

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

AS CHEMISTRY

Paper 2 Organic and Physical Chemistry

Thursday 21 May 2020

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.
- 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.

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	



J U N 2 0 7 4 0 4 2 0 1

Section A

Answer **all** questions in this section.

0 1

This question is about 1-chloropropane.

0 1 . 1

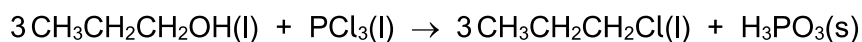
Define the term standard enthalpy of formation.

[2 marks]

The enthalpy change when 1 mol of a compound is formed from its constituent elements, with all reactants and products in their standard states (100 kPa and a stated temperature, usually 298 K).

0 1 . 2

The equation for a reaction used to manufacture 1-chloropropane is

The enthalpy change for this reaction, ΔH , is -114 kJ mol^{-1} **Table 1** contains some standard enthalpy of formation data.**Table 1**

Substance	$\text{PCl}_3\text{(l)}$	$\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl(l)}$	$\text{H}_3\text{PO}_3\text{(s)}$
$\Delta_f H^\ominus / \text{kJ mol}^{-1}$	-339	-130	-972

Calculate a value for the standard enthalpy of formation of propan-1-ol using the enthalpy change for the reaction and data from **Table 1**.**[3 marks]**

$$\Delta H = \sum \Delta_f H(\text{products}) - \sum \Delta_f H(\text{reactants})$$

$$-114 = [3(-130) + (-972)] - [3X + (-339)]$$

$$3X = 3(-130) - 972 + 339 + 114$$

$$3X = -909$$

$$X = -909 \div 3 = -303$$

Standard enthalpy of formation -303 kJ mol^{-1} 

0 1 . 3

1-chloropropane can also be produced by the reaction between propane and chlorine in the presence of ultraviolet light.

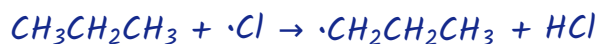
State why ultraviolet light is needed for this reaction to occur.

Give an equation for each propagation step in the formation of 1-chloropropane from propane.

[3 marks]

Why ultraviolet light is needed It provides the energy to break the
(covalent) Cl-Cl bond in chlorine, $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$, forming chlorine free
radicals.

Propagation step 1



Propagation step 2



0 1 . 4

The C-Cl bond in 1-chloropropane is polar because carbon and chlorine have different electronegativities.

Define the term electronegativity.

[1 mark]

The power (ability) of an atom to attract the pair of electrons in a
covalent bond.

Question 1 continues on the next page

Turn over ►



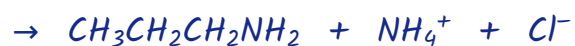
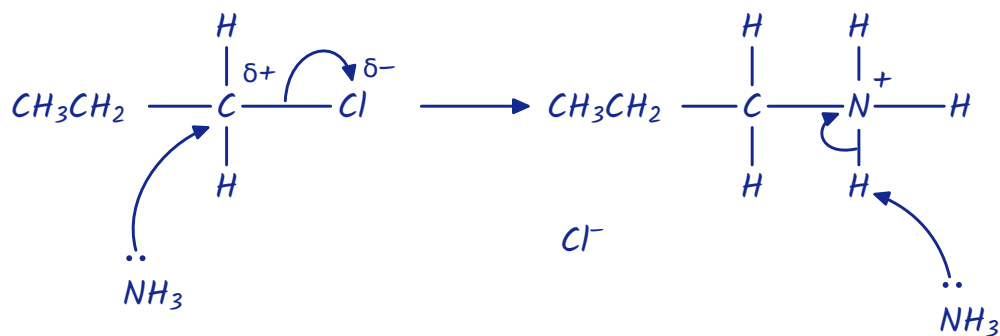
0 1 . 5

Ammonia reacts with 1-chloropropane to form propylamine.

Name and outline the mechanism for this reaction.

[5 marks]Name of mechanism Nucleophilic substitution

Outline of mechanism



Turn over for the next question

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ANSWER IN THE SPACES PROVIDED**

Turn over ►



0 2

A student investigates the effect of temperature on the rate of reaction between sodium thiosulfate solution and dilute hydrochloric acid.



The student mixes the solutions together in a flask and places the flask on a piece of paper marked with a cross.

The student records the time for the cross to disappear. The cross disappears because the mixture becomes cloudy.

Table 2 shows the student's results.

Table 2

Temperature / °C	22	31	36	42	49	54
Time, t, for cross to disappear / s	87	48	36	26	44	12
$\frac{1}{t} / \text{s}^{-1}$	0.0115	0.0208	0.0278	0.0385	0.0227	0.0833

0 2 . 1

The student uses a stopwatch to measure the time. The stopwatch shows each time to the nearest 0.01 s

Suggest why the student records the times to the nearest second and not to the nearest 0.01 s

[1 mark]

It is hard to judge the exact moment the cross disappears (because of the student's reaction time), so the time cannot be measured to 0.01 s.

0 2 . 2

The rate of reaction is proportional to $\frac{1}{t}$

Complete **Table 2**.

[1 mark]



0 2 . 3

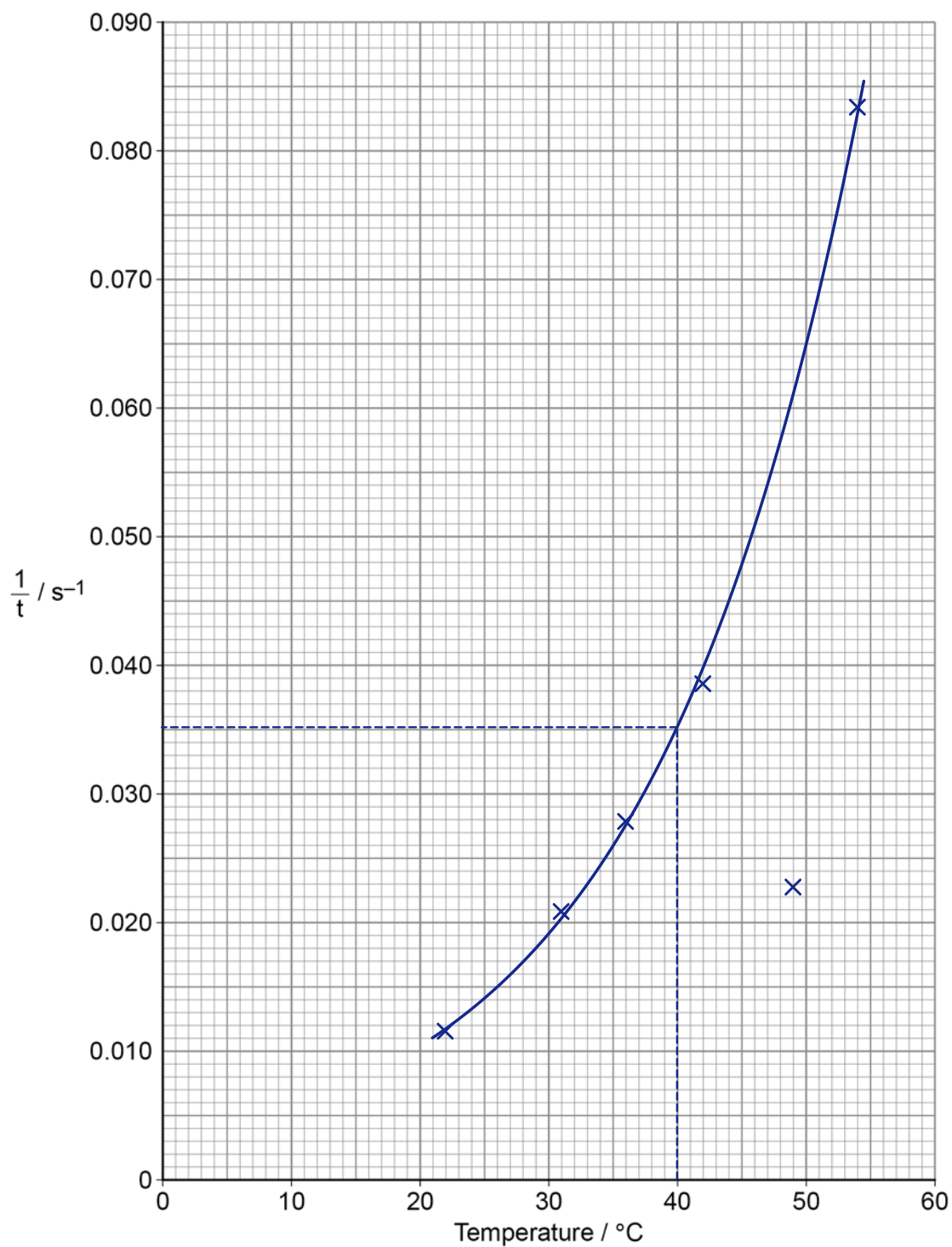
Plot the values of $\frac{1}{t}$ against temperature on **Figure 1**.

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Draw a line of best fit.

[2 marks]

Figure 1



Question 2 continues on the next page

Turn over ►



0 2 . 4

Use your line of best fit to estimate the time for the cross to disappear at 40 °C
Show your working.

[1 mark]

From my line of best fit, at 40 °C $1/t = 0.0351 \text{ s}^{-1}$

$$t = 1 \div 0.0351 = 28.5 \text{ s}$$

Time 28.5 s

0 2 . 5

Suggest, by considering the products of this reaction, why small amounts of reactants are used in this experiment.

[1 mark]

One of the products, SO_2 , is a toxic gas, so using small amounts limits the amount of SO_2 formed.

0 2 . 6

The student could do the experiment at lower temperatures using an ice bath.

Suggest why the student chose **not** to carry out experiments at temperatures in the range 1–10 °C

[1 mark]

At these low temperatures the reaction would be very slow, so it would take too long for the cross to disappear.



Turn over for the next question

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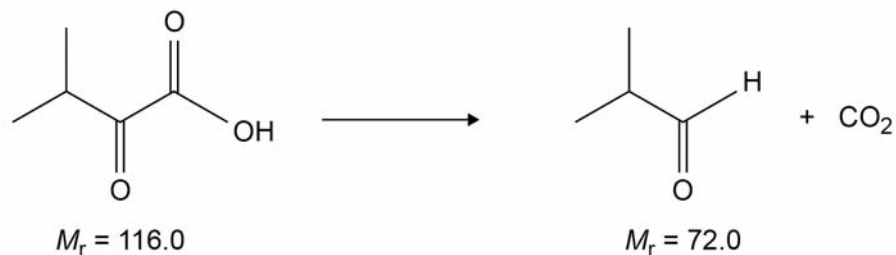
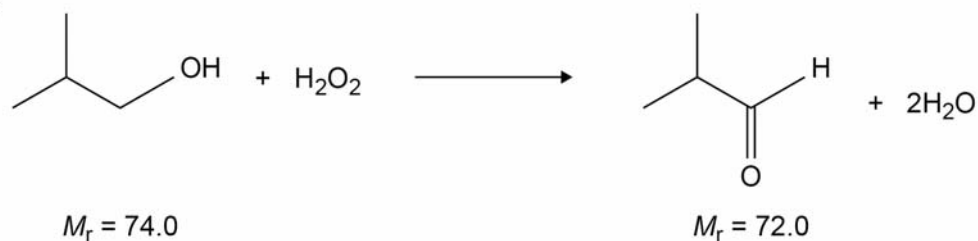
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0 3

A student investigates two experimental methods of making methylpropanal. The equations for these two methods are shown.

Method 1**Method 2**

In each method, the student uses 1.00 g of organic starting material.

The yield of methylpropanal obtained using each method and other data are included in **Table 3**.

Table 3

	Method 1	Method 2
Yield of methylpropanal / mg	552	778
Percentage yield	88.9%	80.0%
Percentage atom economy	62.1%	66.7%

Calculate the percentage yield for Method 1.

Calculate the percentage atom economy for Method 2.

State the importance of percentage yield and percentage atom economy when choosing the method used to make a compound.

[6 marks]



$$\text{Moles of starting material} = 1.00 \div 116.0 = 0.00862 \text{ mol}$$

$$\text{Moles of methylpropanal} = 0.552 \div 72.0 = 0.00767 \text{ mol}$$

$$(1 : 1 \text{ ratio, so the maximum mass} = 0.00862 \times 72.0 = 0.621 \text{ g})$$

$$\% \text{ yield} = (0.00767 \div 0.00862) \times 100 = 88.9\%$$

$$\% \text{ yield } \underline{88.9\%}$$

Importance of percentage yield It shows how much of the product is actually obtained compared with the maximum possible. A high percentage yield means as much product as possible is made from the reactants, so the conversion of reactants to products is efficient and less starting material is wasted.

$$\text{Total } M_r \text{ of reactants} = 74.0 + 34.0 = 108.0$$

$$\begin{aligned} \% \text{ atom economy} &= (M_r \text{ of desired product} \div \text{total } M_r \text{ of reactants}) \times 100 \\ &= (72.0 \div 108.0) \times 100 = 66.7\% \end{aligned}$$

$$\% \text{ atom economy } \underline{66.7\%}$$

Importance of percentage atom economy It shows the proportion of the mass of the reactants (atoms) that ends up in the desired product. A high atom economy means as many reactant atoms as possible end up in the desired product, so the amount of by-products (waste) is minimised, which is more sustainable and cheaper.



0	4
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This question is about pentan-2-ol and pent-1-ene.

0	4	.	1
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The boiling point of pentan-2-ol is 119 °C

The boiling point of pent-1-ene is 30 °C

Explain why pentan-2-ol has a higher boiling point than pent-1-ene.

[3 marks]

Pentan-2-ol has stronger intermolecular forces than pent-1-ene, so more energy is needed to overcome them.

Pent-1-ene molecules only have van der Waals' forces between them.

Pentan-2-ol has hydrogen bonds between its molecules (because of the O-H group) as well as van der Waals' forces, and hydrogen bonds are much stronger than van der Waals' forces.



0 4 . 2

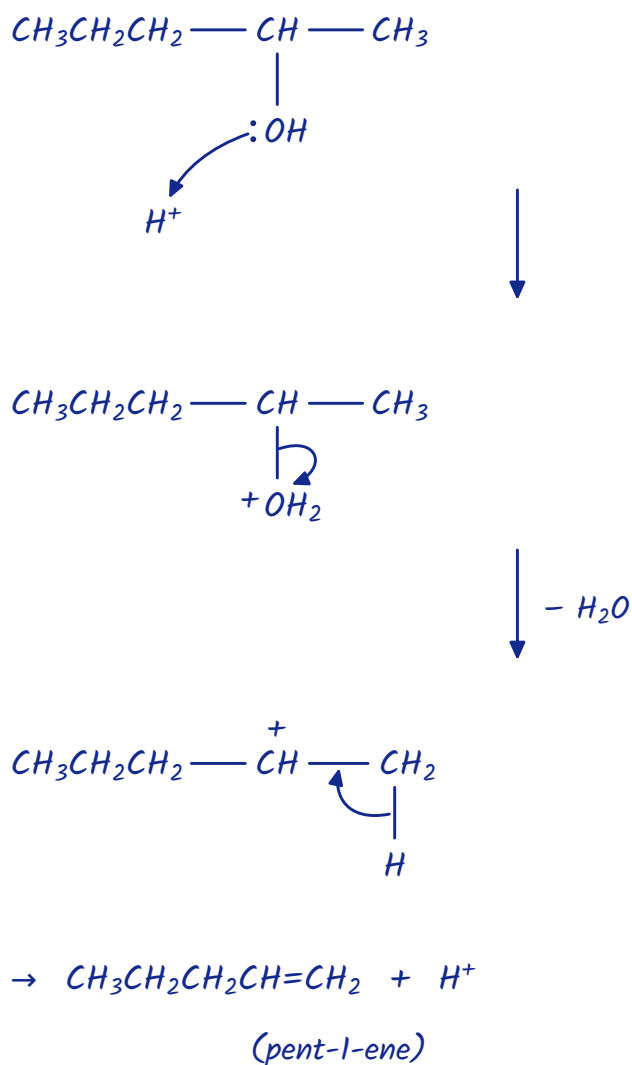
Pent-1-ene is formed by the elimination of water from pentan-2-ol.

State the reagent and condition for this reaction.

Outline the mechanism for this reaction.

[5 marks]Reagent concentrated sulfuric acidCondition hot, about 170 °C

Outline of mechanism



Turn over for the next question

Turn over ►



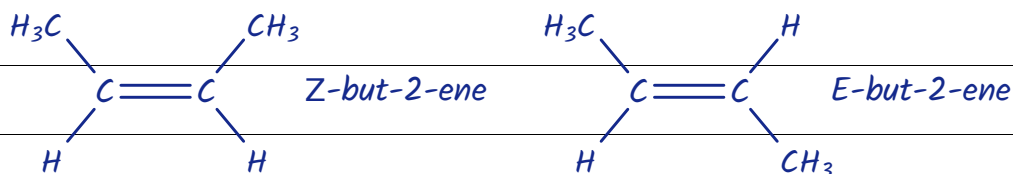
0 5

Explain the differences between structural isomerism and stereoisomerism. Use examples to show how compounds with the molecular formula C_4H_8 exhibit stereoisomerism and the three types of structural isomerism.

[6 marks]

Structural isomers are compounds with the same molecular formula but a different structural formula. Stereoisomers have the same molecular formula and the same structural formula, but a different arrangement of the atoms in space.

Stereoisomerism: C_4H_8 shows E/Z isomerism in but-2-ene, $CH_3CH=CHCH_3$. There is restricted (no) rotation about the $C=C$ double bond and each C of the $C=C$ has two different groups attached:



In Z-but-2-ene the two CH_3 groups (the higher priority groups) are on the same side of the double bond; in E-but-2-ene they are on opposite sides. The two isomers cannot interconvert because the $C=C$ cannot rotate.

Structural isomerism, type 1, chain isomerism: the carbon chain is different (branched or unbranched). For example but-1-ene, $CH_2=CHCH_2CH_3$ (straight chain) and methylpropene, $CH_2=C(CH_3)_2$ (branched chain).

Type 2, position isomerism: the same functional group is in a different position on the same carbon chain. For example but-1-ene, $CH_2=CHCH_2CH_3$ ($C=C$ between $C1$ and $C2$) and but-2-ene, $CH_3CH=CHCH_3$ ($C=C$ between $C2$ and $C3$).



Type 3, functional group isomerism: the compounds have different functional groups. For example cyclobutane (a cycloalkane, a ring of four CH_2 groups with no $\text{C}=\text{C}$) and but-1-ene (an alkene with a $\text{C}=\text{C}$ double bond); both are C_4H_8 .

So structural isomers differ in which atoms are bonded to which, whereas E and Z stereoisomers have the same bonding and differ only in the spatial arrangement about the $\text{C}=\text{C}$.



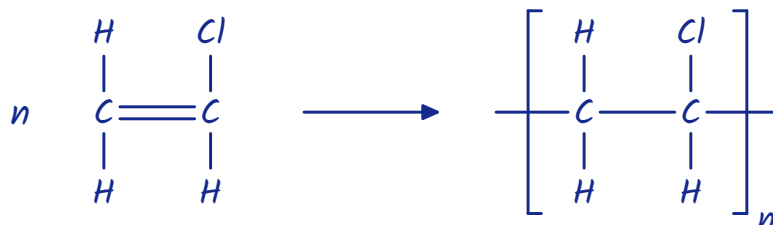
0 6

This question is about poly(chloroethene), commonly known as PVC.

0 6 . 1

Give an equation, showing structural formulas, for the conversion of chloroethene into poly(chloroethene).

[3 marks]



0 6 . 2

State what you would observe if bromine water was added to poly(chloroethene). Explain this observation.

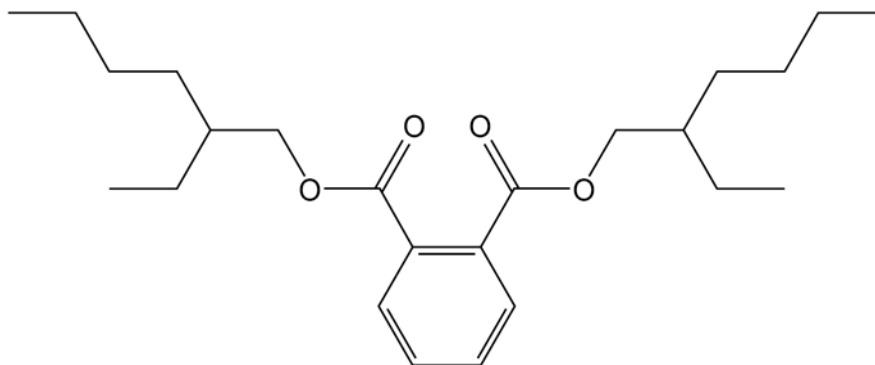
[2 marks]

Observation Stays orange (no reaction, no colour change)

Explanation Poly(chloroethene) is saturated: it does not contain any C=C double bonds, so bromine cannot add to it.

0 6 . 3

Plasticisers are often added during the manufacture of PVC. The structure of the plasticiser DEHP is shown.



Deduce the molecular formula of DEHP and state why a plasticiser is added to PVC.

[2 marks]

Molecular formula C₂₄H₃₈O₄

Why a plasticiser is added To make the PVC more flexible (less brittle): the plasticiser molecules get between the polymer chains, so the chains can slide over each other more easily.



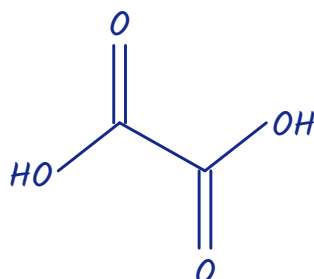
0 7

This question is about ethanedioic acid ($\text{H}_2\text{C}_2\text{O}_4$) which is a dicarboxylic acid.

0 7 . 1

Draw the skeletal formula of ethanedioic acid.

[1 mark]



0 7 . 2

Ethanedioic acid is formed by the oxidation of ethane-1,2-diol ($\text{HOCH}_2\text{CH}_2\text{OH}$).

State suitable reagent(s) and a condition for this reaction.

[2 marks]

Reagent(s) acidified potassium dichromate(VI): $\text{K}_2\text{Cr}_2\text{O}_7$ with dilute sulfuric acid (H_2SO_4)

Condition heat under reflux (with an excess of the oxidising agent)

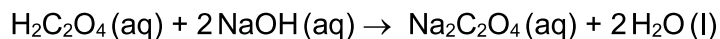
Question 7 continues on the next page

Turn over ►



0 7 . 3

Ethanedioic acid reacts with an excess of sodium hydroxide to form sodium ethanedioate.



A student mixes 10.0 cm^3 of $0.400 \text{ mol dm}^{-3}$ ethanedioic acid with 50.0 cm^3 of $0.200 \text{ mol dm}^{-3}$ sodium hydroxide.

Show that the sodium hydroxide is in excess.

Calculate the mass, in mg, of sodium ethanedioate that can be formed in this reaction.

[5 marks]

$$\text{Moles of } \text{H}_2\text{C}_2\text{O}_4 = 0.400 \times (10.0 \div 1000) = 0.00400 \text{ mol}$$

$$\text{Moles of } \text{NaOH} = 0.200 \times (50.0 \div 1000) = 0.0100 \text{ mol}$$

$$\text{NaOH needed to react with all the acid} = 2 \times 0.00400 = 0.00800 \text{ mol}$$

$$0.0100 \text{ mol} > 0.00800 \text{ mol, so NaOH is in excess (0.00200 mol left over)}$$

$$\text{Moles of } \text{Na}_2\text{C}_2\text{O}_4 \text{ formed} = \text{moles of } \text{H}_2\text{C}_2\text{O}_4 = 0.00400 \text{ mol}$$

$$M_r \text{ of } \text{Na}_2\text{C}_2\text{O}_4 = 2(23.0) + 2(12.0) + 4(16.0) = 134.0$$

$$\text{Mass} = 0.00400 \times 134.0 = 0.536 \text{ g} = 536 \text{ mg}$$

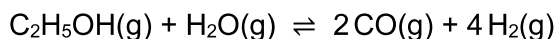
Mass of sodium ethanedioate 536 mg

8



0 8

Hydrogen gas can be made by reacting ethanol with steam in the presence of a catalyst.



0 8

1

Give an expression for K_c for this equilibrium.

State its units.

[2 marks]

$$K_c = \frac{[\text{CO}]^2 [\text{H}_2]^4}{[\text{C}_2\text{H}_5\text{OH}] [\text{H}_2\text{O}]}$$

Units of K_c $\text{mol}^4 \text{dm}^{-12}$

0 8

2

Table 4 shows the amount of each substance in an equilibrium mixture in a container of volume 750 cm^3

Table 4

Substance	$\text{C}_2\text{H}_5\text{OH}(\text{g})$	$\text{H}_2\text{O}(\text{g})$	$\text{CO}(\text{g})$	$\text{H}_2(\text{g})$
Amount of substance / mol	0.0750	0.156	0.110	0.220

Calculate K_c

[3 marks]

Concentration = moles $\div$ volume, with $V = 750 \div 1000 = 0.750 \text{ dm}^3$

$$[\text{C}_2\text{H}_5\text{OH}] = 0.0750 \div 0.750 = 0.100 \quad [\text{H}_2\text{O}] = 0.156 \div 0.750 = 0.208$$

$$[\text{CO}] = 0.110 \div 0.750 = 0.147 \quad [\text{H}_2] = 0.220 \div 0.750 = 0.293 \text{ (mol dm}^{-3}\text{)}$$

$$K_c = (0.110 \div 0.750)^2 (0.220 \div 0.750)^4 \div [(0.0750 \div 0.750)(0.156 \div 0.750)]$$

$$K_c = (0.147)^2 (0.293)^4 \div [(0.100)(0.208)] = 7.66 \times 10^{-3}$$

K_c $7.66 \times 10^{-3} \text{ mol}^4 \text{dm}^{-12}$

Question 8 continues on the next page

Turn over ►



0 8 . 3

The pressure of the equilibrium mixture was increased by reducing the volume of the container at constant temperature.

Predict the effect of increasing the pressure on the equilibrium yield of hydrogen. Explain your answer.

Predict the effect of increasing the pressure on the value of K_c

[4 marks]

Effect on equilibrium yield of hydrogen The yield of hydrogen decreases.

Explanation The position of equilibrium shifts to the left (in the direction of the reverse reaction) to oppose the increase in pressure, i.e. to reduce the pressure.

This is because there are fewer moles of gas on the left-hand side: 2 moles of gas on the left compared with 6 moles of gas on the right.

Effect on value of K_c No effect: K_c stays the same (K_c only changes with temperature).

9



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

Which statement is correct about thermal cracking?

[1 mark]

A A pressure between 100 and 200 kPa is used.

☐

B Aromatic hydrocarbons are the major products.

☐

C C–C bonds are broken.

☒

D Zeolite catalysts are used.

☐

1 0

Which statement is **not** correct about ozone?

[1 mark]

A It absorbs harmful ultraviolet radiation in the upper atmosphere.

☐

B It decomposes to form oxygen.

☐

C Its decomposition is catalysed by chlorine molecules.

☒

D Ozone holes are regions of the upper atmosphere where there is a reduced concentration of ozone.

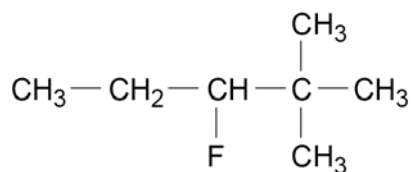
☐

Turn over ►



1 1

What is the IUPAC name for this compound?



[1 mark]

- A 2-dimethyl-3-fluoropentane
- B 2,2-dimethyl-3-fluoropentane
- C 3-fluoro-2,2-dimethylpentane
- D 3-fluoro-2-dimethylpentane

☐☐☒☐

1 2

What is the IUPAC name of the major product of the reaction between 2-ethylbut-1-ene and hydrogen bromide?

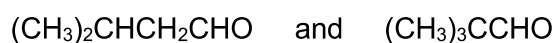
[1 mark]

- A 1-bromo-2-ethylbutane
- B 2-bromo-2-ethylbutane
- C 2-bromo-2-methylpentane
- D 3-bromo-3-methylpentane

☐☐☐☒

1 3

Which can be used to distinguish between these two compounds?



[1 mark]

- A Acidified potassium dichromate(VI)
- B Fingerprint region of infrared spectrum
- C M_r value in high resolution mass spectrometry
- D Tollens' reagent

☐☒☐☐

1 4

An excess of methane reacts with chlorine in the presence of ultraviolet radiation.

What are the main products of this reaction?

[1 mark]

A CCl_4 and H_2

☐

B CCl_4 and HCl

☐

C CH_3Cl and H_2

☐

D CH_3Cl and HCl

☒**1 5**

In which reaction does the inorganic reagent act initially as an electrophile?

[1 mark]

A bromoethane with ethanolic potassium hydroxide

☐

B chloroethane with aqueous sodium hydroxide

☐

C ethane with chlorine

☐

D ethene with concentrated sulfuric acid

☒**1 6**

What is the empirical formula of a hydrocarbon that contains 90% carbon by mass?

[1 mark]

A C_2H_3

☐

B C_3H_2

☐

C C_3H_4

☒

D C_4H_3

☐**Turn over ►**

1 7

Which compound has the lowest relative molecular mass?

[1 mark]**A** ethanoic acid☐**B** 1-fluoropropane☐**C** propanenitrile☒**D** propylamine☐**1 8**

Which statement is correct about the production and use of ethanol as a biofuel?

[1 mark]**A** Biofuel ethanol is produced by the fermentation of glucose in the presence of yeast and air.☐**B** Biofuel ethanol is purified by fractional distillation.☒**C** No carbon dioxide is released when biofuel ethanol is burned.☐**D** Biofuel ethanol burns with a cleaner flame than ethanol made by hydration of ethene.☐**1 9**What is the minimum volume of $0.0500 \text{ mol dm}^{-3}$ aqueous bromine needed to react completely with 0.0200 g of buta-1,3-diene? $(M_r \text{ of buta-1,3-diene} = 54.0)$ **[1 mark]****A** 7.40 cm^3 ☐**B** 14.8 cm^3 ☒**C** 29.6 cm^3 ☐**D** 67.5 cm^3 ☐

2 0

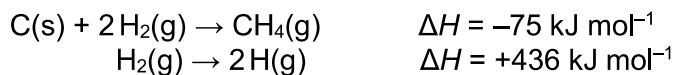
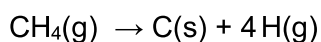
Which statement about the molecules in a sample of a gas is correct?

[1 mark]

- A** At a given temperature they all move at the same speed.
- B** At a given 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.

☐☒☐☐**2 1**

Some enthalpy change data are shown.

What is the enthalpy change, in kJ mol^{-1} , for the following reaction?**[1 mark]**

- A** -947
- B** -361
- C** +361
- D** +947

☐☐☐☒**Turn over for the next question****Turn over ►**

2 2

The temperature changed from 21.8 °C to 19.2 °C during a calorimetry experiment.

The uncertainty of each reading of the thermometer is ± 0.1 °C

What is the percentage uncertainty in the temperature change?

[1 mark]

A 0.5%

☐

B 1.0%

☐

C 3.8%

☐

D 7.7%

☒
2 3

An experiment is done to determine the enthalpy of combustion of a fuel using a calorimeter containing water.

b = mass of fuel burned / g

w = mass of water heated / g

ΔT = temperature rise of water / K

M_r = relative molecular mass of fuel

c = specific heat capacity of water / J K⁻¹ g⁻¹

Which expression gives the enthalpy of combustion (in J mol⁻¹), assuming there is no heat loss?

[1 mark]

A $-\frac{c w \Delta T M_r}{b}$

☒

B $-\frac{c b \Delta T M_r}{w}$

☐

C $-\frac{c b w M_r}{\Delta T}$

☐

D $-\frac{c b w \Delta T}{M_r}$

☐
15**END OF QUESTIONS**

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ANSWER IN THE SPACES PROVIDED**



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