AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname MODEL ANSWERS

Forename(s)

Candidate signature

AS CHEMISTRY

Paper 2 Organic and Physical Chemistry

Friday 25 May 2018 Morning Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

Advice
- You are advised to spend about 65 minutes on **Section A** and 25 minutes on **Section B**.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
Section B	
TOTAL	

Do not write outside the box

Section A

Answer **all** questions in this section.

0 1 Hydrogen peroxide solution decomposes slowly to form water and oxygen.
The reaction is much faster in the presence of a manganese(IV) oxide catalyst.

$$2H_2O_2(aq) \longrightarrow 2H_2O(l) + O_2(g)$$

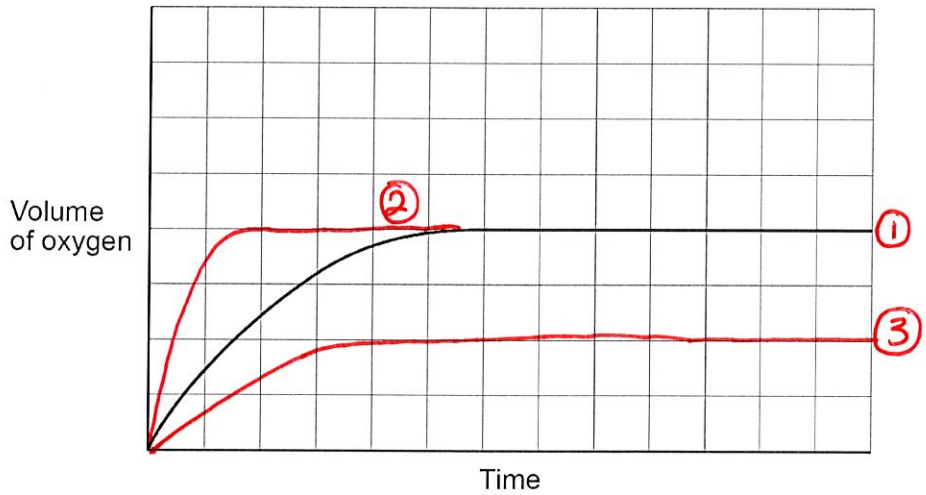
Three experiments, shown in **Table 1**, were carried out to investigate how the volume of oxygen produced varied over time under different conditions. The same mass of catalyst was used in each experiment.

Table 1

Experiment	Concentration of $H_2O_2(aq)$ / mol dm^{-3}	Volume of $H_2O_2(aq)$ / cm^3	Temperature / °C	Catalyst
1	1.0	50	20	lumps
2	1.0	50	20	powder
3	0.5	50	20	lumps

Figure 1 shows how the volume of oxygen collected varied with time in Experiment **1**.

Figure 1



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0 1 . 1 Explain, in general terms, how a catalyst increases the rate of a reaction.

[2 marks]

• provides an alternative route / pathway M1

• with lower activation energy M2

0 1 . 2 Draw **two** lines on **Figure 1** to show how the volume of oxygen collected varied with time in Experiments **2** and **3**.
Label each line with the experiment number.

[2 marks]

0 1 . 3 Explain, in terms of collision theory, the effect of increasing the concentration of hydrogen peroxide on the rate of reaction.

[2 marks]

• more particles / molecules H_2O_2 in same volume M1

• more frequent successful collisions M2

6

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0 2 Citric acid, $C_3H_5O(COOH)_3$, occurs naturally in many fruits and can also be synthesised in the laboratory for use as a food flavouring. A student analysed a sample of citric acid to determine its percentage purity.

The student dissolved 784 mg of impure citric acid in water to prepare 250 cm^3 of solution in a volumetric flask.

The student titrated 25.0 cm^3 samples of this solution with 0.0500 mol dm^{-3} sodium hydroxide solution using phenolphthalein as the indicator.

$$C_3H_5O(COOH)_3(aq) + 3NaOH(aq) \longrightarrow C_3H_5O(COO)_3Na_3(aq) + 3H_2O(l)$$

0 2 . 1 The student rinsed the burette before filling it with the sodium hydroxide solution.

State why the student should use sodium hydroxide solution rather than water for the final rinse of the burette.

[1 mark]

water would dilute the NaOH
or water would change the concentration NaOH
or ensure concentration NaOH is not changed

0 2 . 2 The student carried out several titrations. The results are shown in **Table 2**.

Complete **Table 2** to show the titre in each titration.

[1 mark]

Table 2

Titration	Rough	1	2	3
Final reading / cm^3	25.2	23.95	47.65	24.10
Start reading / cm^3	0.0	0.05	23.95	0.10
Titre / cm^3	25.2	23.90	23.70	24.00

2dp

0 2 . 3 Calculate the mean titre using the concordant results.
Give your answer to the appropriate number of significant figures.

[2 marks]

$$\frac{23.90 + 24.00}{2}$$

Mean titre 23.95 cm^3

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0 2 . 4 The total uncertainty when using the burette is ±0.15 cm^3. This is the combination of uncertainties in the start reading, final reading and the determination of the end point.

Use your answer to Question **02.3** to calculate the percentage uncertainty for the use of the burette in this experiment.

[1 mark]

$\frac{0.15}{23.95} \times 100$

Percentage uncertainty 0.63 %

0 2 . 5 Use your answer to Question **02.3** to find the mass, in mg, of citric acid dissolved in 250 cm^3 of the solution.
The relative molecular mass (M_r) of citric acid is 192.0

[3 marks]

$n_{NaOH} = cv \quad 0.05 \times 23.95 \times 10^{-3} = 1.1975 \times 10^{-3}$ M1

$n_{CA} = \frac{1.1975 \times 10^{-3}}{3} = 3.99 \times 10^{-4}$ mol in 25 cm^3

n_{CA} in 250 $cm^3 = 3.99 \times 10^{-4} \times \frac{250}{25} = 3.99 \times 10^{-3}$ M2

$m_{CA} = nMr \quad 3.99 \times 10^{-3} \times 192 = 0.766\,g$

m_{CA} in mg $= 0.766 \times 10^3$ M3

Mass 766 mg

0 2 . 6 Calculate the percentage purity of this sample of citric acid.

[1 mark]

$\frac{766}{784} \times 100$

Percentage purity 97.7 %

9

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0 3 This question is about enthalpy changes.

0 3 . 1 When ethanoic acid reacts with sodium hydroxide, the enthalpy change, ΔH, is $-56.1\ kJ\ mol^{-1}$

$$CH_3COOH(aq) + NaOH(aq) \longrightarrow CH_3COONa(aq) + H_2O(l)$$

Calculate the temperature rise when $25\ cm^3$ of 2.0 mol dm^{-3} aqueous ethanoic acid react with $25\ cm^3$ of 2.0 mol dm^{-3} aqueous sodium hydroxide.

Assume that both solutions have the same initial temperature, have a density of 1.0 g cm^{-3} and a specific heat capacity of 4.18 J K^{-1} g^{-1}

[4 marks]

$\Delta H = \frac{q}{n}$ kJ mol^{-1} $\quad q = mc\Delta T$ J

$m = 25 + 25 = 50$g

$n = 2 \times 25 \times 10^{-3} = 0.05$ M1

$q = \Delta H \times n \quad 56.1 \times 0.05 = 2.805$ kJ M2

2805 J

$\Delta T = \frac{q}{mc} \quad \frac{2805}{50 \times 4.18}$ M3 M4

Temperature rise 13.4 °C

Allow 13

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0 3 . 2 A student recorded the temperature of aqueous ethanoic acid in a polystyrene cup for three minutes.

At the fourth minute, the student added sodium hydrogencarbonate.

The student stirred the mixture and carried on recording the temperature every minute for several minutes.

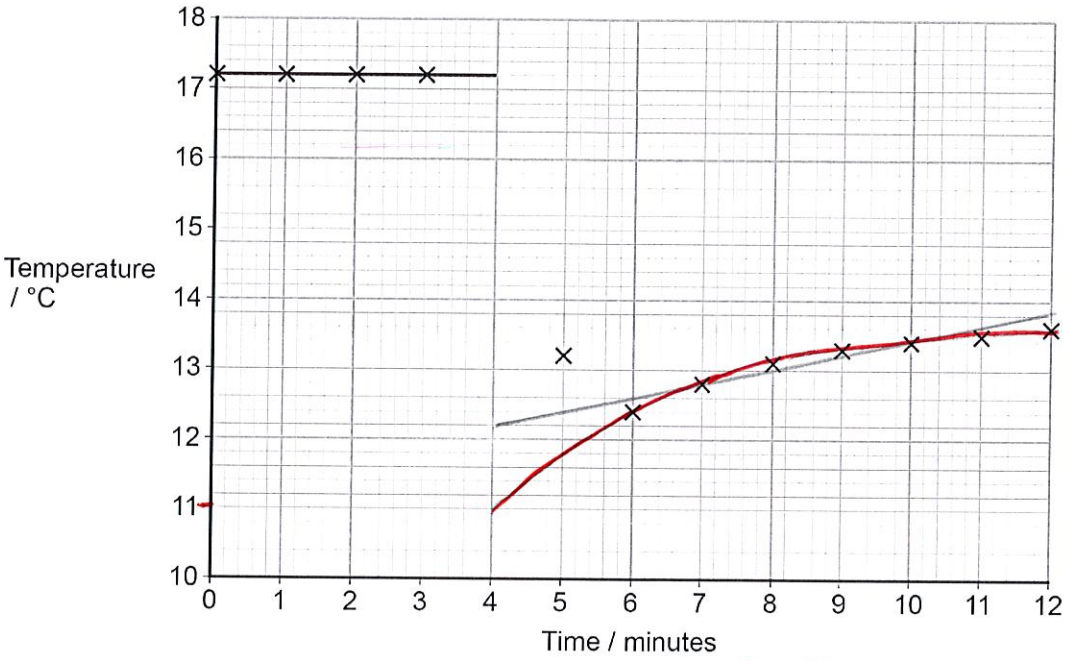
The student's measurements are shown in **Figure 2**.

A best-fit line showing the temperature before mixing has been drawn.

Draw an appropriate best-fit line on **Figure 2** and use it to find the temperature change at the time of mixing.

[2 marks]

Figure 2



straight line alternative

17.2 − 11

Temperature change at time of mixing 6.2 °C

6

Straight line 17.2 − 12.1 = 5.1 °C

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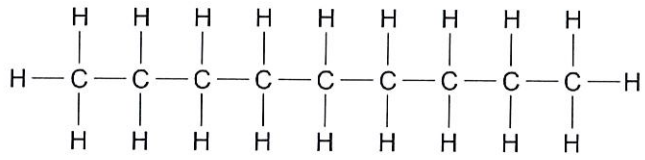
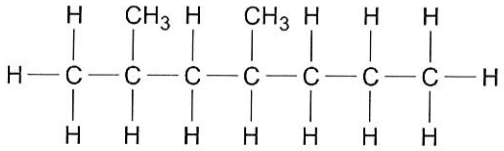
0 4 The alkanes nonane and 2,4-dimethylheptane are structural isomers with the molecular formula C_9H_{20}
They are found in crude oil and can be separated by fractional distillation.
Both can be used in fuels or cracked to form other products.

nonane



boiling point 151 °C

2,4-dimethylheptane



boiling point 134 °C

0 4 . 1 State the general formula of an alkane containing *n* carbon atoms.
Deduce an expression for the relative molecular mass (M_r) of an alkane in terms of *n*.
[2 marks]

General formula C_nH_{2n+2}

$12n + 12n + 2$

Expression $14n + 2$

0 4 . 2 Explain why nonane has a higher boiling point than 2,4-dimethylheptane.
[2 marks]

- nonane molecules pack closer / more surface contact M1

- stronger / more van der Waals' forces between molecules M2

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0 4 . 3 Give an equation for the complete combustion of nonane.

[1 mark]

$C_9H_{20} + 14O_2 \rightarrow 9CO_2 + 10H_2O$

0 4 . 4 Nonane is often found in fuel for jet engines. Combustion in jet engines produces pollutants including nitrogen monoxide (NO).

Explain how this nitrogen monoxide is formed.

[2 marks]

- nitrogen and oxygen react M1
- at high temperatures M2

0 4 . 5 Nonane can be cracked to form large quantities of propene.

Name the type of cracking used.

alkene

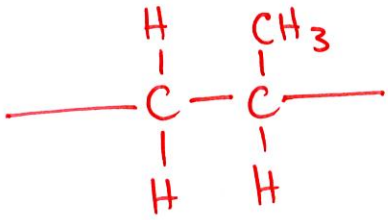
[1 mark]

thermal

0 4 . 6 The main use of propene, formed from cracking, is to make poly(propene).

Draw the repeating unit of poly(propene).

[1 mark]



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Turn over for the next question

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0 5 . 1 A hydrocarbon contains 87.8% by mass of carbon and has a relative molecular mass (M_r) of 82.0
The hydrocarbon decolourises bromine water. alkene

Determine the empirical and molecular formulae of the hydrocarbon.
Suggest **two** possible structures for the hydrocarbon.
Name the type of reaction taking place when bromine water reacts with the hydrocarbon.

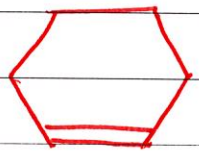
[6 marks]

	C	H	
	87.8	12.2	M1
n	$87.8/12 = 7.316$	$12.2/1 = 12.2$	
ratio	$7.316/7.316 = 1$	$12.2/7.316 = 1.67$	$\times 3$
	3	5	

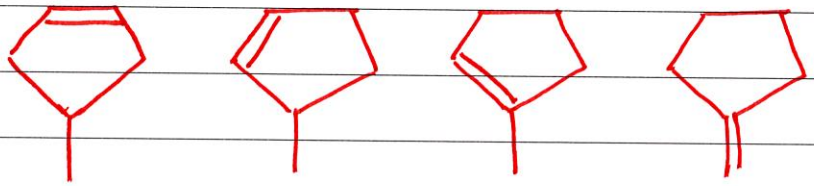
empirical formula C_3H_5 M2

M_r (EF) = 41.0 $\Rightarrow 82/41 = 2$

molecular formula $2 \times C_3H_5 \Rightarrow C_6H_{10}$ M3



M4



M5

Electrophilic addition M6

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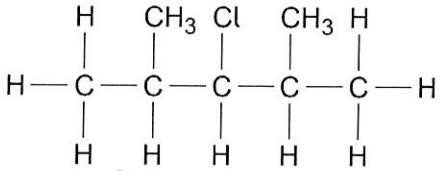
0 6 Compound **A** is a halogenoalkane.

Compound A



0 6 . 1 Name Compound **A**.

[1 mark]

3-chloro-2,4-dimethylpentane

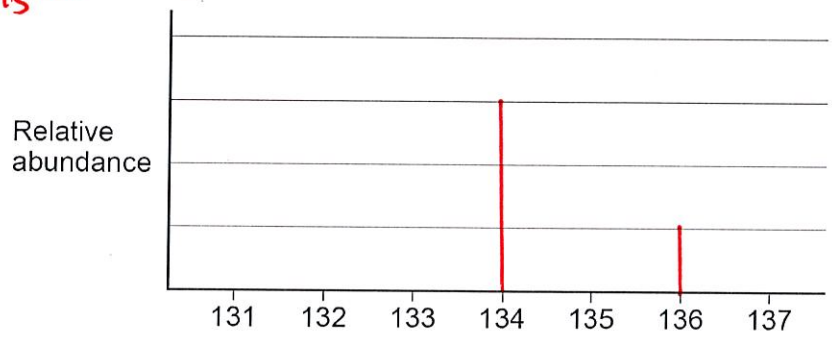
0 6 . 2 Compound **A** has a relative molecular mass (M_r) of 134.5
The main isotope of hydrogen is ^{1}H
The main isotope of carbon is ^{12}C
Chlorine consists of two common isotopes, ^{35}Cl and ^{37}Cl, of which 75% is ^{35}Cl
The mass spectrum of **A** was recorded when **A** was ionised by electron impact to form A^+ ions.

Draw, on **Figure 3**, the peaks for the main molecular ions in the mass spectrum of **A**.

[2 marks]

$C_7H_{15}Cl^{35}$ $M_r = 134$
$C_7H_{15}Cl^{37}$ $M_r = 136$

Figure 3



Question 6 continues on the next page

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0 6 . 3 Reaction of **A** with warm, dilute aqueous sodium hydroxide forms alcohol **B**.

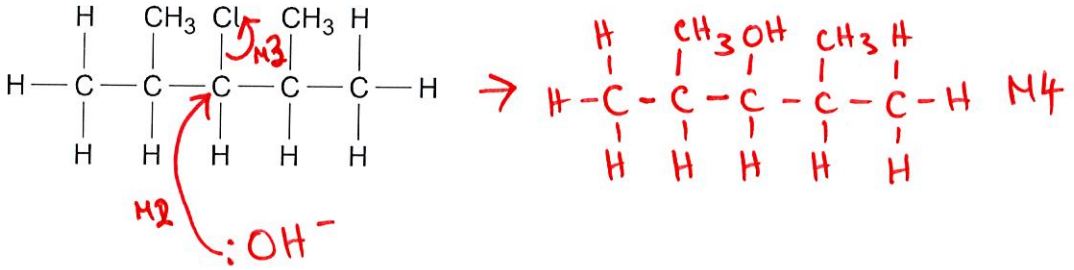
Name the mechanism for this reaction.

Outline the mechanism using the structure of **A** shown.
Include the structure of the product, alcohol **B**.

[4 marks]

Mechanism nucleophilic substitution M1

Outline of mechanism



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0 6 . 4 Reaction of **A** with hot, ethanolic potassium hydroxide gives alkene **C**.

Name the mechanism for this reaction.
State the role of the hydroxide ions.

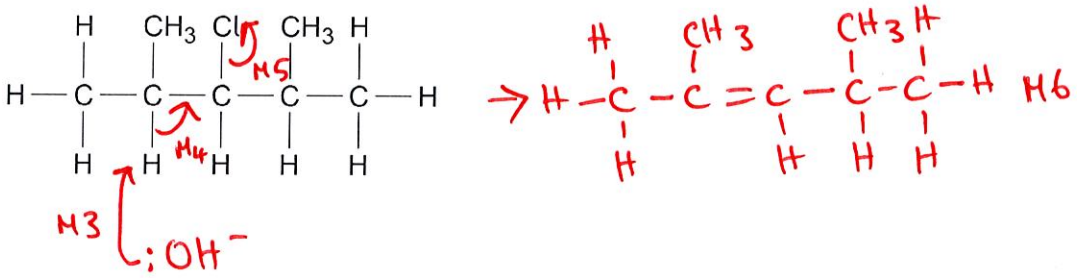
Outline the mechanism using the structure of **A** shown.
Include the structure of the product, alkene **C**.

[6 marks]

Mechanism Elimination M1

Role of hydroxide ions Base M2

Outline of mechanism



Question 6 continues on the next page

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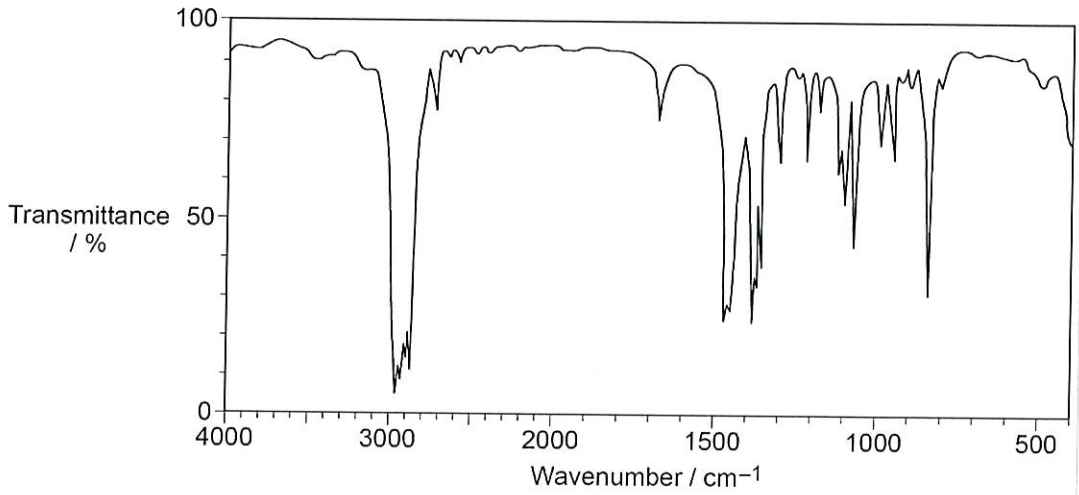
0 6 . 5 The infrared spectrum in **Figure 4** is that of either alcohol **B** or alkene **C**.

Figure 4



Tick the box that shows the correct compound.
Explain your answer with reference to a bond and the wavenumber of its absorption.

[1 mark]

Alcohol **B** ☐ Alkene **C** ☑

Explanation peak at 1620-1680 C=C

OR no peak at 3230-3550 O-H

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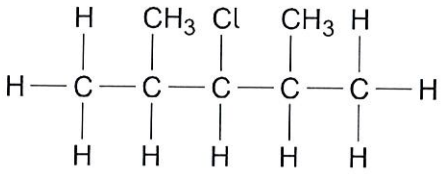
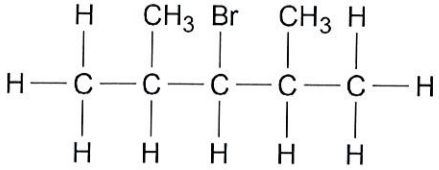
0 6 . 6 Compound **D** reacts with dilute aqueous sodium hydroxide in a similar way to **A** to form alcohol **B**.

Compound A



Compound D



Explain why **D** reacts more quickly than **A** with dilute aqueous sodium hydroxide at the same temperature.

[1 mark]

C-Br bond is weaker than C-Cl

or C-Br bond breaks more easily than C-Cl

15

Turn over for the next question

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0 7 . 1 Four compounds, all colourless liquids, are

- butan-2-ol 1° alcohol
- butanal aldehyde
- butanone ketone
- 2-methylpropan-2-ol 3° alcohol

Two of these compounds can be identified using different test-tube reactions.

Describe these **two** test-tube reactions by giving reagents and observations in each case.
Suggest how the results of a spectroscopic technique could be used to distinguish between the **other** two compounds.

[6 marks]

- Acidified potassium dichromate
  Reacts butan-2-ol and butanol only
  (Orange to) green
- Tollens' or Fenlings
  Reacts butanal only
  silver mirror or (blue to) red ppt
- IR
  Alcohols OH 3230-3550
  Aldehyde and ketone C=O 1680-1750
  Fingerprint region can be used to distinguish between molecules with same functional groups

Do not write outside the box

6

Do not write outside the box

0 8 Methanol can be manufactured in a reversible reaction as shown by the equation.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

0 8 . 1 State and explain the effect of using a catalyst on the yield of methanol in this equilibrium.

[2 marks]

- no effect on yield
- increases rate of both forward and backward reactions equally

0 8 . 2 Give an expression for the equilibrium constant (K_c) for this reaction.

[1 mark]

$$K_c = \frac{[CH_3OH]}{[CO][H_2]^2}$$

Do not write outside the box

0 8 . 3 A mixture of carbon monoxide and hydrogen was allowed to reach equilibrium in a container of volume 250 cm^3 at temperature T.
At equilibrium, the mixture contained 0.340 mol of carbon monoxide, 0.190 mol of hydrogen and 0.0610 mol of methanol.

Calculate the value of the equilibrium constant (K_c) for this reaction at temperature T.

[3 marks]

$$K_c = \frac{0.0610 / 250\times10^{-3}}{\left(\frac{0.34}{250\times10^{-3}}\right)\left(\frac{0.19}{250\times10^{-3}}\right)^2}$$ M1 M2

$$= \frac{0.244}{1.36 \times 0.76^2}$$

K_c 0.311 $mol^{-2}\ dm^6$ M3

0 8 . 4 Methanol decomposes on heating in a reaction that is the reverse of that used in its manufacture.

$$CH_3OH(g) \rightleftharpoons CO(g) + 2H_2(g)$$

Use your answer from Question **08.3** to determine the value of K_c for this equilibrium at temperature T.
State the units for this value of K_c

(If you were unable to complete the calculation in Question **08.3**, assume a value of $K_c = 0.825\ mol^{-2}\ dm^6$. This is **not** the correct value.)

[2 marks]

$$K_c = \frac{[CO][H_2]^2}{[CH_3OH]}$$

$$K_c = \frac{1}{0.311} \quad mol^{-2}\ dm^6$$

Value of K_c 3.22 M1

Units of K_c $mol^2\ dm^{-6}$ M2

8

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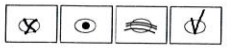
Section B

Answer **all** questions in this section.

Only **one** answer per question is allowed.
For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD  WRONG METHODS 

If you want to change your answer you must cross out your original answer as shown. 

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. 

You may do your working in the blank space around each question but this will not be marked.
Do **not** use additional sheets for this working.

0 9 A student has a 10 cm^3 sample of 1.00×10^{-2} mol dm^{-3} methanoic acid solution. The student is asked to dilute the methanoic acid solution to a concentration of 2.00×10^{-4} mol dm^{-3} by adding distilled water.

Which volume of water should be added?

[1 mark]

$n_1 = n_2$

$c_1 V_1 = c_2 V_2$

$1 \times 10^{-2} \times 10 \times 10^{-3} = 2 \times 10^{-4} V_2$

$V_2 = \frac{1 \times 10^{-2} \times 10 \times 10^{-3}}{2 \times 10^{-4}}$

$= 0.5\ dm^3 \Rightarrow 500\ cm^3$

water added $500 - 10 = 490\ cm^3$

A $200\ cm^3$ ○

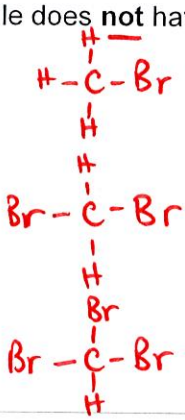
B $490\ cm^3$ ●

C $500\ cm^3$ ○

D $510\ cm^3$ ○

1 0 Which molecule does **not** have a permanent dipole?

[1 mark]



A CH_3Br ○

B CH_2Br_2 ○

C $CHBr_3$ ○

D CBr_4 ●

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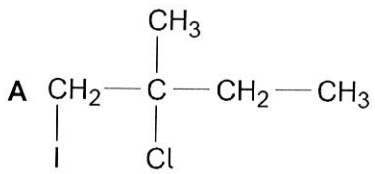
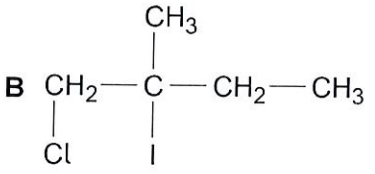
1 1 Which is the major product of the reaction between 2-methylbut-2-ene and iodine monochloride (ICl)?

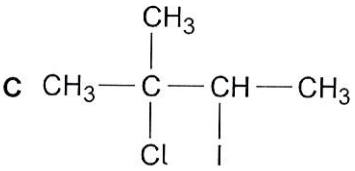
[1 mark]



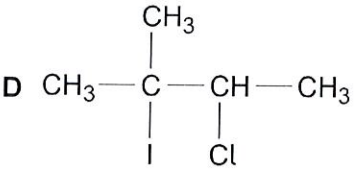
A



B



C



D

1 2 Which statement is **not** correct about the industrial preparation of ethanol by the hydration of ethene at 300 °C?

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -46 \text{ kJ mol}^{-1}$$

[1 mark]

A The reaction is catalysed by an acid.

B The higher the pressure, the higher the equilibrium yield of ethanol.

C The higher the temperature, the higher the equilibrium yield of ethanol.

D A low equilibrium yield of ethanol is acceptable because unreacted ethene is recycled.

Do not write outside the box

1 3 Which compound has the highest boiling point?

[1 mark]

A butanal ○

B butan-2-ol ● hydrogen bonding

C but-2-ene ○

D 1-fluorobutane ○

1 4 Which statement is correct about the fractional distillation of crude oil?

[1 mark]

A A zeolite catalyst is used. ○

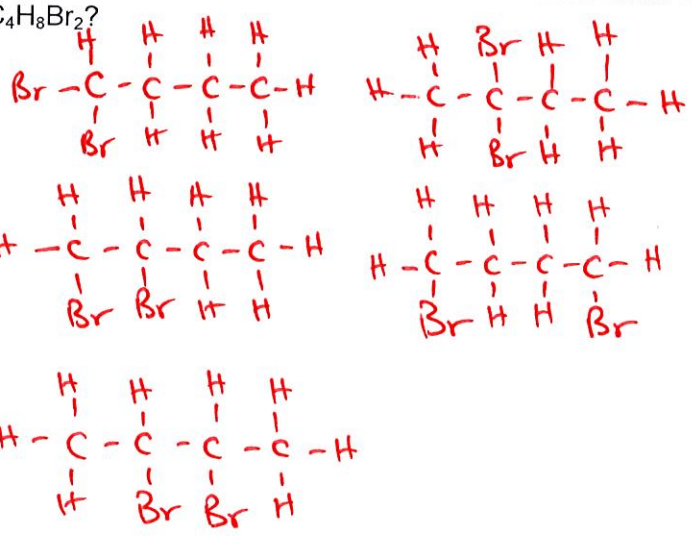
B Each fraction contains a mixture of hydrocarbons. ●

C Gaseous fractions are formed by breaking covalent bonds. ○

D The fractionating column is hottest at the top. ○

1 5 How many structural isomers with an unbranched carbon chain have the molecular formula $C_4H_8Br_2$?

[1 mark]



A 4 ○

B 5 ●

C 6 ○

D 7 ○

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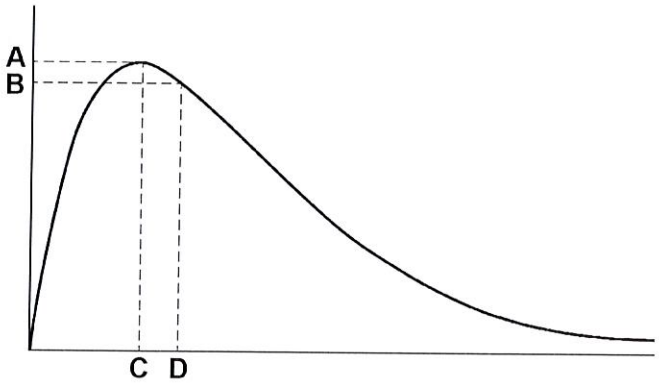
1 6 The Maxwell–Boltzmann distribution of molecular energies in a sample of gas at a fixed temperature is shown.

Which letter represents the mean energy of the molecules?

[1 mark]



A ○

B ○

C ○

D ●

1 7 Ethanol can be made from glucose by fermentation.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

1.44kg 1440 g

In an experiment, 268 g of ethanol (M_r = 46.0) were made from 1.44 kg of glucose (M_r = 180.0).

What is the percentage yield?

[1 mark]

n(glucose) = $\frac{1440}{180}$ = 8

n(ethanol) = 2 × 8 = 16

m(ethanol) = 16 × 46 = 736

yield = $\frac{268}{736}$ × 100 = 36.4%

A 18.6% ○

B 36.4% ●

C 51.1% ○

D 72.8% ○

Turn over ▶

Do not write outside the box

18 Which species could act as a nucleophile?

[1 mark]

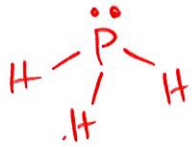
A BH_3

B NH_4^+

C PH_3

D SiH_4

lone pair donor



19 Which statement is correct about poly(chloroethene)?

[1 mark]

A It has the empirical formula CHCl

B It decolourises bromine water.

C Its brittleness is reduced by plasticisers.

D Its polymer chain contains alternate single and double bonds.

20 What is the enthalpy of formation of buta-1,3-diene, $C_4H_6(g)$?

Substance	Enthalpy of combustion / kJ mol^{-1}
$C_4H_6(g)$	–2546
C(s)	–394
$H_2(g)$	–286

[1 mark]

$4C + 3H_2 \rightarrow C_4H_6$

$\Delta H_f = \Sigma \Delta H_c(R) - \Sigma \Delta H_c(P)$

$= [4(-394) + 3(-286)] - [-2546]$

$= (-2434) - (-2546)$

$= +112$

A +112 kJ mol^{-1}

B –112 kJ mol^{-1}

C +746 kJ mol^{-1}

D –746 kJ mol^{-1}

Do not write outside the box

2 1 A gas cylinder contains 5.0 kg of propane. 5000 g Mr C_3H_8 = 44.0

How many propane molecules are in the cylinder?

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

[1 mark]

no. molecules = nL

A 6.8×10^{22} $n\,C_3H_8 = \frac{5000}{44} = 113.6$ ○

B 7.2×10^{22} ○

C 6.8×10^{25} no. = $113.6 \times 6.022 \times 10^{23}$ ●

D 7.2×10^{25} ○

2 2 Which sample of liquid has the greatest volume?

$d = \frac{m}{v} \Rightarrow v = \frac{m}{d}$

[1 mark]

A 500 mg of pentane (density = 0.63 g cm^{-3}) ○
0.5 / 0.63 = 0.79

B 650 mg of propan-1-ol (density = 0.80 g cm^{-3}) ○
0.65 / 0.8 = 0.81

C 1.20 g of dichloromethane (density = 1.33 g cm^{-3}) ●
1.2 / 1.33 = 0.90

D 1.30 g of trichloromethane (density = 1.48 g cm^{-3}) ○
1.3 / 1.48 = 0.87

2 3 Which equation represents an initiation step?

[1 mark]

A $CH_3CH_2\dot{C}HBr + Br_2 \longrightarrow CH_3CH_2CHBr_2 + \dot{B}r$ ○

B $O_3 + \dot{C}l \longrightarrow O_2 + \dot{C}lO$ ○

C $RCH_2\dot{C}H_2 + H_2C{=}CH_2 \longrightarrow RCH_2CH_2CH_2\dot{C}H_2$ ○

D $CH_3CFCl_2 \longrightarrow CH_3\dot{C}FCl + \dot{C}l$ ●

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END OF QUESTIONS