOH$

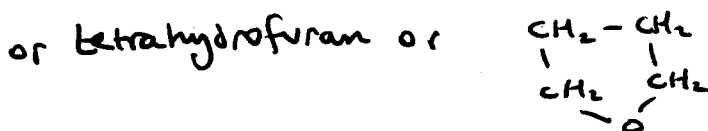(b) Functional group isomerism is one type of structural isomerism.

(i) Explain what is meant by the term *functional group isomerism*.

(compounds) with same molecular formula or number + type of atoms (1)

2 tied to with atoms arranged in different functional groups (1)

or in different classes of compounds.

(ii) Give the name or structural formula of a functional group isomer of compound **A** which contains only one functional group.

butanone or $CH_3COCH_2CH_3$ (1)

                                                    (3 marks)

or tetrahydrofuran or
$$\begin{array}{cc} CH_2 - CH_2 \\ | \quad\quad | \\ CH_2 \quad CH_2 \\ \searrow O \swarrow \end{array}$$

or other acceptable structure

(c) (i) State what is meant by the terms *empirical formula* and *molecular formula*.

Empirical formula simplest ratio of atoms of each element in the compound of molecule (1)

Molecular formula (actual) number of atoms of each element present in a compound of molecule (1)

(ii) Deduce the empirical formula and the molecular formula of compound **D** ($M_r = 116$) which contains 62.07% carbon, 10.34% hydrogen and 27.59% oxygen by mass.

$$\begin{array}{ccc} C & H & O \\ \frac{62.07}{12} & \frac{10.34}{1} & \frac{27.59}{16} \quad (1) \\ 5.17 & 10.34 & 1.72 \end{array}$$

ratio C : H : O = 3 : 6 : 1 ∴ Emp. Form. = C_3H_6O (1)

Mol. Form $\left(= \frac{116}{58} \times C_3H_6O \right)$ = $C_6H_{12}O_2$ (1)

(If correct answer, working not essential) *(5 marks)*

⑪

TURN OVER FOR THE NEXT QUESTION

Turn over ▶

5 **(a)** The equation below shows the reaction of 2-bromopropane with an excess of ammonia.

$$CH_3CHBrCH_3 + 2NH_3 \rightarrow CH_3CH(NH_2)CH_3 + NH_4Br$$

Name and outline the mechanism involved.

Name of mechanism ...... nucleophilic substitution (1) ......

Mechanism

[handwritten margin note:] wrong dipole δ⁻–δ⁺ C–Br or ⁺C–Br loses C–Br mark

[handwritten note:] (M3 is for correct carbocation – if used wrong halogenoalkane lose M3)
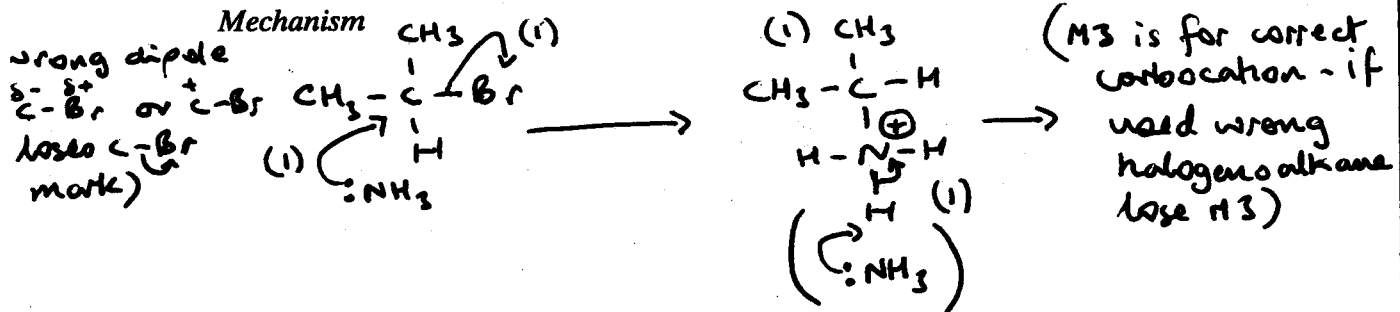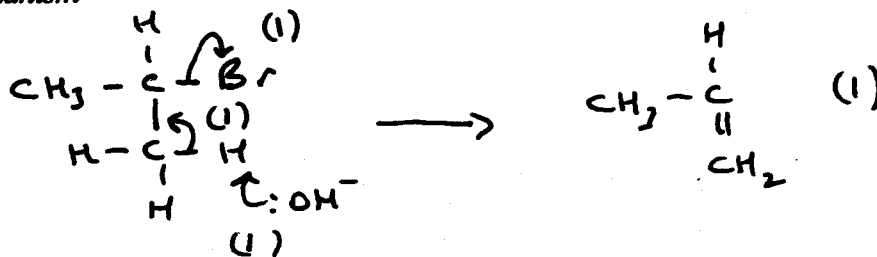
[handwritten note:] Mark S_N1 using same points ∴ M2 requires
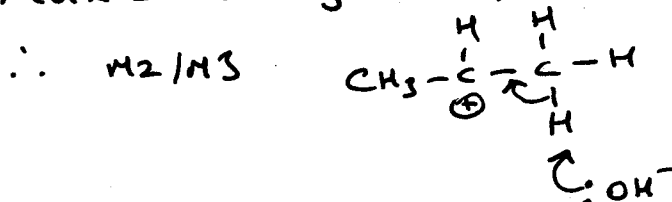

(5 marks)

(b) When 2-bromopropane is heated with ethanolic potassium hydroxide, an elimination reaction occurs. State the role of potassium hydroxide and outline a mechanism for this reaction.

Role of potassium hydroxide ...... Base (1) ......

Mechanism

[handwritten note:] Mark E1 using same points ∴ M2/M3

(5 marks)

10

SECTION B

Answer **both** questions below in the space provided on pages 9 to 12 of this booklet.

6 (a) Gas oil (diesel), kerosine (paraffin), mineral oil (lubricating oil) and petrol (gasoline) are four of the five fractions obtained by the fractional distillation of crude oil within the temperature range 40–400 °C.

Identify the missing fraction and state the order in which the five fractions are removed as the fractionating column is ascended. Give **two** reasons why the fractions collect at different levels in the fractionating column. *(4 marks)*

(b) Thermal cracking of large hydrocarbon molecules is used to produce alkenes. State the type of mechanism involved in this process. Write an equation for the thermal cracking of $C_{21}H_{44}$ in which ethene and propene are produced in a 3:2 molar ratio together with one other product. *(3 marks)*

(c) Write equations, where appropriate, to illustrate your answers to the questions below.

(i) Explain why it is desirable that none of the sulphur-containing impurities naturally found in crude oil are present in petroleum fractions.

(ii) The pollutant gas NO is found in the exhaust gases from petrol engines. Explain why NO is formed in petrol engines but is not readily formed when petrol burns in the open air.

(iii) The pollutant gas CO is also found in the exhaust gases from petrol engines. Explain how CO and NO are removed from the exhaust gases and why the removal of each of them is desirable. *(10 marks)*

7 Ethanol is produced commercially by fermentation of aqueous glucose, $C_6H_{12}O_6$
State **two** conditions, other than temperature, which are necessary for fermentation.
Explain why neither a low temperature nor a high temperature is suitable for this reaction.
Give **two** advantages of this method of production over that by the direct hydration of ethene.
Write an equation for the production of ethanol by fermentation and an equation for the complete combustion of ethanol. *(8 marks)*

END OF QUESTIONS

....

....

....

SECTION B

Question 6

(a)   Missing fraction = naphtha *(allow naphtha from list if not quoted separately)*   (1)

Order =   mineral oil (lubricating oil), gas oil (diesel), kerosine (paraffin),   (1)
naphtha, petrol (gasoline)
(mark order consequential on M1)   (if no missing fraction given, M2=0)
(accept correct reversed order)

Negative temperature gradient on the <u>column</u>   (1)
or temperature of <u>column</u> decreases upwards

Larger molecules **or** heavier fractions condense at higher temperatures **or**   (1)   **4**
lower down the column **or** reference to different boiling points *(ignore mp)*

(b)   Type of mechanism = (free) radical / homolytic fission - **used in complete**   (1)
sentence/phrase

$C_{21}H_{44}$ $\rightarrow$ $3C_2H_4$ + $2C_3H_6$ + C_9H_{20} correct alkenes   (1)
        Accept CH_2CH_2 & CH_2CHCH_3   all correct   (1)   **3**

(c)   (i)   Sulphur (containing impurities) <u>burn</u> to form **or** <u>forms</u> SO_2 **or** oxides of   (1)
sulphur *(if oxide identified, must be correct)*
Or equation: e.g. $S + O_2 \rightarrow SO_2$ **or** $H_2S + 1\frac{1}{2}O_2 \rightarrow SO_2 + H_2O$

Leading to acid rain *(must have specified oxides of S or burning)*   (1)
or toxic product   **or** respiratory problems

(ii)   NO formed by reaction between N_2 and O_2 from the air   (1)
Or $N_2 + O_2 \rightarrow 2NO$
High combustion temperature **or** spark in engine   (1)
provides E_A **or** sufficient heat/energy to <u>break</u> $N\equiv N$ bond   (1)

(iii)   Need to remove NO as forms acid rain **or** toxic product **or** causes respiratory   (1)
problems
$2NO + O_2 \rightarrow 2NO_2$ (1)
$4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$ (1)

Need to remove CO as it is poisonous   (1)

Catalytic converter   (1)
uses Pt/Rh/Pd/Ir   *(wrong answer cancels a correct one)*   (1)
provides active sites / reduces E_A (1)
Forms $N_2 + CO_2$ (1)
$2NO + 2CO \rightarrow N_2 + 2CO_2$ *(correct equation worth last 2 marks)*   (1)   **Max 10**

Total 17

Question 7

Conditions = two from   yeast *(anywhere in question)*

                                   Air excluded **or** sterile/clean   (2)

(Ignore references to pressure/temperature/aqueous/dark/high alcohol conc)

Temperature too low inactivates/deactivates enzymes **or** reaction too slow   (1)

Temperature too high destroys **or denatures** yeast/enzymes   (1)

(Not – kills enzymes; no t – deactivates here)

Advantage 1 = sugar/glucose/carbohydrate is <u>renewable resource/source</u>   (1)

Advantage 2 = production uses low level technology/cheap equipment   (1)

(Ignore references to energy. Do not allow contra-arguments about ethene)

$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$ **balanced**   (1)

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ **balanced**   (1)   **8**

(Allow C_2H_6O but penalise C_2H_5HO once)

                                                             Total

                                                               8