



Please write clearly in block capitals.

Centre number

--	--	--	--	--

Candidate number

--	--	--	--

Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

AS CHEMISTRY

Paper 2 Organic and Physical Chemistry

Tuesday 20 May 2025

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 65 minutes on **Section A** and 25 minutes on **Section B**.

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



J U N 2 5 7 4 0 4 2 0 1

Section A

Answer **all** questions in this section.

0 1

This question is about halogenoalkanes.

0 1 . 1

Halogenoalkanes undergo substitution reactions with nucleophiles such as CN^- , NH_3 and OH^-

Explain why halogenoalkanes react with nucleophiles.

[2 marks]

The halogen is more electronegative than carbon, so the C-halogen bond is polar and the carbon atom bonded to the halogen is $\delta+$.

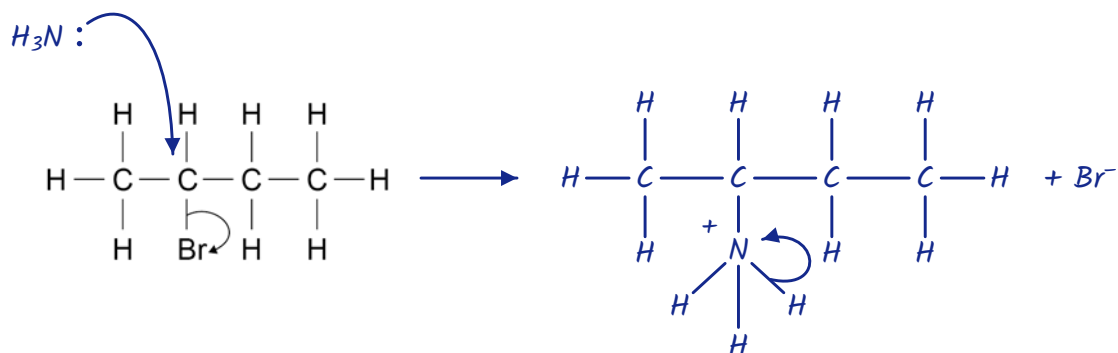
The nucleophile has a lone pair of electrons, which is attracted to and attacks the $\delta+$ carbon atom.

0 1 . 2

2-Bromobutane reacts with ammonia to form $\text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_2\text{CH}_3$

Complete the mechanism for this reaction.

[3 marks]



2-Bromobutane reacts with KOH to give a mixture of products.

0 1 . 3

Identify the solvent that should be used to ensure that butan-2-ol is the main organic product when 2-bromobutane reacts with KOH

[1 mark]

Water (use aqueous KOH , not ethanol)



0 1 . 4

Under different conditions, 2-bromobutane reacts with KOH to form but-1-ene and two other alkenes.

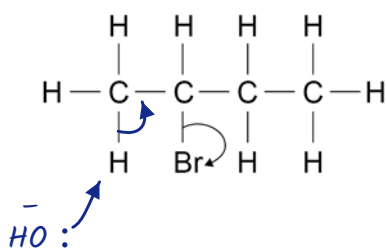
Name and complete the mechanism to form but-1-ene from 2-bromobutane.

Identify the other two alkenes formed.

[5 marks]

Name of mechanism (Base) elimination

Mechanism



Other alkene 1

E-but-2-ene (trans-but-2-ene)



Other alkene 2

Z-but-2-ene (cis-but-2-ene)



0 1 . 5

The carbocation $(\text{CH}_3)_3\text{C}^+$ is formed as an intermediate in the reaction of 2-bromo-2-methylpropane with KCN

Suggest the value of the bond angle around the central C atom in the $(\text{CH}_3)_3\text{C}^+$ carbocation.

[1 mark]

120°

Question 1 continues on the next page

Turn over ►



0 1 . 6

A co-ordinate bond is formed when the $(\text{CH}_3)_3\text{C}^+$ carbocation reacts with CN^- to form a nitrile.

Explain how this co-ordinate bond is formed during this reaction.

[2 marks]

A co-ordinate bond is a covalent bond (shared pair of electrons) in which both electrons come from the same species.

The lone pair of electrons on the carbon atom of CN^- is donated to the positively charged central C atom of the $(\text{CH}_3)_3\text{C}^+$ carbocation.

14



0 2

Methanol can be made by the reaction of carbon monoxide with hydrogen.

This reaction is done with a catalyst at a high temperature.

0 2 . 1

Describe how a catalyst increases the rate of a reaction.

[2 marks]

A catalyst provides an alternative reaction route (pathway) with a lower activation energy.

So more particles have energy greater than or equal to the activation energy, and successful collisions are more frequent.

0 2 . 2

Explain why the rate of a reaction increases as the temperature increases.

[3 marks]

As the temperature increases, the particles (molecules) move faster because they have more kinetic energy.

So more of the molecules have energy greater than or equal to the activation energy.

Therefore successful collisions (collisions that lead to a reaction) are more frequent, so the rate increases.

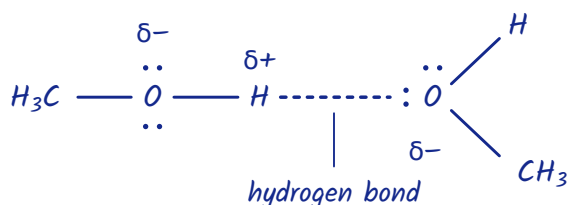
0 2 . 3

Hydrogen bonds exist between molecules of liquid methanol.

Draw a diagram to show a hydrogen bond between two molecules of methanol.

Include all the lone pairs of electrons and the partial charges on the atoms involved in this hydrogen bond.

[3 marks]



0 3

Molecules of CCl_4 and CHCl_3 have similar tetrahedral shapes.

The boiling point of CCl_4 is 77°C

The boiling point of CHCl_3 is 61°C

Explain why CCl_4 has a higher boiling point than CHCl_3

Your answer should

- explain why these molecules have a tetrahedral shape
- explain why the molecules of each compound are polar or non-polar
- compare the intermolecular forces in these compounds.

[6 marks]

Shape: in both CCl_4 and CHCl_3 the central carbon atom has four bonding pairs of electrons and no lone pairs. These electron pairs repel each other as far apart as possible (equally, to minimise repulsion), so both molecules are tetrahedral with bond angles of 109.5° .

Polarity: chlorine is more electronegative than carbon, so each C-Cl bond is polar ($\text{C}^{\delta+}-\text{Cl}^{\delta-}$).

CCl_4 is not polar: the molecule is symmetrical, with four identical polar C-Cl bonds arranged tetrahedrally, so the bond dipoles cancel out due to symmetry and there is no overall dipole.

CHCl_3 is polar: one of the four bonds is a C-H bond, which is almost non-polar, so the molecule is not symmetrical and the dipoles do not cancel out, giving a permanent dipole.

Intermolecular forces: CCl_4 molecules only have van der Waals' forces between them. CHCl_3 molecules have permanent dipole-dipole forces as well as van der Waals' forces.

However, CCl_4 has more electrons than CHCl_3 (a higher M_r , 154 compared with 119.5, and a bigger molecule), so the van der Waals' forces between CCl_4 molecules are stronger.



The van der Waals' forces in CCl_4 are stronger than the combined van der Waals' and dipole-dipole forces in CHCl_3 . So more energy is needed to overcome the intermolecular forces in CCl_4 , so CCl_4 has the higher boiling point. (No covalent bonds are broken when the liquids boil.)



0 4

This question is about some compounds with the molecular formula $C_4H_6O_2$

0 4 . 1

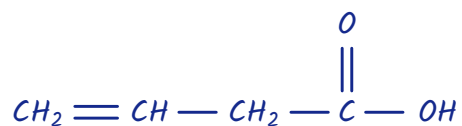
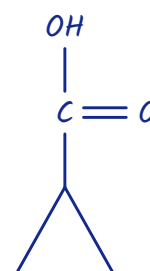
Compounds **A** and **B**

- each have the molecular formula $C_4H_6O_2$
- are functional group isomers of each other
- each react with sodium carbonate to form a gas.

Compound **A** decolourises bromine water but compound **B** does not.

Draw a possible structure of **A** and a possible structure of **B**.

[2 marks]

Compound **A**Compound **B**

0 4 . 2

Compound **C** has the molecular formula $C_4H_6O_2$ In the infrared spectrum of **C**, there is

- absorption in the range $3230\text{--}3550\text{ cm}^{-1}$
- absorption in the range $1620\text{--}1680\text{ cm}^{-1}$
- **no** absorption in the range $1680\text{--}1750\text{ cm}^{-1}$

Draw a possible structure of **C**.Use **Table A** on the Data Sheet to help you answer this question.

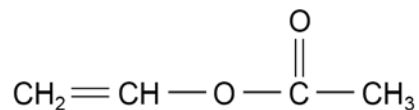
[1 mark]



0 4 . 3

Vinyl acetate (VA) has the molecular formula $C_4H_6O_2$

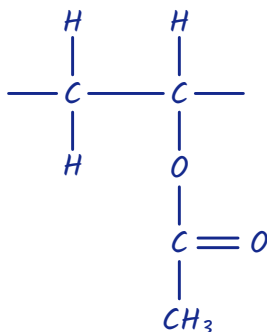
The structure of vinyl acetate is shown.



PVA is an addition polymer of vinyl acetate.

Draw the repeating unit of PVA.

[1 mark]



4

Turn over ►



There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



0 5

This question is about determining the relative molecular mass (M_r) of different compounds.

0 5 . 1

The M_r of a compound can be determined by mass spectrometry.

Propanone, prop-2-en-1-ol and butane each have $M_r = 58.0$

Give the reason why high resolution mass spectrometry can distinguish between propanone and butane, but cannot distinguish between propanone and prop-2-en-1-ol.

[2 marks]

High resolution mass spectrometry gives M_r to several decimal places:

butane (C_4H_{10}) has a different precise M_r from propanone (C_3H_6O), so they can be distinguished.

Prop-2-en-1-ol and propanone have the same molecular formula, C_3H_6O (they are isomers), so they have the same precise M_r .

Question 5 continues on the next page

Turn over ►

0 5 2

A student does an experiment to determine the M_r of a volatile liquid **X**.

In this experiment a conical flask of known volume is filled with vaporised **X** which is then condensed back into a liquid in the flask.

Method

1. Place a piece of aluminium foil over the opening of a conical flask.
2. Record the mass of the conical flask and foil.
3. Remove the foil and add 5 cm³ of liquid **X** to the flask.
4. Replace the foil and use a pin to make a tiny hole in the middle of the foil.
5. Place the conical flask in a large beaker of boiling water (see **Figure 1**) until all of liquid **X** has vaporised. The flask is now full of vaporised **X** (the air and some of **X** escaped through the tiny hole).
6. Allow the conical flask to cool so that the vaporised **X** that was in the flask cools and condenses (air returns to the flask).
7. Record the mass of the conical flask with foil and condensed **X**.

Figure 1

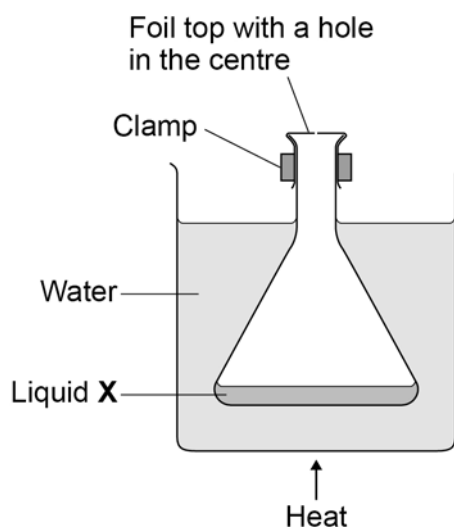


Table 1 shows the student's results.

Table 1

Volume of conical flask / cm ³	272
Temperature of boiling water / °C	100
Pressure / Pa	102 000
Mass of flask + foil in step 2 / g	105.872
Mass of flask + foil + X in step 7 / g	106.633



Calculate the M_r of X.

Assume that the mass of air in the flask is the same in steps 2 and 7.

Gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

[5 marks]

$$pV = nRT, \text{ so } n = pV \div RT$$

$$V = 272 \text{ cm}^3 = 272 \times 10^{-6} \text{ m}^3 \quad T = 100 + 273 = 373 \text{ K}$$

$$n = (102\,000 \times 272 \times 10^{-6}) \div (8.31 \times 373)$$

$$n = 27.744 \div 3099.63 = 0.00895 \text{ mol}$$

$$\text{Mass of X} = 106.633 - 105.872 = 0.761 \text{ g}$$

$$M_r = \text{mass} \div n = 0.761 \div 0.00895$$

$$M_r = 85.0$$

M_r 85.0

7

Turn over for the next question

Turn over ►



There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



0 6

Cyclohexanol can be made in the laboratory by the hydration of cyclohexene using concentrated phosphoric acid as a catalyst at low temperature. The cyclohexanol is purified by distillation.

0 6 . 1

Complete the equation for the conversion of cyclohexene to cyclohexanol in this reaction.

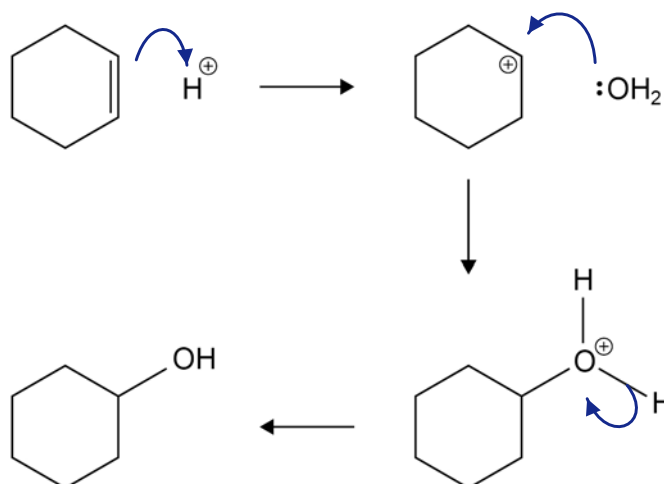
[1 mark]



0 6 . 2

Complete the mechanism for this reaction by adding curly arrows in the relevant places.

[3 marks]



0 6 . 3

Concentrated phosphoric acid (H_3PO_4) has a density of 1.69 g cm^{-3}

The concentrated acid contains 85% phosphoric acid and 15% water by mass.

Calculate the amount, in mol, of phosphoric acid in 6.0 cm^3 of concentrated phosphoric acid.

[2 marks]

$$\text{Mass of concentrated acid} = 6.0 \times 1.69 = 10.14 \text{ g}$$

$$\text{Mass of } \text{H}_3\text{PO}_4 = 10.14 \times 0.85 = 8.619 \text{ g}$$

$$M_r \text{ of } \text{H}_3\text{PO}_4 = 3(1.0) + 31.0 + 4(16.0) = 98.0$$

$$\text{Amount} = 8.619 \div 98.0 = 0.0879 \text{ mol}$$

Amount of phosphoric acid 0.0879 mol

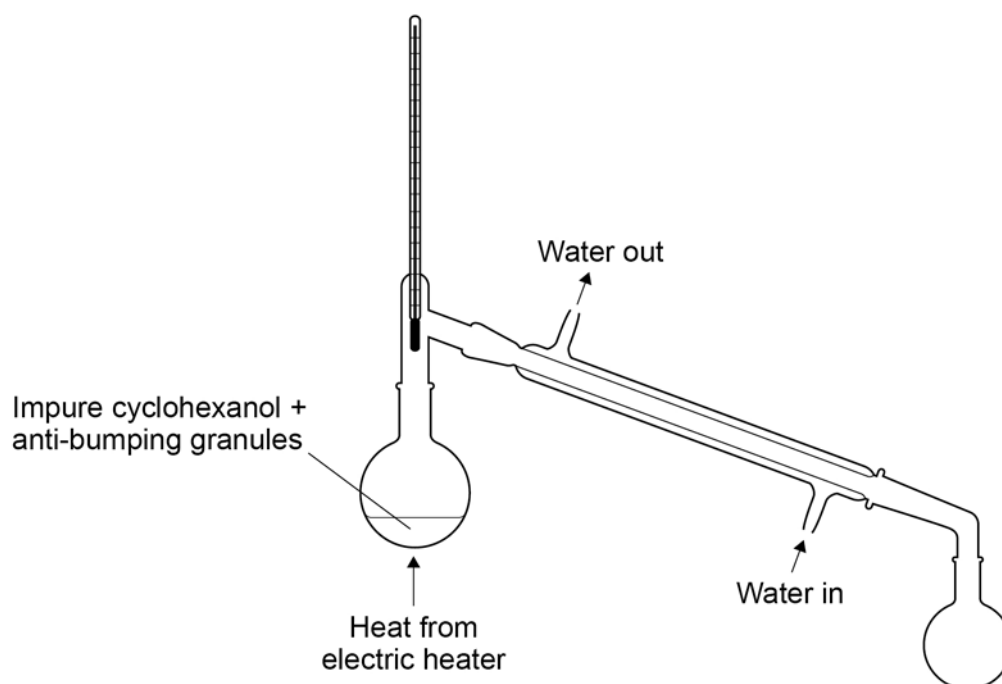
Question 6 continues on the next page

Turn over ►



A student sets up the apparatus shown in **Figure 2** to purify the cyclohexanol by distillation. Suitable clamps are used to hold the apparatus firmly in place.

Figure 2



0 6 . 4

Explain why the condenser in **Figure 2** is connected so that water enters at the bottom and not at the top.

[2 marks]

So that the condenser jacket fills completely with water, with no air bubbles (air pockets).

This keeps the condenser cooler, so more of the vapour condenses (more efficient condensing).

0 6 . 5

The flask heated in **Figure 2** contains anti-bumping granules.

State why these are used.

[1 mark]

To produce smaller bubbles and prevent the formation of large bubbles, so the mixture boils smoothly.



0 6 . 6

Suggest why the flask in **Figure 2** is heated with an electric heater, rather than a Bunsen burner.

[1 mark]

Cyclohexanol (the mixture) is flammable, so a Bunsen flame could ignite it.

0 6 . 7

State why the apparatus set up in **Figure 2** is dangerous.

State how this problem could be solved.

[2 marks]

Why the apparatus is dangerous *The system is closed (sealed), so pressure builds up on heating and the apparatus could explode.*

How to solve the problem *Have a vent (an opening) on or near the collection flask, e.g. leave the receiver flask open to the air.*

0 6 . 8

The cyclohexanol can be dehydrated to re-form cyclohexene by heating with concentrated phosphoric acid.

Name the mechanism for this reaction.

[1 mark]

(Acid-catalysed) elimination

Question 6 continues on the next page

Turn over ►



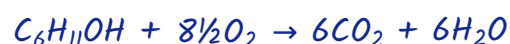
Cyclohexanol biofuel can be made from waste biomass materials such as rice and straw.

Cyclohexanol biofuel can be mixed with diesel and used as fuel in cars.

0 6 . 9

Give an equation for the complete combustion of cyclohexanol ($C_6H_{11}OH$).

[1 mark]



0 6 . 10

The use of cyclohexanol biofuel mixed with diesel in cars is not carbon-neutral.

State the meaning of the term carbon-neutral.

Give a reason why the use of this mixture as a fuel is **not** carbon-neutral.

[2 marks]

Carbon-neutral meaning *There is no net emission of carbon dioxide into the atmosphere (CO_2 given out = CO_2 absorbed).*

Why the fuel is not carbon-neutral *Fossil fuels are used in processing and transporting the fuel, emitting extra CO_2 . Also, diesel is a fossil fuel (non-renewable), not a biofuel.*

16



07

This question is about enthalpies of combustion.

07.1

Define enthalpy change.

[1 mark]

The heat energy change (change in heat content) at constant pressure.

07.2

The enthalpy of combustion of ethanol is $-1371 \text{ kJ mol}^{-1}$ A sample of ethanol is burned completely in air to raise the temperature of 55.0 g of water by 46.2°C Calculate the mass of ethanol in the sample.
Assume there is no heat loss.Specific heat capacity of water, $c = 4.18 \text{ J K}^{-1} \text{ g}^{-1}$

[5 marks]

$$q = mc\Delta T = 55.0 \times 4.18 \times 46.2$$

$$q = 10\,621 \text{ J} = 10.621 \text{ kJ}$$

$$\text{Amount of ethanol} = q \div \Delta H = 10.621 \div 1371$$

$$= 0.007747 \text{ mol}$$

$$M_r \text{ of ethanol } \text{C}_2\text{H}_5\text{OH} = 46.0$$

$$\text{Mass} = 0.007747 \times 46.0 = 0.356 \text{ g}$$

Mass of ethanol 0.356 g

Question 7 continues on the next page

Turn over ►



An alkane burns completely in oxygen. The equation for this reaction is shown.

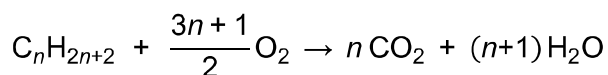


Table 2 gives some mean bond enthalpies.

Table 2

Bond	C=O	O–H
Bond enthalpy / kJ mol ⁻¹	805	463

0 7 . 3

Use **Table 2** to show that an expression for the sum of the bond enthalpies for **all** the bonds in the **products** is $2536n + 926$

[1 mark]

Products: $n\text{CO}_2$ contains $2n\text{ C=O bonds} = 2n \times 805 = 1610n$

$(n+1)\text{H}_2\text{O}$ contains $2(n+1)\text{ O-H bonds} = 2(n+1) \times 463 = 926n + 926$

Sum = $2n(805) + 2(n+1)463 = 1610n + 926n + 926 = 2536n + 926$

0 7 . 4

An expression for the sum of the bond enthalpies for **all** the bonds in the **reactants** is $1916n + 724$

A calculated value for the enthalpy of combustion of an alkane is -3302 kJ mol^{-1}

Use this enthalpy change and the expressions to calculate a value of n for this alkane.

Use your value of n to deduce the molecular formula of the alkane.

[3 marks]

$$\Delta H = \Sigma(\text{bonds broken}) - \Sigma(\text{bonds formed})$$

$$-3302 = (1916n + 724) - (2536n + 926)$$

$$-3302 = -620n - 202, \text{ so } 620n = 3100$$

$$n = 3100 \div 620 = 5$$

Value of n 5

Molecular formula C_5H_{12}

10



Section B

Answer **all** questions in this section.Only **one** answer per question is **allowed**.For each question **completely fill** in the circle alongside the appropriate answer.

CORRECT METHOD



WRONG METHODS



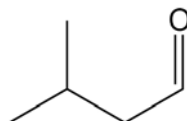
If you want to change your answer you must cross out your original answer as shown.

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

What is the name of this compound according to IUPAC rules?



[1 mark]

A 2-methylbutanal

☐

B 3-methylbutanal

☒

C 2-methylbutan-1-one

☐

D 3-methylbutan-1-one

☐

Turn over for the next question

Turn over ►



0 9

Which statement about the combustion of petrol in vehicles is correct?

[1 mark]

- A** Exhaust gases can contain a mixture of unburned hydrocarbon molecules. ☒
- B** In the catalytic converter, carbon dioxide is converted into carbon monoxide. ☐
- C** More nitrogen gas is emitted from the catalytic converter than enters the internal combustion engine. ☐
- D** Combustion in a plentiful supply of oxygen often causes an increased amount of black solid to be emitted from the exhaust. ☐

1 0

Which statement about catalytic cracking is correct?

[1 mark]

- A** A high percentage of alkenes is formed. ☐
- B** A pressure of about 70 MPa is used. ☐
- C** C–C bonds are broken. ☒
- D** A nickel catalyst is used. ☐

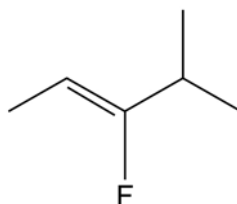
1 1Which compound produces $(\text{CH}_3)_2\text{CHCOCH}_3$ on oxidation?**[1 mark]**

- A** 2-methylpropan-1-ol ☐
- B** 2,2-dimethylpropan-1-ol ☐
- C** 2-methylbutan-2-ol ☐
- D** 3-methylbutan-2-ol ☒



1 2

What is the name of this compound according to IUPAC rules?



[1 mark]

A *E*-3-fluoro-2-methylpent-3-ene

☐

B *Z*-3-fluoro-2-methylpent-4-ene

☐

C *E*-3-fluoro-4-methylpent-2-ene

☐

D *Z*-3-fluoro-4-methylpent-2-ene

☒

1 3

2-Methylpentane-1,2,4-triol is refluxed with an excess of acidified potassium dichromate(VI).

What is the molecular formula of the main organic product?

[1 mark]

A $C_6H_8O_4$

☐

B $C_6H_{10}O_3$

☐

C $C_6H_{10}O_4$

☒

D $C_6H_{12}O_3$

☐

1 4

Sulfur dioxide can be found in the flue gases from the combustion of some fuels.

Which statement about sulfur dioxide is correct?

[1 mark]

A Sulfur dioxide molecules have a linear shape.

☐

B Sulfur dioxide is a basic oxide.

☐

C Sulfur dioxide reacts with calcium oxide to form $CaSO_4$ as the main product.

☐

D Sulfur dioxide molecules contain polar bonds.

☒

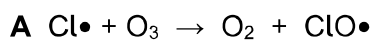
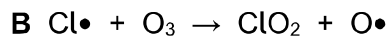
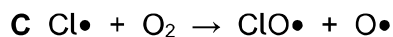
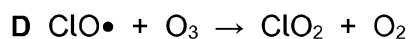
Turn over ►



1 5

Which equation shows a step in the decomposition of ozone by free radicals formed from CFCs in the upper atmosphere?

[1 mark]

☒☐☐☐

1 6

Crude oil is separated into fractions in a fractionating column at an oil refinery.

Which statement about the fractions collected higher up in the column, compared with those collected lower down, is correct?

[1 mark]

A They are collected at a higher temperature.

☐

B They have stronger intermolecular forces.

☐

C They are more volatile.

☒

D They are more viscous.

☐

1 7

Which of these gases is **not** linked to global warming caused by the absorption of infrared radiation?

[1 mark]

A CO_2

☐

B C_3H_8

☐

C H_2O

☐

D N_2

☒

1 8

The standard enthalpies of combustion for carbon, hydrogen and benzene (C_6H_6) are -394 , -286 and $-3273 \text{ kJ mol}^{-1}$ respectively.

What is the standard enthalpy of formation of benzene, in kJ mol^{-1} ?

[1 mark]

A +51

☒

B -51

☐

C +807

☐

D -807

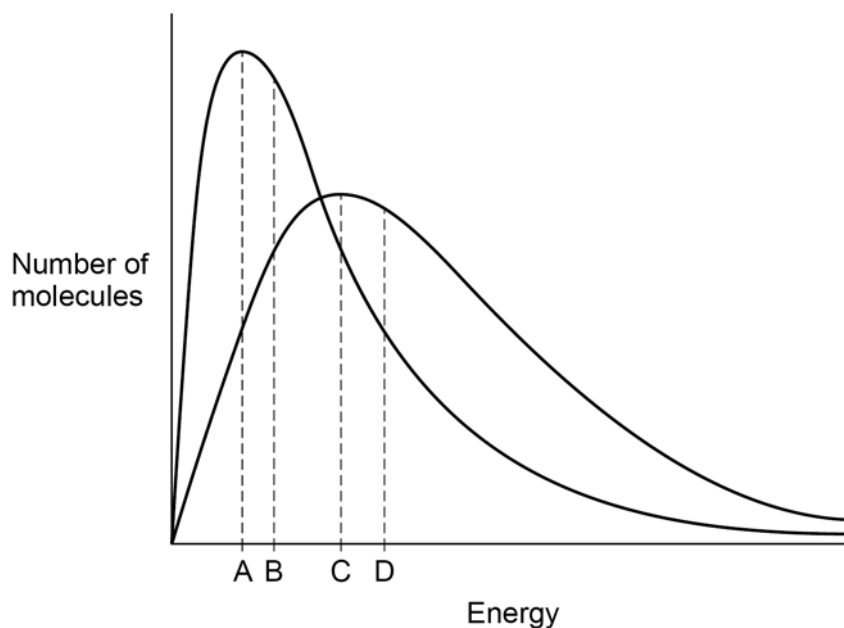
☐

1 9

The Maxwell-Boltzmann distribution of molecular energies for a sample of gas at two different temperatures is shown.

Which letter represents the mean energy of the molecules at the lower temperature?

[1 mark]



A

☐

B

☒

C

☐

D

☐

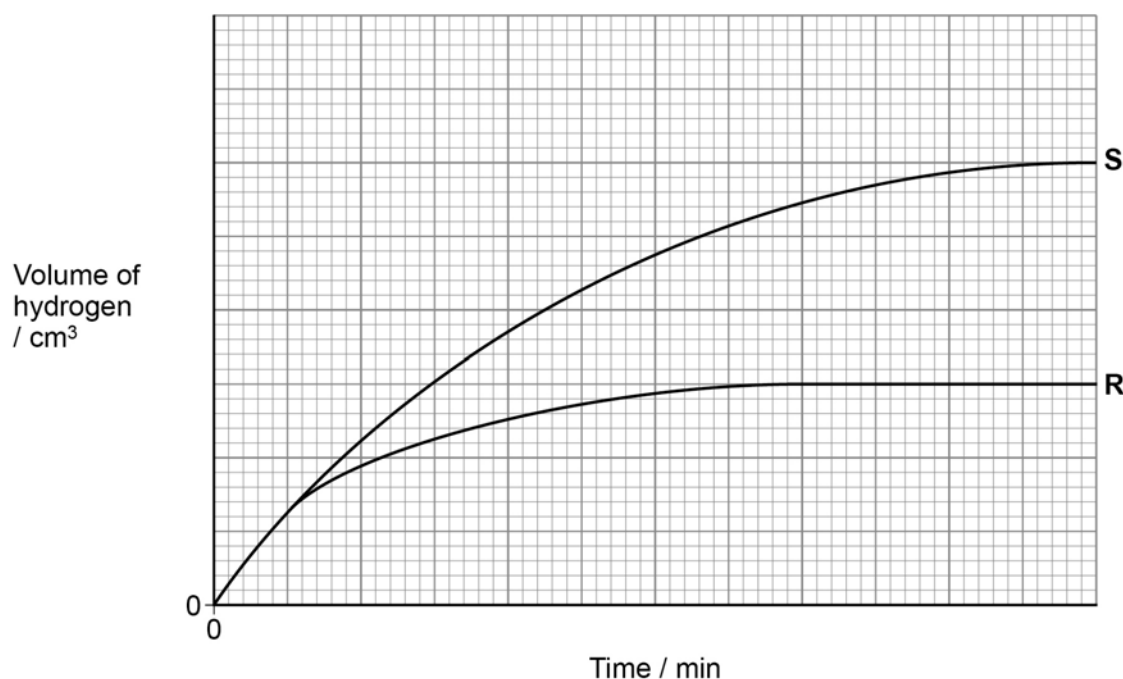
Turn over for the next question

Turn over ►



2 0

A student adds 0.48 g of magnesium ribbon to 100 cm³ of 1.0 mol dm⁻³ hydrochloric acid. The student records the volume of hydrogen collected at regular time intervals. Line **R** on the graph shows the results.



Which of these reactions gives results shown by line **S**?

Assume that the reactions occur at the same temperature.

[1 mark]

A 0.48 g of magnesium reacting with 200 cm³ of 1.0 mol dm⁻³ hydrochloric acid

☐

B 0.48 g of magnesium reacting with 100 cm³ of 2.0 mol dm⁻³ hydrochloric acid

☐

C 0.96 g of magnesium reacting with 200 cm³ of 1.0 mol dm⁻³ hydrochloric acid

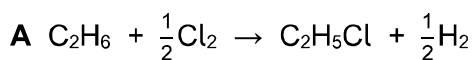
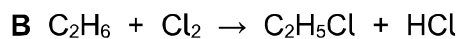
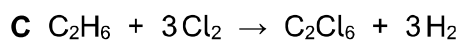
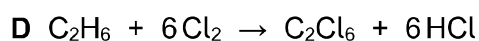
☒

D 0.96 g of magnesium reacting with 200 cm³ of 2.0 mol dm⁻³ hydrochloric acid

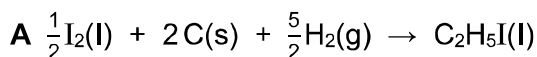
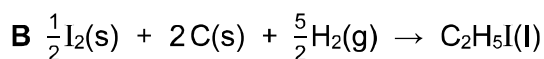
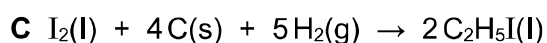
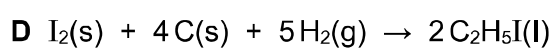
☐


2 1

Which equation for the reaction of chlorine with excess ethane in the presence of ultraviolet light is correct?

[1 mark]☐☒☐☐**2 2**

Which reaction at 298 K has a standard enthalpy change equal to the standard enthalpy of formation of liquid iodoethane?

[1 mark]☐☒☐☐**15****END OF QUESTIONS**

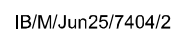
There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



[illegible]

[illegible]

Do not write
outside the
box

[illegible]

There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**

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 © 2025 AQA and its licensors. All rights reserved.

