AQA

Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

AS CHEMISTRY

Paper 2 Organic and Physical Chemistry

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.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

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

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**.

Do not write outside the box

Section A

Answer **all** questions in this section.

0 1 This question is about rates of reaction.

Potassium manganate(VII), $KMnO_4$, reacts with sodium ethanedioate, $Na_2C_2O_4$, in the presence of dilute sulfuric acid.

$$2\,MnO_4^-(aq) + 16\,H^+(aq) + 5\,C_2O_4^{2-}(aq) \rightarrow 2\,Mn^{2+}(aq) + 8\,H_2O(l) + 10\,CO_2(g)$$

The reaction mixture is purple at the start and goes colourless when all the $MnO_4^-(aq)$ ions have reacted.

The rate of reaction can be measured as $\frac{1000}{t}$ where t = the time taken for the mixture to go colourless.

A student investigated how long it takes for this reaction mixture to go colourless at different temperatures. The same concentrations and volumes of each reagent were used in an experiment at each temperature. **Table 1** shows the results.

Table 1

Temperature / °C	32	38	44	54	67
Time *t* / s	155	85	50	22	9
$\frac{\mathbf{1000}}{\boldsymbol{t}}$	6.45	11.8	20.0	45.5	

0 1 . 1 Complete **Table 1**.

[1 mark]

0 1 . 2 State the independent variable in this investigation.

[1 mark]

0 1 . 3 The student noticed that the temperature of each reaction mixture decreased during each experiment.

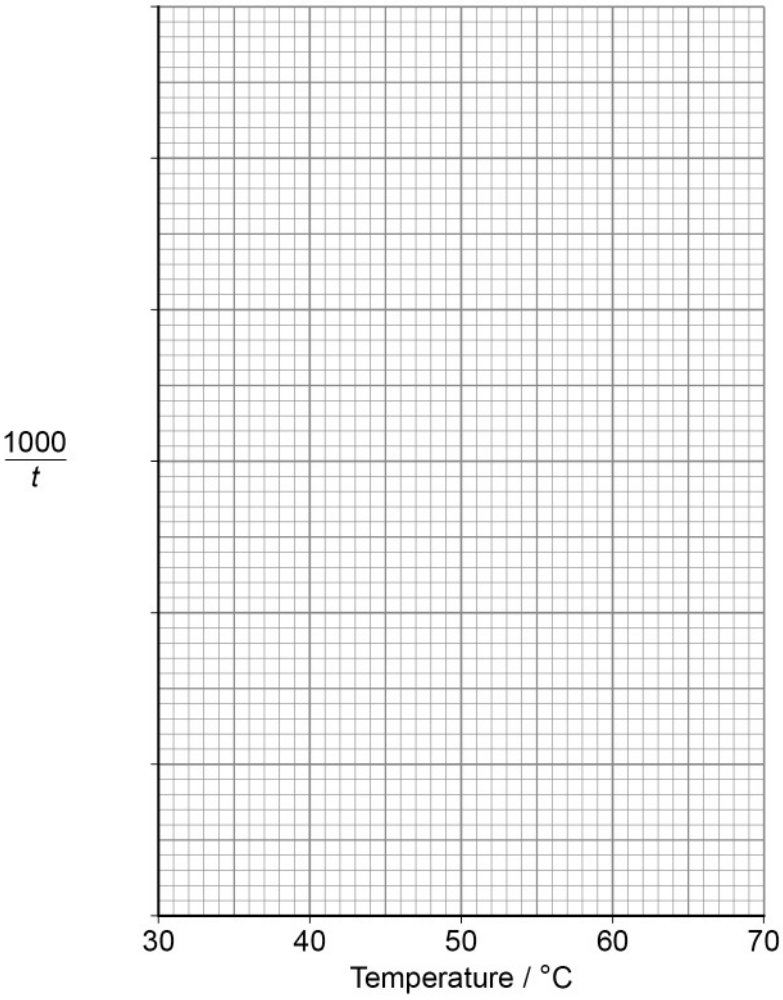
Suggest how the student calculated the temperature values in **Table 1**.

[1 mark]

Do not write outside the box

0 1 . 4 Use the data in **Table 1** to plot a graph of $\frac{1000}{t}$ against temperature.

[3 marks]



0 1 . 5 Use your graph in Question **01.4** to find the time taken for the mixture to go colourless at 60 °C
Show your working.

[1 mark]

Time *t* _____ s

Turn over ►

Do not write outside the box

0 1 . 6 The investigation shows that increasing the temperature causes the rate of reaction to increase.

Explain why a small increase in temperature causes a large increase in the rate of reaction.

[2 marks]

9

Do not write outside the box

Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

0 2 A student has samples of these four compounds but does not know which is which:

- butanoic acid
- 2-methylpropanal
- 2-methylpropanoic acid
- 2-methylpropan-1-ol

Step 1: Two of these compounds can be identified by simple chemical tests.

Step 2: The other two compounds, that contain the same functional group as each other, can then be distinguished using a spectroscopic technique.

Describe how these two steps could be used to identify which compound is which.

[6 marks]

Do not write outside the box

6

Turn over ►

Do not write outside the box

0 3 This question is about isomers.

Hex-2-ene has the molecular formula C_6H_{12}

0 3 . 1 Draw the displayed formula of a **position** isomer of hex-2-ene that exists as *E* and *Z* isomers.

[1 mark]

0 3 . 2 Draw the displayed formula of a **chain** isomer of hex-2-ene that does **not** exist as *E* and *Z* isomers.

[1 mark]

Butanal has the molecular formula C_4H_8O

0 3 . 3 Draw the skeletal formula of a **functional group** isomer of butanal that has an absorption in the range 1680–1750 cm^{-1} in its infrared spectrum.

[1 mark]

Do not write outside the box

0 3 . 4 Draw the skeletal formula of a structural isomer of butanal that has an absorption in the range 3230–3550 cm^{-1} in its infrared spectrum.

[1 mark]

0 3 . 5 Several saturated halogenoalkanes contain 17.8% carbon, 3.0% hydrogen and 79.2% bromine by mass.

Calculate the empirical formula of these compounds.

Give the IUPAC names of **two** saturated halogenoalkanes that have this empirical formula.

[4 marks]

Empirical formula _____

Names of halogenoalkanes

1 _____

2 _____

8

Turn over ►

Do not write outside the box

0 4 This question is about gas volumes.

0 4 . 1 TNT ($C_7H_5N_3O_6$) is an explosive because it can decompose very quickly and exothermically to form a large volume of gas. An equation for this decomposition is

$$2\,C_7H_5N_3O_6(s) \rightarrow 3\,N_2(g) + 5\,H_2(g) + 12\,CO(g) + 2\,C(s)$$

Calculate the volume of gas, in m^3, measured at 1250 °C and 101 000 Pa, produced by the decomposition of 1.00 kg of TNT (M_r = 227.0).

The gas constant, R = 8.31 J mol^{-1} K^{-1}

[5 marks]

Volume of gas _____ m^3

Do not write outside the box

0 4 . 2 Alkenes have the general formula C_nH_{2n}

When alkenes undergo complete combustion, 1.0 mol of C_nH_{2n} reacts with $\frac{3n}{2}$ mol of oxygen.

Calculate the volume of oxygen needed for the complete combustion of 200 cm^3 of but-1-ene.

The volumes of all gases are measured at the same temperature and pressure.

[1 mark]

Volume of oxygen _____ cm^3

0 4 . 3 Alkanes have the general formula C_nH_{2n+2}

Alkanes undergo complete combustion in a plentiful supply of oxygen.

$$C_nH_{2n+2} + x\,O_2 \rightarrow n\,CO_2 + (n+1)\,H_2O$$

Determine x in terms of n

[1 mark]

x _____

7

Turn over for the next question

Do not write outside the box

0 5 This question is about the synthesis of propylamine ($CH_3CH_2CH_2NH_2$) by the reaction of 1-iodopropane ($CH_3CH_2CH_2I$) with an excess of ammonia.

$$CH_3CH_2CH_2I + 2\,NH_3 \rightarrow CH_3CH_2CH_2NH_2 + NH_4I$$

0 5 . 1 Name and outline the mechanism for this reaction.

[5 marks]

Name of mechanism _____

Outline of mechanism

Do not write outside the box

0 5 . 2 1-iodopropane is a liquid at room temperature.

Calculate the number of molecules in 5.0 cm^3 of 1-iodopropane (M_r = 169.9). Give your answer in standard form.

For 1-iodopropane, density = 1.75 g cm^{-3}

The Avogadro constant, L = 6.022 x 10^{23} mol^{-1}

[2 marks]

Number of molecules _____

0 5 . 3 In an experiment, 10.3 g of 1-iodopropane (M_r = 169.9) are reacted with an excess of ammonia. 2.3 g of propylamine (M_r = 59.0) are produced.

Calculate the percentage yield in this experiment.

[2 marks]

Percentage yield _____

9

Do not write outside the box

0 6 Trichlorofluoromethane (CCl_3F) was developed as a refrigerant. The production and use of CCl_3F is now restricted.

0 6 . 1 The equation for a process used to manufacture CCl_3F is

$$SbF_3Br_2 + CCl_4 \rightarrow CCl_3F + SbF_2Br_2Cl$$

Calculate the percentage atom economy for the production of CCl_3F in this reaction. Give your answer to 3 significant figures.

[2 marks]

Percentage atom economy _____

An alternative synthesis of CCl_3F is the free-radical substitution reaction between fluoromethane (CH_3F) and chlorine.

0 6 . 2 An intermediate in this alternative synthesis is dichlorofluoromethane ($CHCl_2F$)

Give equations to represent the two propagation steps in the conversion of $CHCl_2F$ into CCl_3F

[2 marks]

Propagation step 1

_____

Propagation step 2

_____

Do not write outside the box

0 6 . 3 Analysis of the products of this reaction shows the formation of a compound with the empirical formula CCl_2F

Give an equation to represent a termination step forming this compound.
Show the structural formula of the product in the equation.

[1 mark]

5

Turn over for the next question

Do not write outside the box

0 7 In Europe, some of the glucose from crops is fermented to produce ethanol.

Use of a carbon-neutral fuel leads to no net emissions of carbon dioxide to the atmosphere.

0 7 . 1 The ethanol produced by fermentation of glucose may be regarded as a carbon-neutral fuel.

Justify this statement. Include the relevant chemical equations in your answer.

[4 marks]

Coffee beans from South America are exported to Europe in an outer layer called silverskin.

The waste silverskin can be fermented to produce a solution containing propanone, ethanol and butan-1-ol.

0 7 . 2 Suggest why ethanol produced in Europe using silverskin from South America is less likely to be carbon-neutral than ethanol produced from crops grown in Europe.

[1 mark]

Do not write outside the box

0 7 . 3 **Table 2** shows the enthalpies of combustion of the three fuels from the fermentation of silverskin.

Table 2

Fuel	**Standard enthalpy of combustion / kJ mol^{-1}**	**Energy released per mole of CO_2 produced / kJ**
ethanol, $C_2H_5OH(l)$	–1371	
butan-1-ol, $C_4H_9OH(l)$	–2673	
propanone, $C_3H_6O(l)$	–1786	

One way to measure a fuel's environmental impact is to measure the amount of energy released per mole of CO_2 produced.

Complete **Table 2**.

Use your answers to deduce the fuel with the lowest environmental impact by this measure.

[2 marks]

Question 7 continues on the next page

Do not write outside the box

0 7 . 4 A student investigated the combustion of propanone (C_3H_6O) using calorimetry.

A copper calorimeter containing water was heated by the complete combustion of some propanone. The student did not record the final temperature of the water.

Table 3 shows the student's results.

Table 3

Mass of propanone burned / g	1.18
Mass of water / g	260
Initial temperature of water / °C	22.3
Final temperature of water / °C	Not recorded

Use the results in **Table 3** to calculate a value for final temperature of the water in the experiment.

Assume that no heat was lost in the experiment and that the heat capacity of the calorimeter is negligible.

For propanone, enthalpy of combustion = –1786 kJ mol^{-1}

For water, specific heat capacity = 4.18 J g^{-1} K^{-1}

[4 marks]

Final temperature of water _____ °C

Do not write outside the box

0 7 . 5 Butan-1-ol can be added to petrol for cars.

An equation for the complete combustion of gaseous butan-1-ol is shown.

$$C_4H_9OH(g) + 6\,O_2(g) \rightarrow 4\,CO_2(g) + 5\,H_2O(g) \quad \Delta H = -2504 \text{ kJ mol}^{-1}$$

Table 4 shows some mean bond enthalpy data.

Table 4

Bond	C=O	C–H	C–O	O–H	O=O
Mean bond enthalpy / kJ mol^{-1}	805	412	360	463	496

Use these data to calculate a value for the mean C–C bond enthalpy in gaseous butan-1-ol.

[3 marks]

C–C bond enthalpy _____ kJ mol^{-1}

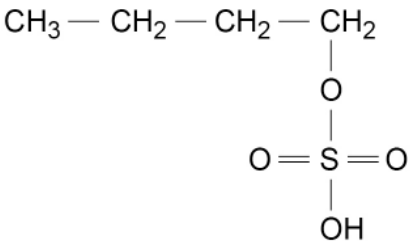
Question 7 continues on the next page

Turn over ►

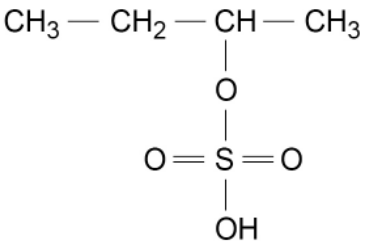
Do not write outside the box

Butan-1-ol can be manufactured by reacting steam with but-1-ene in the presence of the catalyst, concentrated sulfuric acid.

In the first part of this process, but-1-ene reacts with concentrated sulfuric acid to form compounds **W** and **X**.



Compound **W**



Compound **X**

Butan-1-ol is then made from compound **W**.

0 7 . 6 Name and outline a mechanism to show the conversion of but-1-ene into compound **W** in the first part of this process.

[5 marks]

Name of mechanism _____

Outline of mechanism

Do not write outside the box

0 7 . 7 There is a very low yield of butan-1-ol from but-1-ene in this manufacturing process.

Explain why.

[2 marks]

21

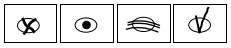
Turn over for Section B

Do not write outside the box

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 8 When hexadecane ($C_{16}H_{34}$) is heated to a high temperature, one molecule of hexadecane decomposes to form an alkane containing eight carbon atoms and two different unsaturated compounds.

Which equation could represent this reaction?

[1 mark]

A $C_{16}H_{34} \rightarrow C_8H_{16} + C_5H_{12} + C_3H_6$ ⬭

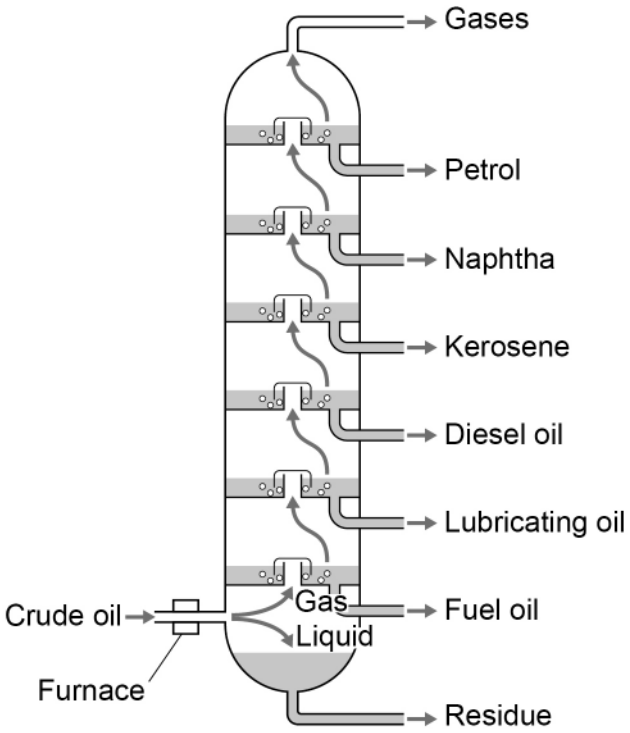
B $C_{16}H_{34} \rightarrow C_8H_{18} + C_6H_{10} + C_2H_6$ ⬭

C $C_{16}H_{34} \rightarrow C_8H_{18} + 2\,C_2H_4 + C_4H_8$ ⬭

D $C_{16}H_{34} \rightarrow C_8H_{18} + C_6H_{14} + C_2H_2$ ⬭

Do not write outside the box

0 9 The diagram shows a fractionating column used in the industrial fractional distillation of crude oil.



Which statement is correct?

[1 mark]

A The most viscous product is fuel oil. ⬭

B The boiling point of naphtha is higher than diesel oil. ⬭

C Molecules in diesel oil are held together by hydrogen bonds. ⬭

D Kerosene is a mixture of compounds. ⬭

1 0 Which statement about poly(ethene) is correct?

[1 mark]

A It has a lower relative molecular mass than ethene. ⬭

B It has a lower density than ethene at standard temperature and pressure. ⬭

C It has a higher melting point than ethene. ⬭

D It decolourises bromine water. ⬭

Turn over ►

Do not write outside the box

1 1 A polymer is formed from the monomer $CH_2=CHCN$

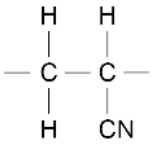
Which statement is **not** correct?

[1 mark]

A The monomer is propanenitrile. ⬭

B The monomer is unsaturated. ⬭

C The polymer is an addition polymer. ⬭

D The polymer has the repeating unit  ⬭

1 2 Which alcohol when dehydrated forms a mixture of alkenes?

[1 mark]

A propan-1-ol ⬭

B propan-2-ol ⬭

C pentan-1-ol ⬭

D pentan-2-ol ⬭

1 3 Which compound has the highest boiling point?

[1 mark]

A $CH_3COCH_2CH_3$ ⬭

B $CH_3CH_2CH_2CH_2OH$ ⬭

C $CH_3CH_2CH_2CHO$ ⬭

D $CH_3CH_2CH_2CH_2CH_3$ ⬭

Do not write outside the box

1 4 Which statement about molecules in a gas is correct?

[1 mark]

A At a fixed temperature they all move at the same speed. ⬭

B At a fixed temperature their average kinetic energy is constant. ⬭

C As temperature increases, there are more molecules with the most probable energy. ⬭

D As temperature decreases, there are fewer molecules with the mean energy. ⬭

1 5 Which compound produces $(CH_3)_2CHCOCH_3$ when oxidised?

[1 mark]

A 2-methylpropan-1-ol ⬭

B 2,2-dimethylpropanol ⬭

C 2-methylbutan-2-ol ⬭

D 3-methylbutan-2-ol ⬭

1 6 Which reaction does **not** result in a change in the shape around a carbon atom?

[1 mark]

A chloromethane with aqueous sodium hydroxide ⬭

B ethene with bromine ⬭

C propane with excess oxygen ⬭

D propan-1-ol with acidified potassium dichromate(VI) ⬭

Do not write outside the box

1 7 Which compound has the same empirical formula and molecular formula?

[1 mark]

A butane ⬭

B but-1-ene ⬭

C propane ⬭

D propene ⬭

Questions **18**, **19** and **20**

Methanol is made in this equilibrium reaction, using a catalyst.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91 \text{ kJ mol}^{-1}$$

1 8 The reaction reaches equilibrium in a container of fixed volume.

Which is the expression for K_c for this equilibrium?

[1 mark]

A $K_c = \dfrac{[CH_3OH]}{[CO] + [H_2]^2}$ ⬭

B $K_c = \dfrac{[CH_3OH]}{[CO]\,[H_2]^2}$ ⬭

C $K_c = \dfrac{[CO] + [H_2]^2}{[CH_3OH]}$ ⬭

D $K_c = \dfrac{[CO]\,[H_2]^2}{[CH_3OH]}$ ⬭

Do not write outside the box

1 9 2.0 mol of carbon monoxide is mixed with 3.0 mol of hydrogen and allowed to reach equilibrium.

The equilibrium mixture contains 0.6 mol of methanol.

What is the total amount, in mol, of gas at equilibrium?

[1 mark]

A 3.2 ⬭

B 3.8 ⬭

C 4.4 ⬭

D 5.0 ⬭

2 0 Which change in condition will decrease the equilibrium yield of methanol?

[1 mark]

A Increase the amount of CO in the equilibrium mixture. ⬭

B Increase the pressure. ⬭

C Increase the surface area of the catalyst. ⬭

D Increase the temperature. ⬭

Turn over for the next question

Do not write outside the box

Questions **21** and **22**

When 2-bromobutane is warmed with potassium hydroxide solution, substitution and elimination reactions both occur.

2 1 Which of these compounds is **not** produced?

[1 mark]

A butan-1-ol ⬭

B butan-2-ol ⬭

C but-1-ene ⬭

D *E*-but-2-ene ⬭

2 2 What is the role of the hydroxide ions in the elimination reaction?

[1 mark]

A base ⬭

B catalyst ⬭

C electrophile ⬭

D nucleophile ⬭

15

END OF QUESTIONS

Do not write outside the box

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

Do not write outside the box

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

Do not write outside the box

Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**
	Copyright information For confidentiality purposes, all acknowledgements of third-party copyright material are published in a separate booklet. This booklet is published after each live examination series and is available for free download from www.aqa.org.uk. Permission to reproduce all copyright material has been applied for. In some cases, efforts to contact copyright-holders may have been unsuccessful and AQA will be happy to rectify any omissions of acknowledgements. If you have any queries please contact the Copyright Team. Copyright © 2022 AQA and its licensors. All rights reserved.