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 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**.

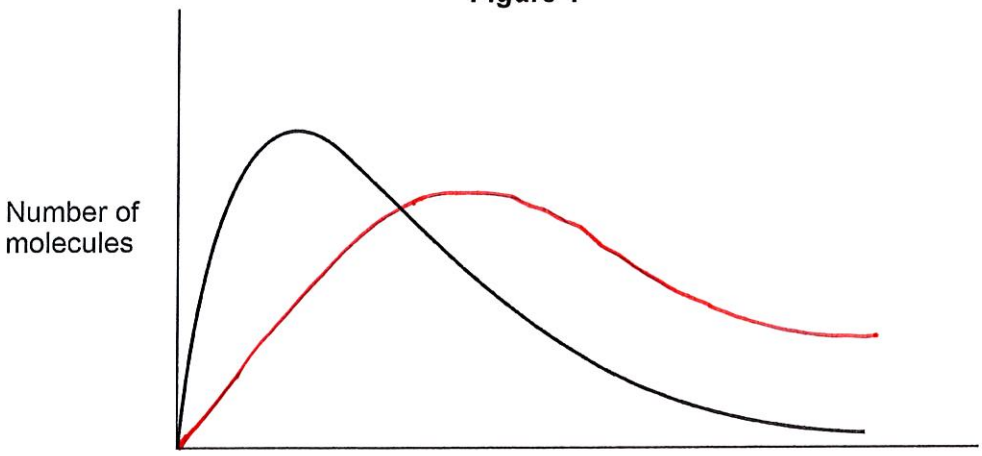
For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
Section B	
TOTAL	

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.

[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]

- more molecules have $E \geq Ea$ M1
- more successful collisions in a given period of time M2

or higher frequency of successful 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

Unit conversions

194×10^{-3} g

102×10^3 Pa

72×10^{-6} m^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]

$PV = nRT$

$\therefore n = \frac{PV}{RT}$ $\quad \frac{102 \times 10^3 \times 72 \times 10^{-6}}{8.31 \times 373} = 2.37 \times 10^{-3}$ M1 M2 M3

$n = \frac{m}{M_r}$

$M_r = \frac{m}{n}$ $\quad \frac{194 \times 10^{-3}}{2.37 \times 10^{-3}} = 82$ (2 s.f.) M4

Relative molecular mass 82 M5

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]

	C	H	
	83.7	16.3	
n	$\frac{83.7}{12.0} = 6.975$	$\frac{16.3}{1.0} = 16.3$	M1
ratio	1 : 2.37	× 3	M2
	3 : 7		

empirical formula $M_r = 43$

$\frac{86}{43} = 2$

Empirical formula C_3H_7 M3

Molecular formula C_6H_{14} M4

9

Do not write outside the box

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

CHALLENGING

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**.

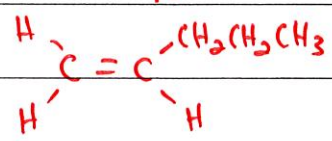
LEVELLED

[6 marks]

Stage 1:
- A + B are unsatwated | alkenes
- they decolowice bromine water
- C is satwated | cyclohexane
- it doesnt decolourice bromine water

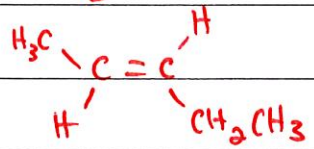
Stage 2: possible structures

A

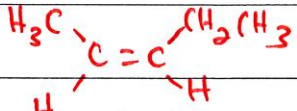


pent-1-ene

B

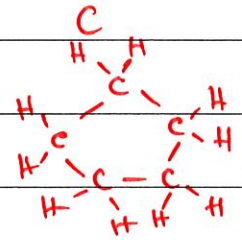


E-pent-2-ene



Z-pent-2-ene

C



cyclopentane

Stage 3:
- Stereoisomerism is when molecules have the same structural formula but a different arrangement of atoms in space.
- It arises because there is restricted rotation around the C=C bond.
- So different groups bond to the C=C carbon atoms.

Level 3 (5-6) - all stages
Level 2 (3-4) - 2 stages or parts of 3 stages
Level 1 (1-2) - 1 stage or parts of 2 stages

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 (Δ_cH) of an alkane.

For an alkane with ***n*** carbon atoms: $\Delta_cH = -(496n + 202)$ 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]

$\Delta H_c = -(496n + 202) = -6650$

$-496n = -6650 + 202$

$-496n = -6448$

$n = 13$ M1

Molecular formula of alkane $C_{13}H_{28}$ M2

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]

- alkane not gaseous

or equation relates to gaseous alkane

or it takes energy to convert it to 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

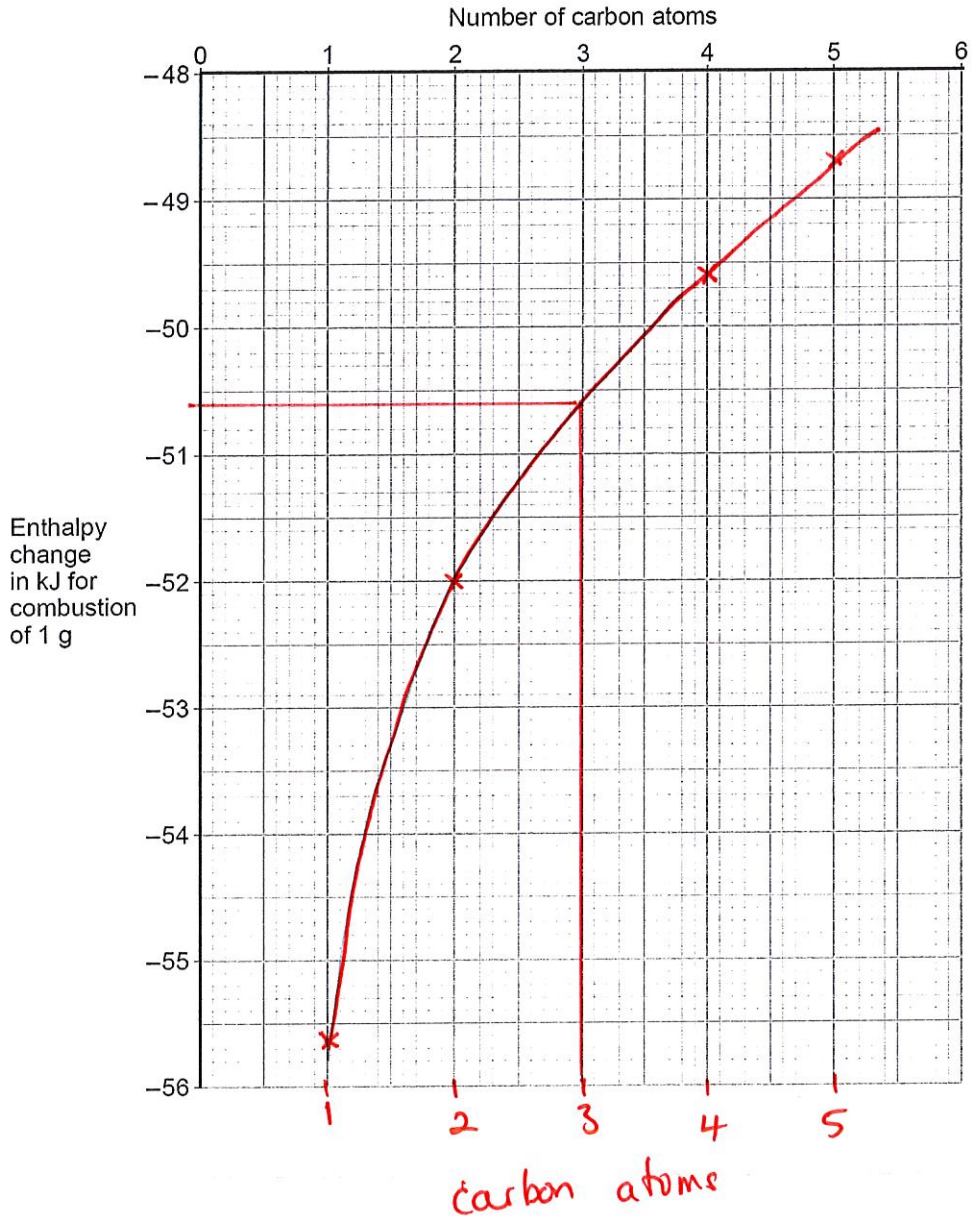
	methane	ethane	propane	butane	pentane
Enthalpy change in kJ for combustion of 1 g	–55.6	–52.0	–50.6	–49.6	–48.7
C =	1	2	3	4	5

M3 (± 1sq)

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]



M1 points

M2 smooth curve

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]

1000 cm^3

Mass = $0.692 \times 1000 = 692$ g M1

$\Delta H = -47.8 \times 692 = -33077.6$

Heat energy released $\underline{-33100}$ kJ M2
(3 s.f.)

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.

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

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]

$n = cV$ $\quad n\ NaOH = 0.5 \times 25.30 \times 10^{-3} = 0.01265$ M1

$n\ H_2C_2O_4 = \frac{0.01265}{2} = 6.325 \times 10^{-3}$ M2

$m = nM_r$ $\quad m\ H_2C_2O_4 = 6.325 \times 10^{-3} \times 90 = 0.56925\ g$ M3

$\times 10^3$

Mass of acid 569 mg M4

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]

To remove any acid or alkali that may be on the sides of the flask to ensure they all react.

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

[1 mark]

Titres (volumes) that are within the uncertainty of the burette - they are $\pm 0.1\ cm^3$ of each other

6

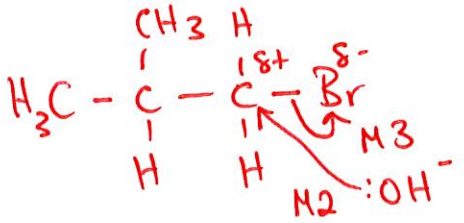
0 6 2-Methylpropan-1-ol can be prepared by reacting 1-bromo-2-methylpropane with dilute aqueous sodium hydroxide.

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

[3 marks]

Name of mechanism nucleophilic substitution M1

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.

CHALLENGING need to use density

895×10^{-3} g

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

Calculate the percentage yield for this reaction.

[3 marks]

m C_4H_9Br = $1.26 \times 2 = 2.52$ g

n C_4H_9Br = $\frac{2.52}{136.9}$ = 0.0184 mol M1

n C_4H_9OH = 0.0184 mol

m C_4H_9OH = $0.0184 \times 74.0 = 1.3621$ g M2

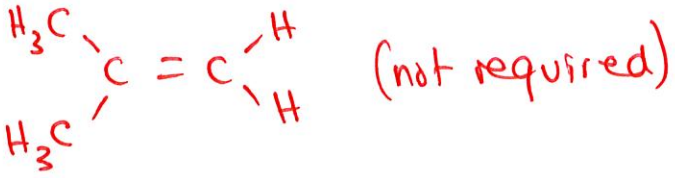
% yield = $\frac{895 \times 10^{-3}}{1.3621} \times 100$

Percentage yield 65.7% (65-67%) M3

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]



(not required)

Name of organic product methyl propene M1

Name of mechanism elimination M2

Turn over for the next question

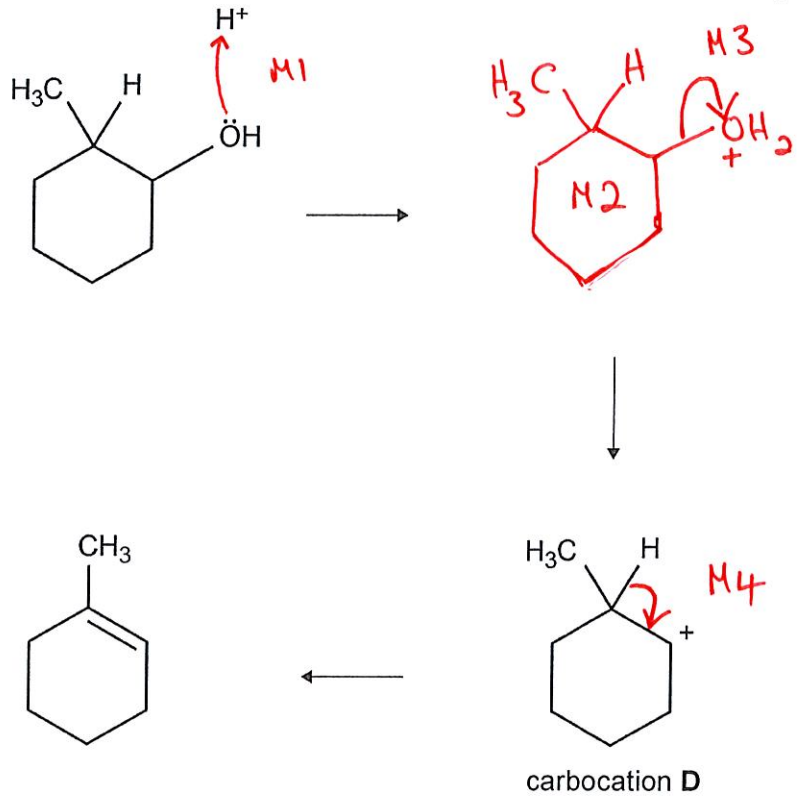
8

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.

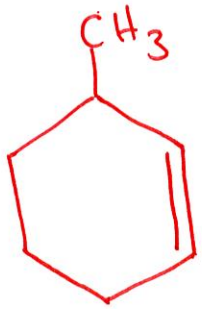
[4 marks]



carbocation **D**

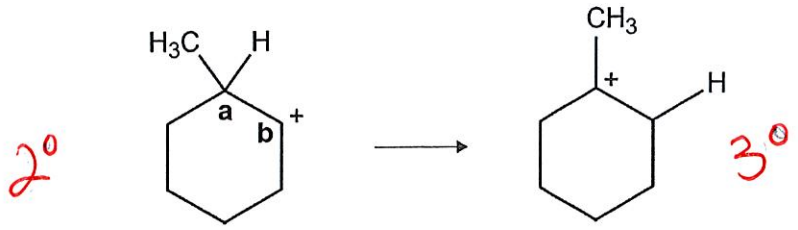
0 7 . 2 Draw the structure of a different cyclic alkene formed from carbocation **D**.

[1 mark]



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°

3°

carbocation **D** carbocation **E**

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

[2 marks]

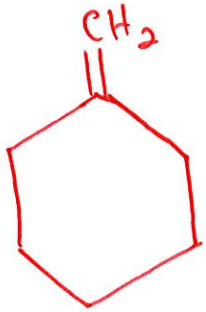
D is a 2° carbocation and E a 3° carbocation M2

A more stable carbocation is formed M1

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.

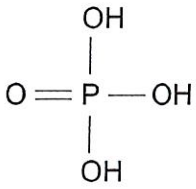
[1 mark]



Turn over for the next question

0 7 . 5 CHALLENGING

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



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

[6 marks]

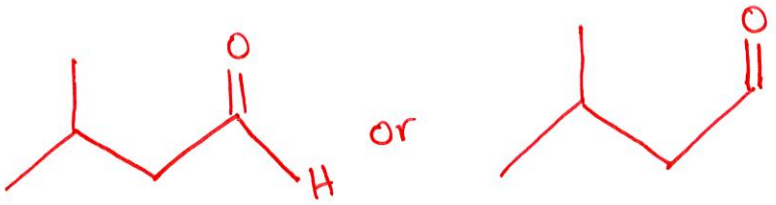
- Cyclohexene has vander Waals' forces between the molecules M1
- Cyclohexanol has hydrogen bonds between the molecules M2
- (phosphoric acid has hydrogen between the molecules) M3
- they can be separated by distillation M4
- cyclohexene has the weakest forces M5
- so it boils first or has lowest boiling point M6

14

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

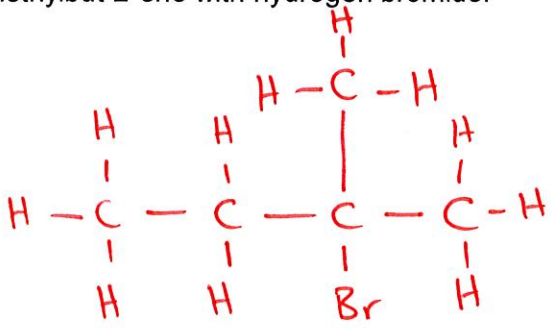
0 8 . 1 Draw the **skeletal** formula of 3-methylbutanal.

[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.

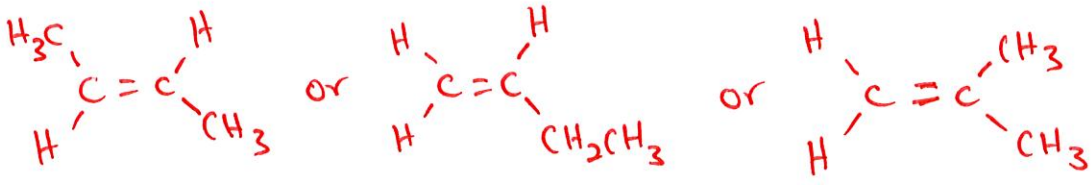
[1 mark]



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]

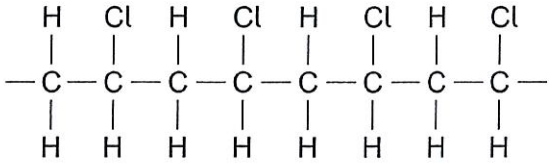


Turn over for the next question

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

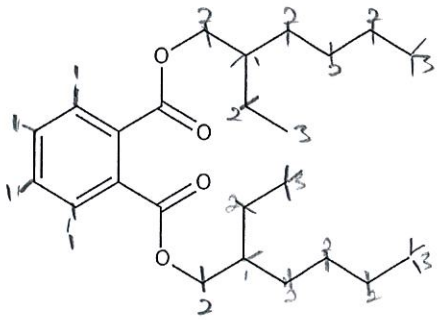
All types of PVC melt at temperatures over 100 °C

Explain why PVC melts at a higher temperature than chloroethene.

[2 marks]

- PVC is a larger molecule M1
- PVC has stronger forces between the molecules (intermolecular forces) M2

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]

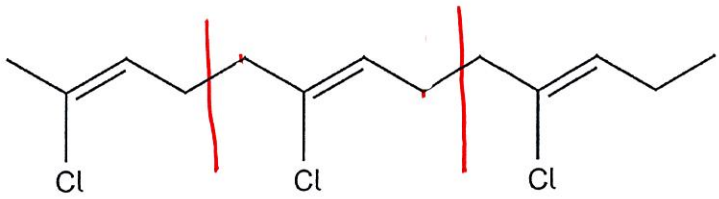
38

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 would be in PVC for electrical cables
- because they need to be flexible

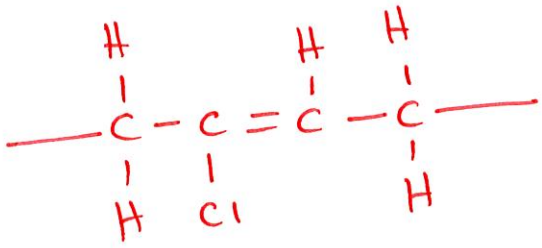
0 9 . 4 A section of the polymer poly(chloroprene), a synthetic rubber, is shown.



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

[1 mark]

Other arrangements possible



Turn over for the next question

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 

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

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

[1 mark]

mass solute = 10.13 − 4.48 = 5.65 g

two mass readings ∴ uncertainty ± 2 × 0.005 = 0.010 g

% uncertainty $\frac{0.01}{5.65} \times 100$

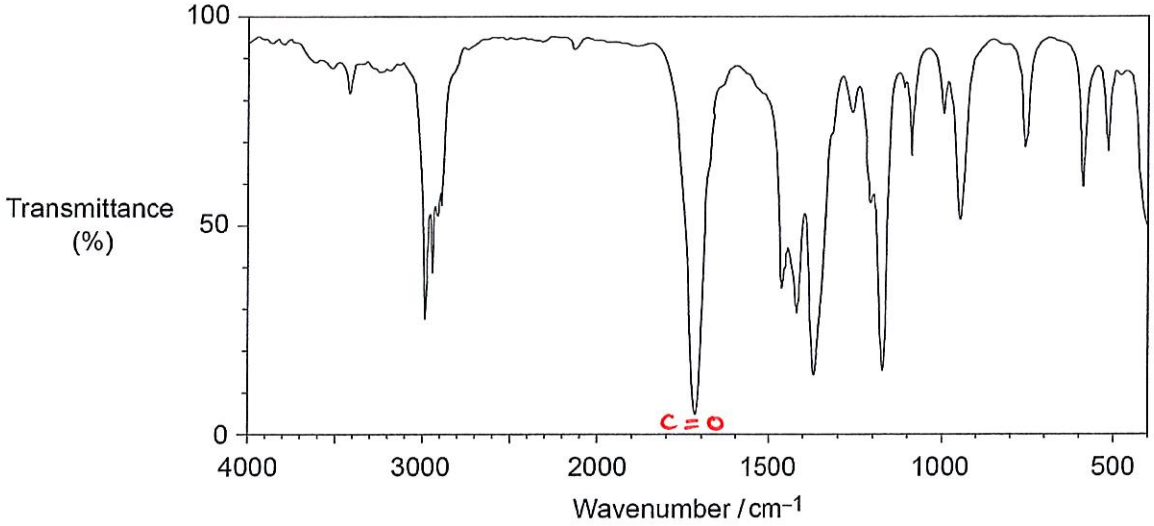
A 0.09%

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

B ethanol

C pent-2-ene

D propanoic acid

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°

tetrahedral but angle reduced due to 2 lone pairs

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

[1 mark]

A butane not isomer

B *E*-but-2-ene stereoisomer

C cyclobutane

D methylbut-2-ene not 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 $CHCl_3 + Cl_2 \rightarrow CCl_4 + HCl$ overall

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

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

D $\bullet CCl_3 + Cl_2 \rightarrow CCl_4 + \bullet Cl$ propagation

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 ● weaker bond between carbon and halogen because iodine is a larger molecule

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 2,3-dimethylbutan-2-ol ○

B 2,2-dimethylpropan-1-ol ● 1° alcohol

C 2-methylpropan-2-ol ○

D pentan-3-ol ○

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

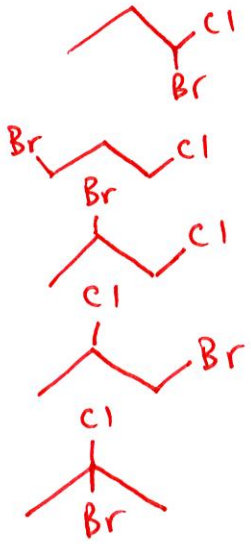
[1 mark]

A 4 ○

B 5 ●

C 6 ○

D 7 ○



1 9 Which sample contains the most molecules?

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

molecules = nL

[1 mark]

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

B 1.00 g of oxygen, O_2 $\frac{1.00}{32} \times L = 1.88 \times 10^{22}$ ○

C 65.0 mg of hydrogen, H_2 $\frac{65 \times 10^{-3}}{2} \times L = 1.96 \times 10^{22}$ ○

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

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

[1 mark]

A butanone C_4H_8O ○

B cyclobutanol C_4H_8O ○

C dimethylpropane C_5H_{12} ●

D methylpropanal C_4H_8O ○

2 1 Hydrogen can be produced by this reaction.

$$\underset{n_i}{} \quad \underset{4.20}{} \quad \underset{2.00}{} \quad \underset{0}{} \quad \underset{0}{}$$
$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$
$$\underset{\text{reqn}}{} \quad \underset{4.2-1.6}{} \quad \underset{2.0-1.6}{} \quad \underset{1.6}{} \quad \underset{1.6}{}$$

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]**

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

$$= \frac{1.6 \times 1.6}{2.6 \times 0.4}$$

$$= \frac{2.56}{1.04}$$

$$= 2.46$$

A 0.30 ○

B 0.41 ○

C 1.54 ○

D 2.46 ●

2 2 A sample of 2.0 mol dm^{-3} acid has a volume of 100 cm^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]**

Number of moles remains the same so $n_1 = n_2$

$$c_1V_1 = c_2V_2$$

$$2 \times 100 \times 10^{-3} = 1.5 \times V_2$$

$$V_2 = \frac{0.2}{1.5} = 0.1\dot{3}\ dm^3$$

$$= 13\dot{3}\ cm^3$$

$\therefore$ add $13\dot{3} - 100$

A 25 ○

B 33.3 ●

C 50 ○

D 66.7 ○

Turn over for the next question

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

So same number of moles

Flask **A** contains 4.0×10^{-3} mol of methane.

Flask **B** contains 340 mg of a different gas. 340×10^{-3} g

Both gases are at the same temperature and pressure.

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

[1 mark]

M_r $\quad n = \frac{m}{M_r}$

A CH_2Cl_2 85.0 $\quad 4.0 \times 10^{-3}$ ●

B HBr 80.9 $\quad M_r = \frac{m}{n}$ ○

C Kr 83.8 $\quad = \frac{3.40 \times 10^{-3}}{4 \times 10^{-3}}$ ○

D PF_3 88.0 $\quad = 85$ ○

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]

mole ratio C : N
22 : 6

A 0.041 g $\quad 0.0195 : 0.0195 \times \frac{6}{22}$ ○

B 0.057 g $\quad 5.318 \times 10^{-3}$ ○

C 0.074 g $\quad m = nAr$ ●

D 0.420 g $\quad = 5.318 \times 10^{-3} \times 14$ ○

END OF QUESTIONS