AQA

Model Answers

Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____

AS CHEMISTRY

Paper 2: Organic and Physical Chemistry

Friday 9 June 2017 Afternoon 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 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**.

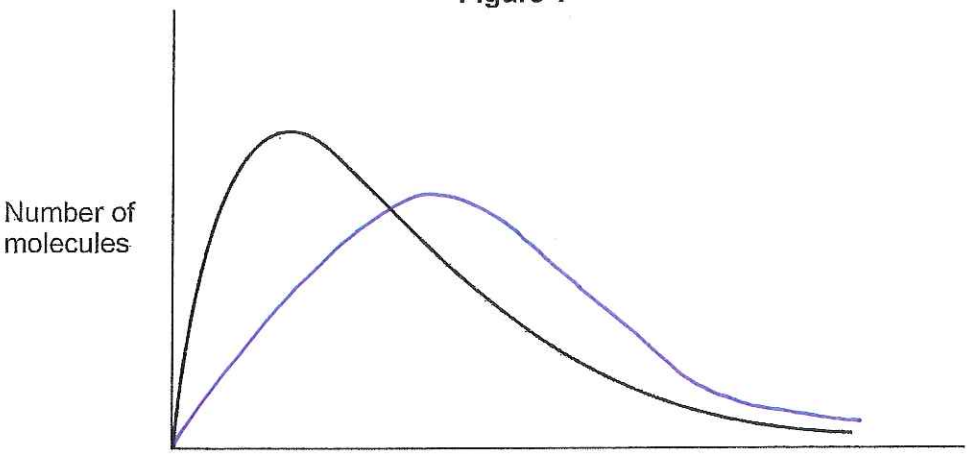
For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
Section B	
TOTAL	

Section A

Answer **all** questions in this section.

0 1 **Figure 1** shows the Maxwell–Boltzmann distribution of molecular energies in a sample of gas at a fixed temperature.

Figure 1



0 1 . 1 Label the horizontal axis in **Figure 1.**

[1 mark]

0 1 . 2 On **Figure 1**, sketch a distribution of molecular energies for this sample of gas at a higher temperature.

* start at origin.
* max peak lower and right.
* asymptote - lines do not touch.

[2 marks]

0 1 . 3 This gas decomposes on heating.

Explain why an increase in temperature increases the rate at which this gas decomposes.

[2 marks]

An increase in temperature increases the number of molecules with the Ea - which means there are more successful collisions, as well as more effective collisions.

5

0 2 An experiment was carried out to determine the relative molecular mass (M_r) of a volatile hydrocarbon **X** that is a liquid at room temperature.

A known mass of **X** was vaporised at a known temperature and pressure and the volume of the gas produced was measured in a gas syringe.

Data from this experiment are shown in **Table 1.**

Table 1

Mass of **X**	194 mg
Temperature	373 K
Pressure	102 kPa
Volume	72 cm^3

0 2 . 1 Calculate the relative molecular mass of **X.**

Show your working.

Give your answer to the appropriate number of significant figures.

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

[5 marks]

$PV = nRT$ $\quad n = \frac{PV}{RT}$

$102kpa = 102000pa$
$72cm^3 = 7.2\times10^{-5}m^3$
$mass = 0.194g$

Don't forget to convert units

$n = \frac{102000 \times 7.2\times10^{-5}}{8.31 \times 373}$ $\quad n = 2.369\times10^{-3}$

$moles = \frac{mass}{Mr}$ $\quad \frac{mass}{moles} = Mr$ $\quad \frac{0.194}{2.369\times10^{-3}} = 81.88$

or 82

MUST be 2s.f

Relative molecular mass _____

0 2 . 2 Analysis of a different hydrocarbon **Y** shows that it contains 83.7% by mass of carbon.

Calculate the empirical formula of **Y**.

Use this empirical formula and the relative molecular mass of **Y** ($M_r = 86.0$) to calculate the molecular formula of **Y**.

[4 marks]

Carbon

$\frac{83.7}{12} = 6.975$

$\frac{6.975}{6.975} = 1$

Hydrogen

$\frac{16.3}{1} = 16.3$

$\frac{16.3}{6.975} = 2.3369$

$\times 3 = C_3H_7$

$36 + 7 = 43$

$43 \times 2 = 86$

Empirical formula C_3H_7

Molecular formula C_6H_{14}

9

Do not write outside the box

0 3 . 1 Compounds **A**, **B** and **C** all have the molecular formula C_5H_{10}

A and **B** decolourise bromine water but **C** does not.

B exists as two stereoisomers but **A** does **not** show stereoisomerism.

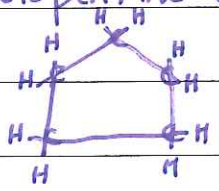
Use this information to deduce a possible structure for each of compounds **A**, **B** and **C** and explain your deductions.

State the meaning of the term stereoisomers and explain how they arise in compound **B**.

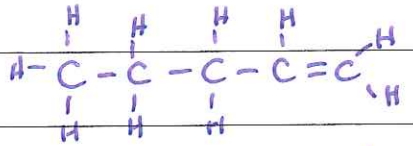
[6 marks]

Be systematic. tick off each part as you go, so as not to forget anything!

* If A and B decolorise bromine water this means they are unsaturated or contain a double bond.
* C therefore must be saturated.
* C could be cyclopentane as it has a saturated form of C_5H_{10}

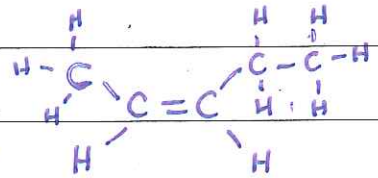


* Stereoisomerism is the same molecular formula but a different arrangement in space.
* A does not show stereoisomerism as it must have the same groups on at least one side of the double bond: A is



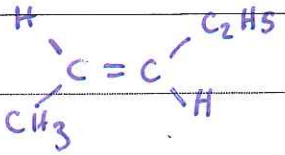
pent-1-ene

* B does show stereoismerism so could be



this is Z pent-2-ene

Stereoisomerism occurs due to a lack of rotation around the C=C.



E - pent-2-ene

6

0 4 When alkanes are burned in an excess of oxygen they produce carbon dioxide and water.

0 4 . 1 Write an equation for the complete combustion of propane in oxygen.

[1 mark]

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

0 4 . 2 An expression can be derived using bond enthalpy data to estimate the enthalpy of combustion ($\Delta_c H$) of an alkane.

For an alkane with ***n*** carbon atoms: $\Delta_c H = -(496n + 202)$ kJ mol^{-1}

The enthalpy of combustion of an alkane was calculated to be –6650 kJ mol^{-1} using this expression.

Deduce the molecular formula of this alkane.
Show your working.

[2 marks]

$-6650 = -(496 \times n + 202)$

$496n = 6650 - 202$

$496n = 6448$

$n = \frac{6448}{496}$ $\quad n = 13$

Molecular formula of alkane _____

0 4 . 3 Suggest **one** reason, other than the use of mean bond enthalpies, why a value for the enthalpy of combustion of a liquid alkane is different from the value obtained using the expression in Question **4.2**

[1 mark]

In the expression above alkanes are assumed gaseous - It requires energy to turn these liquid alkanes into a gas.

0 4 . 4 Values of the enthalpy change for combustion of 1 g of some alkanes are shown in **Table 2.**

Table 2

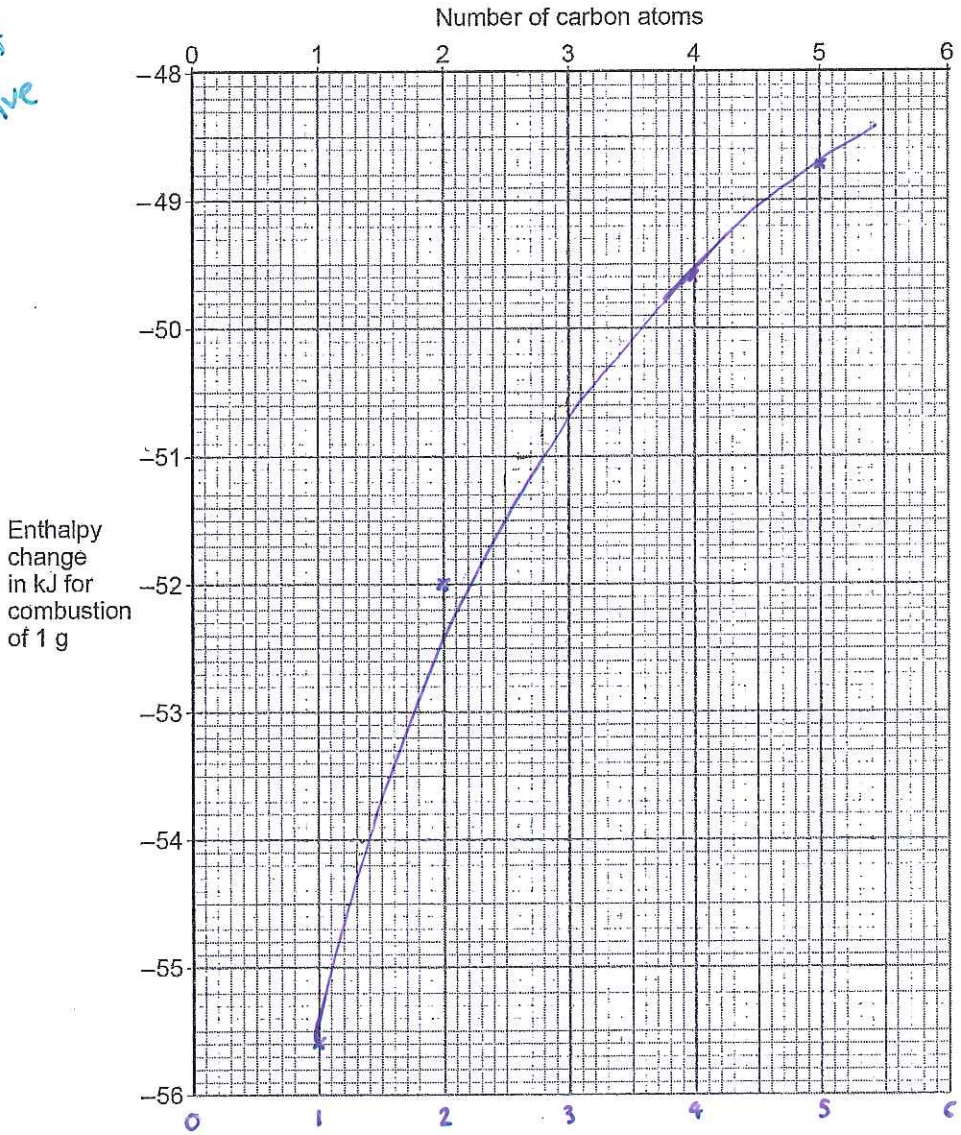
	methane	ethane	propane	butane	pentane
Enthalpy change in kJ for combustion of 1 g	–55.6	–52.0	-50.7	–49.6	–48.7

Plot the enthalpy change for the combustion of 1 g against the number of carbon atoms in the alkanes in **Table 2.**

Draw a best fit line and use this to estimate the enthalpy change for combustion of 1 g of propane.
Write your answer in **Table 2.**

[3 marks]

Don't forget the negative sign.



Do not write outside the box

0 4 . 5 Isooctane (2,2,4-trimethylpentane) is an important component of petrol used in cars.

When isooctane is burned, the enthalpy change is -47.8 kJ g^{-1}

Isooctane is a liquid at room temperature with a density of 0.692 g cm^{-3}

Calculate the heat energy released, in kJ, when 1.00 dm^3 of isooctane burns in excess oxygen.
Give your answer to the appropriate number of significant figures.

[2 marks]

density = mass / volume

$0.692 \times 1000 = 692$ g

$1 dm^3$ to cm^3

$\Delta H = \frac{q}{mass}$

$47.8 \times 692 = 33077.6$ kJ

or

33100 kJ

3sf

normally moles but units of ΔH = kJ g^{-1}

Heat energy released _____ kJ

9

0 5 Ethanedioic acid ($H_2C_2O_4$) is a diprotic acid. Beekeepers use a solution of this acid as a pesticide.

A student carried out a titration with sodium hydroxide solution to determine the mass of the acid in the solution. The student repeated the titration until concordant titres were obtained.

$$H_2C_2O_4(aq) + 2NaOH(aq) \rightarrow Na_2C_2O_4(aq) + 2H_2O(l)$$

0 5 . 1 The student found that 25.0 cm^3 of the ethanedioic acid solution reacted completely with 25.30 cm^3 of 0.500 mol dm^{-3} sodium hydroxide solution.

Calculate the mass, in mg, of the acid in 25.0 cm^3 of this solution.

[4 marks]

conc = moles / vol

$0.500 \times \left(\frac{25.30}{1000}\right) = 0.01265$ moles of NaOH

moles = mass / mr

$\frac{0.01265}{2} = 6.325 \times 10^{-3}$ moles of ethanedioic acid

mr of $H_2C_2O_4 = 90$

$6.325 \times 10^{-3} \times 90$

$= 0.569\,g$

$\times 1000$

don't forget to $\times 1000$!

Mass of acid 569 mg

0 5 . 2 The student used a wash bottle containing deionised water when approaching the end-point to rinse the inside of the conical flask.

Explain why this improved the accuracy of the titration.

[1 mark]

The washing ensured all moles of reactant were in the solution.

0 5 . 3 Give the meaning of the term concordant titres.

[1 mark]

Titres that are within 0.1 cm^3 of each other.

6

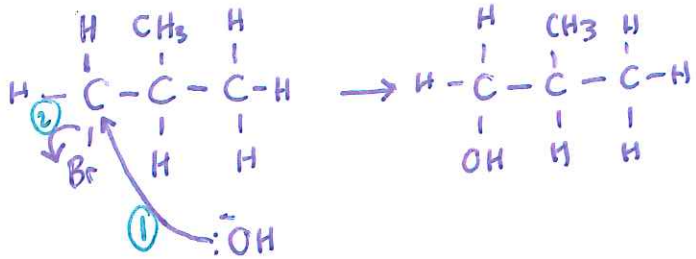
0 6 2-Methylpropan-1-ol can be prepared by reacting 1-bromo-2-methylpropane with dilute aqueous sodium hydroxide.

0 6 . 1 Name and outline the mechanism for this reaction.

[3 marks]

Name of mechanism Nucleophic Substitution

Mechanism



0 6 . 2 When 2.0 cm^3 of 1-bromo-2-methylpropane (M_r = 136.9) were reacted with an excess of sodium hydroxide, 895 mg of 2-methylpropan-1-ol (M_r = 74.0) were obtained.

The density of 1-bromo-2-methylpropane is 1.26 g cm^{-3}

Calculate the percentage yield for this reaction.

[3 marks]

density = mass / volume 1·26 × 2·0 = 2·52 g 2·52 / 136·9 = 0·0184 moles of 1-bromo-2methyl propane

0·0184 × 74·0 = 1·36 g of 2methylpropan-1-ol (theoretical)

actual / theoretical × 100 = % yield

895 / 1000 = 0·895 g (actual) (0·895 / 1·36) × 100 = 65·5%

Percentage yield _____

0 6 . 3 When 1-bromo-2-methylpropane reacts with hot, concentrated ethanolic potassium hydroxide rather than dilute aqueous sodium hydroxide, a different product is formed.

Name this organic product and name the mechanism for this reaction.

[2 marks]

In ethanolic conditions
∴ OH⁻ acts as a base not a nucleophile!

Name of organic product Methylpropene

Name of mechanism Elimination

Turn over for the next question

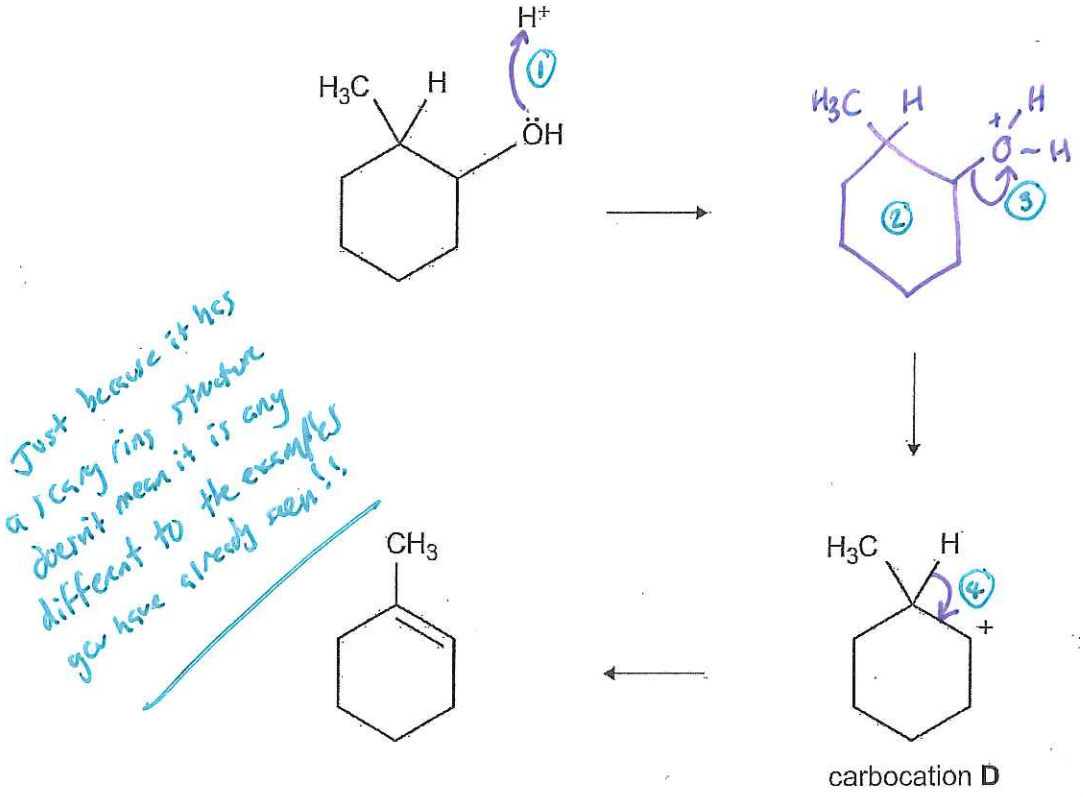
8

0 7 Alcohols undergo dehydration in the presence of concentrated phosphoric acid, via a carbocation intermediate, to form alkenes.

0 7 . 1 Complete the mechanism for the conversion of 2-methylcyclohexanol into 1-methylcyclohexene via carbocation **D** by drawing

- the structure of the missing intermediate
- all necessary curly arrows.

[4 marks]

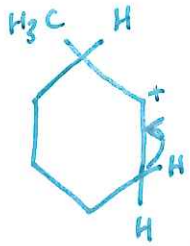


carbocation **D**

Just because it has a ring structure doesn't mean it is any different to the examples you have already seen!!

0 7 . 2 Draw the structure of a different cyclic alkene formed from carbocation **D**.

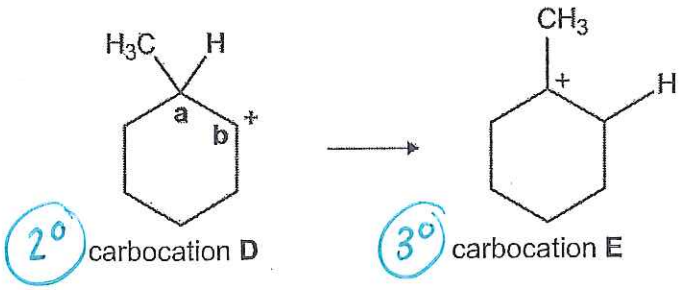
[1 mark]



this could have happened instead!

0 7 . 3 Carbocation **D** can undergo a type of reaction called a rearrangement to form carbocation **E**. In this reaction, a hydrogen atom and its bonding pair of electrons move from carbon **a** to carbon **b** as shown in **Figure 2.**

Figure 2



2° carbocation **D** → 3° carbocation **E**

Use your knowledge of carbocations to explain why this rearrangement takes place.

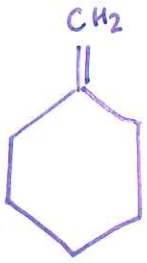
[2 marks]

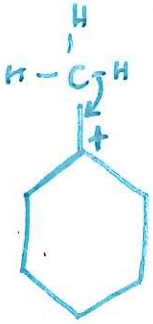
As E is a more stable carbocation because it is now 3° rather than 2°.

0 7 . 4 As a result of the rearrangement in Question **7.3**, a third alkene is formed in this reaction.

Draw the structure of this third alkene.

[1 mark]





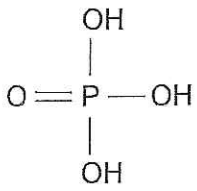
this could have happened.

Also

However this is the same as original product so NOT accepted.

Turn over for the next question

0 7 . 5 Cyclohexene is prepared by the dehydration of cyclohexanol using concentrated phosphoric acid as a catalyst. The structure of concentrated phosphoric acid is shown.



(1) Identify the factors that influence the boiling points of each of the compounds in this reaction mixture. (2) State how and explain why cyclohexene can be separated from the reaction mixture.

[6 marks]

Three chemicals: Cyclohexene, Cyclohexanol, phosphoric acid.

(1)
- Cyclohexene has vander waals forces between molecules (weak)
- Cyclohexanol has hydrogen bonds between molecules (stronger than ← Vdw)
- phosphoric acid has hydrogen bonds between molecules

(2)
- As cyclohexene has the weakest intermolecular forces it has the lowest boiling point so easily separated by distillation.

Do not forget the two separate parts to the question!

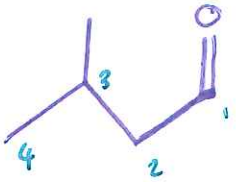
14

Do not write outside the box

0 8 This question is about the structures of some organic molecules.

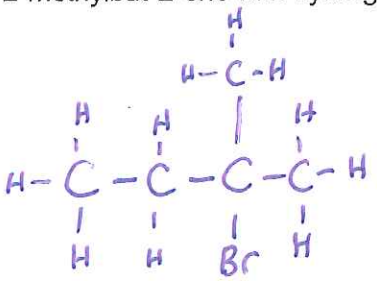
0 8 . 1 Draw the **skeletal** formula of 3-methylbutanal.

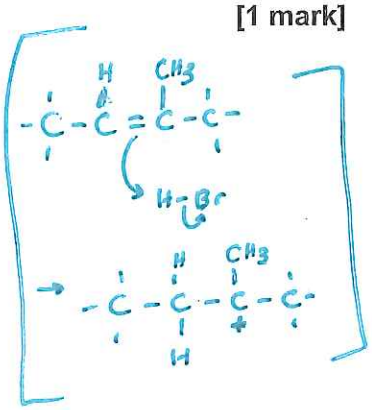
[1 mark]



0 8 . 2 Draw the **displayed** formula of $C_5H_{11}Br$ that is the major product of the reaction of 2-methylbut-2-ene with hydrogen bromide.

[1 mark]

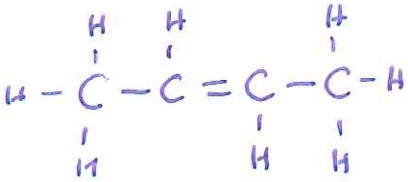




0 8 . 3 Thermal cracking of hydrocarbons produces molecules that are attacked by electrophiles because they have a region of high electron density.

Draw the structure of one of these molecules that contains four carbon atoms.

[1 mark]



* But-1-ene
* But-2-ene
* methylpropene

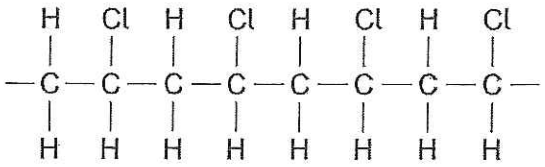
any will do.

Turn over for the next question

3

0 9 Chloroethene can be polymerised to form poly(chloroethene), commonly known as PVC. This polymer can be used to make pipes, window frames and electrical insulation. Plasticisers can be added to change the properties of PVC

A section of poly(chloroethene) is shown.



0 9 . 1 Chloroethene has a melting point of −154 °C

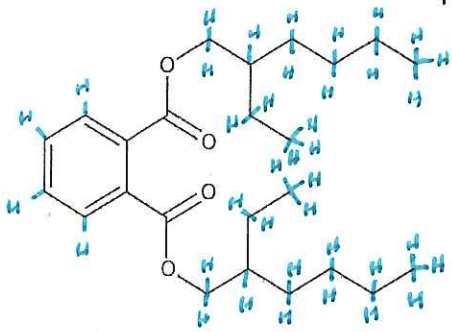
All types of PVC melt at temperatures over 100 °C

Explain why PVC melts at a higher temperature than chloroethene.

[2 marks]

PVC is a much larger molecule and hence has much stronger van der waals between molecules.

0 9 . 2 This structure shows a molecule that has been used as a plasticiser in PVC.



Deduce the number of hydrogen atoms in this molecule.

[1 mark]

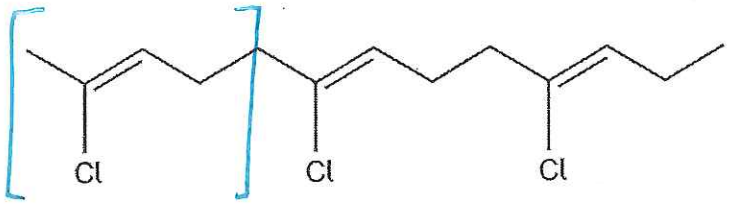
38

0 9 . 3 Use your understanding of the properties of PVC to explain whether you would expect to find a plasticiser in the PVC used to insulate electrical cables.

[1 mark]

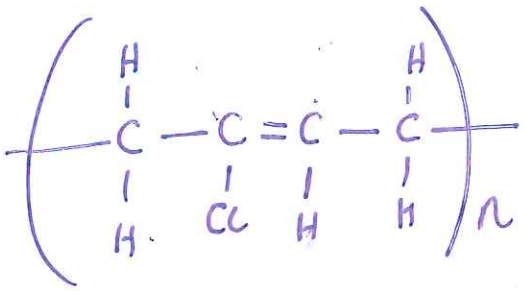
A plasticiser is needed as it allows the PVC to be flexible for wires.

0 9 . 4 A section of the polymer poly(chloroprene), a synthetic rubber, is shown.



Draw the **displayed** formula for the repeating unit of poly(chloroprene).

[1 mark]



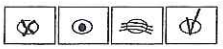
Interesting example. It has a non-polymerised C=C!

5

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.

1 0 What is the burette reading for this transparent liquid?

[1 mark]

A 24.10 cm^3 ○

B 24.30 cm^3 ● (Bottom of the meniscus!)

C 25.70 cm^3 ○

D 25.90 cm^3 ○

1 1 A volumetric flask was used to prepare 250 cm^3 of a solution.

The solute was added from a plastic weighing container.

	Mass / g
Weighing container with solute	10.13
Weighing container after solute added to volumetric flask	4.48

Each reading from the balance has an uncertainty of ±0.005 g ← x2!

What is the percentage uncertainty in the mass of the solute used?

[1 mark]

10.13 − 4.48 = 5.65 g

$\left(\frac{0.010\,g}{5.65}\right) \times 100 = 0.176$ or 0.18%

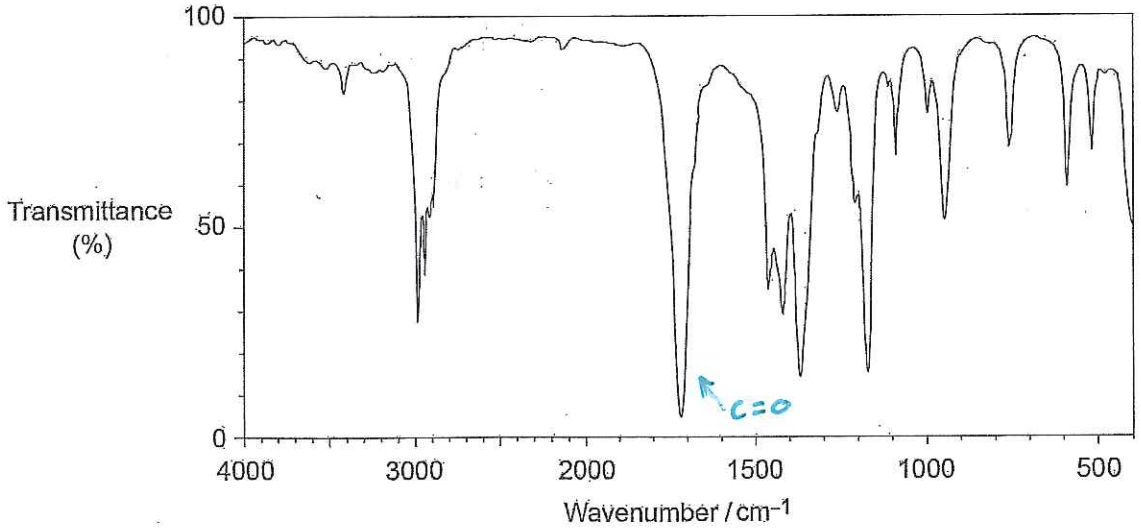
A 0.09%

B 0.11%

C 0.18% ●

D 0.22%

1 2 The infrared spectrum of an organic compound is shown.



Which compound produces this spectrum?

[1 mark]

A butanone ✓ C=O present only

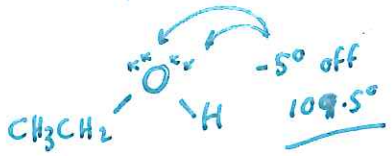
B ethanol × no O–H peak

C pent-2-ene × contains C=O

D propanoic acid × no O–H peak

1 3 Which is the most likely bond angle around the oxygen atom in ethanol?

[1 mark]



A 104.5° ●

B 109.5° ○

C 120° ○

D 180° ○

1 4 Which compound is a structural isomer of *Z*-but-2-ene?

[1 mark]

A butane ✗ functional group isomer ○

B *E*-but-2-ene ✗ stereoisomer ○

C cyclobutane ✓ ●

D methylbut-2-ene ✗ not an isomer ○

1 5 Which equation is a propagation step in the conversion of trichloromethane into tetrachloromethane by reaction with chlorine in the presence of ultraviolet light?

[1 mark]

A $CHCl_3 + Cl_2 \rightarrow CCl_4 + HCl$ ○

B $\bullet CCl_3 + \bullet Cl \rightarrow CCl_4$ ○

C $CHCl_3 + \bullet Cl \rightarrow CCl_4 + \bullet H$ ○

D $\bullet CCl_3 + Cl_2 \rightarrow CCl_4 + \bullet Cl$ ✓ ●

propagation ① $HCCl_3 + Cl^{\bullet} \rightarrow HCl + {}^{\bullet}CCl_3$

② ${}^{\bullet}CCl_3 + Cl_2 \rightarrow CCl_4 + Cl^{\bullet}$

1 6 Which compound has the fastest rate of reaction with potassium cyanide to form pentanenitrile?

[1 mark]

A 1-bromobutane ○

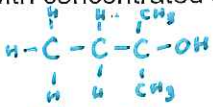
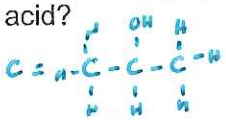
B 1-chlorobutane ○

C 1-fluorobutane ○

D 1-iodobutane ● Lowest bond enthalpy dictates rate!

1 7 Which alcohol can be oxidised by acidified potassium dichromate(VI) but cannot be dehydrated by heating with concentrated sulfuric acid?

[1 mark]

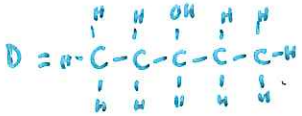
A =  B =  C = 

A 2,3-dimethylbutan-2-ol × 3° alcohol - cannot be oxidised. ○

B 2,2-dimethylpropan-1-ol ✓ No α hydrogens so cannot be dehydrated. ●

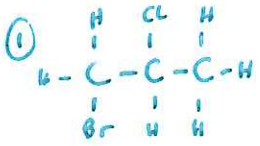
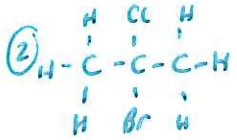
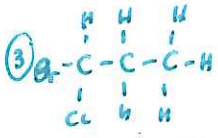
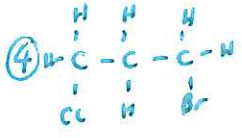
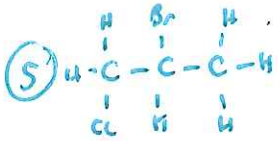
C 2-methylpropan-2-ol × can be both oxidised and dehydrated ○

D pentan-3-ol × Can be both oxidised and dehydrated ○

D = 

1 8 How many structural isomers are there with the molecular formula C_3H_6BrCl?

[1 mark]

A 4 ○

B 5 ●

C 6 ○

D 7 ○

1 9 Which sample contains the most molecules?

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

[1 mark]

A 2.10×10^{22} molecules of methane, CH_4 ✓ ●

B 1.00 g of oxygen, O_2 $\left(\frac{1}{32}\right) \times 6.02 \times 10^{23} = 1.88 \times 10^{22}$ × ○

C 65.0 mg of hydrogen, H_2 $\frac{65}{1000} = 0.065$ $\frac{0.065}{2} \times 6.02 \times 10^{23} = 1.96 \times 10^{22}$ × ○

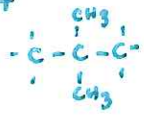
D 0.0300 mol of ethane, C_2H_6 $0.03 \times 6.02 \times 10^{23} = 1.81 \times 10^{22}$ × ○

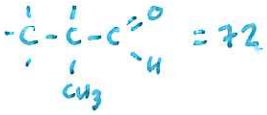
2 0 Which compound forms a molecular ion with a different precise molecular mass from the other three?

[1 mark]

A butanone  = 72 ○

B cyclobutanol  = 72 ○

C dimethylpropane  = 72 BUT! NO oxygen atom. ●

D methylpropanal  = 72 ○

2 1 Hydrogen can be produced by this reaction.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

In an experiment 4.20 mol of carbon monoxide were mixed with 2.00 mol of steam. When the reaction reached equilibrium, 1.60 mol of hydrogen had been formed.

What is the value of the equilibrium constant, K_c, for this reaction?

[1 mark]

	CO	H_2O	CO_2	H_2
I	4.20	2.0	0	0
Eq	4.20 − 1.6 = 2.6	2 − 1.6 = 0.4	1.60	1.60

must be same as H_2 1:1.

A 0.30 ○

B 0.41 ○

C 1.54 ○

D 2.46 ●

$K_c = \frac{[CO_2] \times [H_2]}{[CO] \times [H_2O]}$

$K_c = \frac{(1.60)2}{2.60 \times 0.4}$ $K_c = 2.46$

2 2 A sample of 2.0 mol dm^{-3} acid has a volume of 100 cm^3 ÷ 1000 = 0.1 dm^3

What volume of water, in cm^3, should be added to this acid to dilute the sample to a concentration of 1.5 mol dm^{-3}?

[1 mark]

conc = $\frac{mol}{vol}$ 2.0 × 0.1 = 0.2 moles

A 25 ○

B 33.3 ●

C 50 ○

D 66.7 ○

$\frac{0.2}{1.5} = 0.13$ dm3 or 133.3 cm^3

133.3 − 100 = 33.3 cm^3

↑ initial volume.

Turn over for the next question

2 3 Two sealed flasks with the same volume are left side by side.

Flask **A** contains 4.0×10^{-3} mol of methane.
Flask **B** contains 340 mg of a different gas.
Both gases are at the same temperature and pressure.

Which gas could be in Flask **B**?

[1 mark]

$\frac{340}{1000} = 0.34\text{g}$ $\frac{0.34}{85} = 4 \times 10^{-3}$ ∴ CH_2Cl_2.

A CH_2Cl_2 ●

B HBr ○

C Kr ○ } Do not give 4×10^{-3} moles

D PF_3 ○

Both flasks would have equal moles.

2 4 Analysis of a sample of a chemical with formula $C_{22}H_{30}N_6O_4S$, showed that it contained 0.0195 mol of carbon.

What mass of nitrogen was present in the sample?

[1 mark]

$\frac{0.0195}{22} \times 6 = 0.005318$ (ratio in compound) $\times 14$ (mr of N) $= 0.074\text{g}$

A 0.041 g ○

B 0.057 g ○

C 0.074 g ●

D 0.420 g ○

END OF QUESTIONS

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