

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

AS CHEMISTRY

Paper 2 Organic and Physical Chemistry

Thursday 23 May 2019

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.
- 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	
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8	
9	
Section B	
TOTAL	

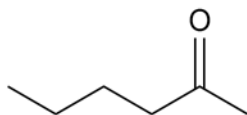
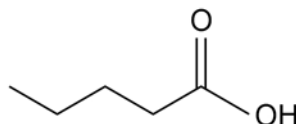
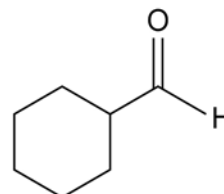


J U N 1 9 7 4 0 4 2 0 1

Section A

Answer **all** questions in this section.

0 1

The structures of three organic compounds **A**, **B** and **C** are shown.Compound **A**Compound **B**Compound **C**

These compounds can be distinguished by simple test-tube reactions.

For each pair of compounds in questions **01.1** and **01.2**, give a reagent (or combination of reagents) that could be added separately to each compound to distinguish between them.

State what is observed in each case.

0 1 . 1

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

[3 marks]

Reagent Sodium carbonate solution (Na_2CO_3)Observation with **A** No visible changeObservation with **B** Effervescence (bubbles of gas / fizzing)

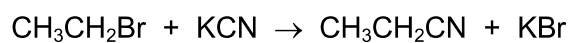
0 1 . 2

Compounds **A** and **C**

[3 marks]

Reagent Tollens' reagent (ammoniacal silver nitrate)Observation with **A** No visible change (stays colourless)Observation with **C** Silver mirror forms (grey / black solid)

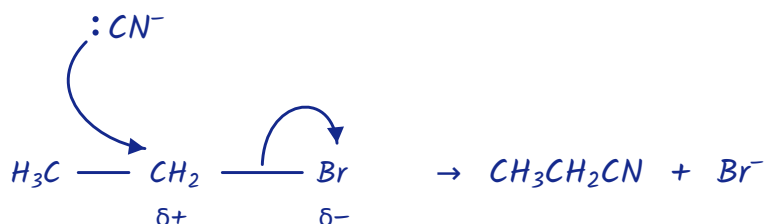
0 2

Bromoethane reacts with potassium cyanide to form compound **D**.Compound **D**

0 2 . 1

Outline the mechanism for this reaction.

[2 marks]



0 2 . 2

Give the IUPAC name of **D**.

[1 mark]

Propanenitrile

0 2 . 3

Calculate the percentage atom economy for the formation of **D** in this reaction.

Give your answer to the appropriate number of significant figures.

[2 marks]

$$\% \text{ atom economy} = M_r \text{ of D} \div \text{total } M_r \text{ of reactants} \times 100$$

$$= 55.0 \div (108.9 + 65.1) \times 100$$

$$= 55.0 \div 174.0 \times 100 = 31.6 \%$$

% atom economy 31.6

5

Turn over ►



0 3

This question is about enthalpy changes.

0 3 . 1

A student determined the enthalpy of combustion of cyclohexane (C_6H_{12}).

The student

- placed a pure sample of cyclohexane in a spirit burner
- placed the spirit burner under a beaker containing 50.0 g of water and ignited the cyclohexane
- extinguished the flame after a few minutes.

The results for the experiment are shown in **Table 1**.**Table 1**

Initial temperature of the water / °C	19.1
Initial mass of spirit burner and cyclohexane / g	192.730
Final mass of spirit burner and cyclohexane / g	192.100

The student determined from this experiment that the enthalpy of combustion of cyclohexane is $-1216 \text{ kJ mol}^{-1}$

Use the data to calculate the final temperature of the water in this experiment.

The specific heat capacity of water = $4.18 \text{ J K}^{-1} \text{ g}^{-1}$

The relative molecular mass (M_r) of cyclohexane = 84.0

[4 marks]

$$\text{Mass of cyclohexane burned} = 192.730 - 192.100 = 0.630 \text{ g}$$

$$\text{Moles} = 0.630 \div 84.0 = 0.00750 \text{ mol}$$

$$\text{Heat released, } q = 1216 \times 1000 \times 0.00750 = 9120 \text{ J}$$

$$q = mc\Delta T, \text{ so } \Delta T = 9120 \div (50.0 \times 4.18) = 43.6 \text{ }^\circ\text{C}$$

$$\text{Final temperature} = 19.1 + 43.6 = 62.7 \text{ }^\circ\text{C}$$



Final temperature of the water 62.7 °C

0 3 . 2 A data book value for the enthalpy of combustion of cyclohexane is $-3920 \text{ kJ mol}^{-1}$

The student concluded that the temperature rise recorded in the experiment was smaller than it should have been.

Suggest a practical reason for this.

[1 mark]

Heat is lost to the surroundings (not all the heat is transferred to the water), e.g. because there is no lid or insulation.

Question 3 continues on the next page

Turn over ►



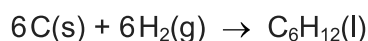
0 3 . 3

Table 2 gives some values of standard enthalpies of combustion ($\Delta_c H^\circ$).

Table 2

Substance	C(s)	H ₂ (g)	C ₆ H ₁₂ (l)
Standard enthalpy of combustion, $\Delta_c H^\circ / \text{kJ mol}^{-1}$	-394	-286	-3920

Use the data in Table 2 to calculate the enthalpy change for the reaction represented by this equation



[3 marks]

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

$$= [6 \times (-394) + 6 \times (-286)] - (-3920)$$

$$= [(-2364) + (-1716)] + 3920$$

$$= -4080 + 3920 = -160 \text{ kJ mol}^{-1}$$

Enthalpy change -160 kJ mol⁻¹

8



0	4
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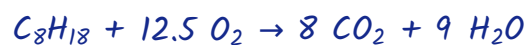
This question is about fossil fuels.

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The petrol fraction from crude oil contains octane (C_8H_{18}).

Give an equation for the complete combustion of octane.

[1 mark]

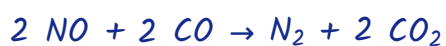


0	4	.	2
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The combustion of petrol in car engines produces the pollutant nitrogen monoxide.

Give an equation for a reaction that removes nitrogen monoxide in a catalytic converter.

[1 mark]



Question 4 continues on the next page

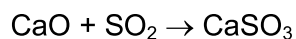
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0 4 . 3

Sulfur dioxide is produced in the combustion of fossil fuels. The total emissions of sulfur dioxide in the UK have fallen dramatically since 1970.

Sulfur dioxide is now removed from the flue gases in power stations by reaction with calcium oxide.



In 1970, the total UK emissions of sulfur dioxide were 6.49 million tonnes (1 tonne = 1000 kg).

Calculate the mass, in kilograms, of calcium oxide needed to react with this mass of sulfur dioxide.

Give your answer in standard form.

[2 marks]

$$\text{Mass of SO}_2 = 6.49 \times 10^6 \times 1000 \times 1000 = 6.49 \times 10^{12} \text{ g}$$

$$\text{Moles of SO}_2 = 6.49 \times 10^{12} \div 64.1 = 1.012 \times 10^{11} \text{ mol}$$

$$1 : 1 \text{ ratio, so moles of CaO} = 1.012 \times 10^{11} \text{ mol}$$

$$\text{Mass of CaO} = 1.012 \times 10^{11} \times 56.1 = 5.68 \times 10^{12} \text{ g}$$

$$= 5.68 \times 10^9 \text{ kg}$$

Mass of calcium oxide 5.68 × 10⁹ kg

4



0 5

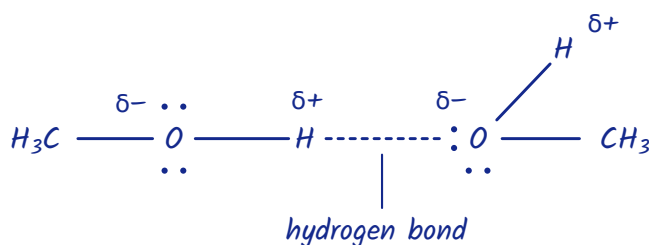
Methanol (CH_3OH) is an important alcohol with many uses.

0 5 . 1

Draw a diagram to show how two methanol molecules interact with each other through hydrogen bonding in the liquid phase.

Include all partial charges and all lone pairs of electrons in your diagram.

[3 marks]



0 5 . 2

The bond angle around the oxygen atom in methanol is slightly smaller than the regular tetrahedral angle of 109.5°

Explain why this bond angle is smaller than 109.5°

[1 mark]

The oxygen atom has two lone pairs of electrons. Lone pairs repel more strongly than bonding pairs, so the bonding pairs are pushed closer together (angle about 104.5°).

Turn over ►



0 5 . 3

Methanol is made by the reaction of carbon monoxide with hydrogen.



The reaction uses a copper-based catalyst, a pressure of 10 MPa and a temperature of 550 K

These conditions are used to provide a balance between equilibrium yield, reaction rate and cost.

Describe how the use of a catalyst, and changes in pressure and temperature, each affect equilibrium yield, reaction rate and cost.

[6 marks]

Catalyst: a catalyst has no effect on the equilibrium yield, because it speeds up the forward and reverse reactions equally. It increases the rate of reaction, because it provides an alternative route with a lower activation energy. Using a catalyst lowers costs, because equilibrium is reached faster and a lower temperature can be used, so less energy is needed.

Pressure: there are 3 moles of gas on the left and only 1 mole of gas on the right, so a higher pressure shifts the position of equilibrium to the right, giving a higher equilibrium yield of methanol. A higher pressure also gives a faster rate, because the gas molecules are closer together, so there are more frequent collisions. However, the higher the pressure, the greater the cost, because of the energy needed to compress the gases and the strong, expensive equipment needed. So 10 MPa is a compromise.

Temperature: the forward reaction is exothermic ($\Delta H = -91 \text{ kJ mol}^{-1}$), so a lower temperature shifts the equilibrium to the right, giving a higher equilibrium yield. However, a higher temperature gives a faster rate, because more molecules have energy greater than or equal to the activation energy, so there are more frequent successful collisions. The higher the temperature, the greater the cost of the energy needed for



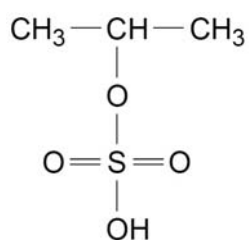
heating. So 550 K is a compromise temperature that gives a reasonable yield at a fast enough rate.



0 6

Propene reacts with concentrated sulfuric acid to form two isomers, **E** and **F**.

The structure of **E** is shown.



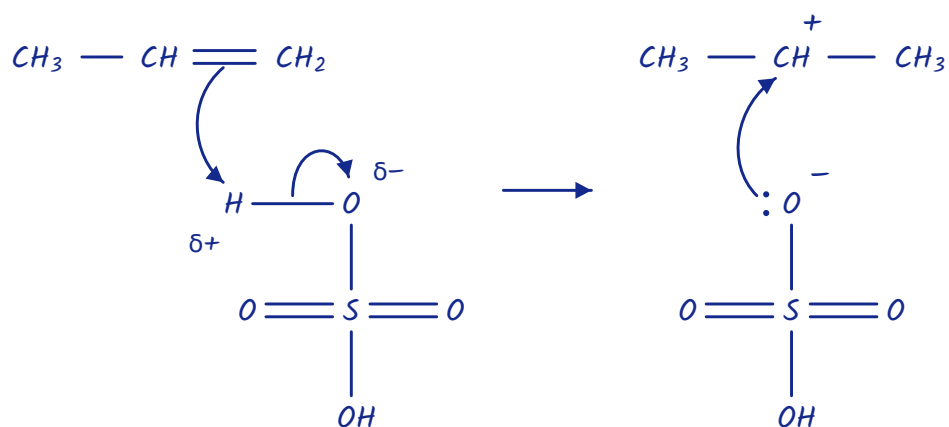
0 6 . 1

Name and outline the mechanism for the formation of **E** in this reaction.

[5 marks]

Name of mechanism Electrophilic addition

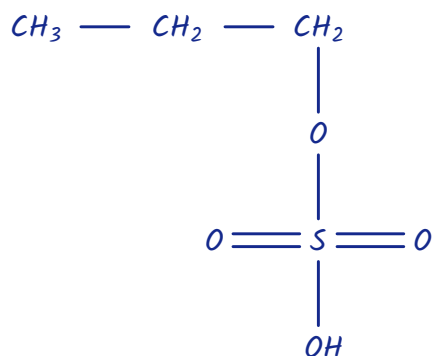
Mechanism



0 6 . 2

Draw the structure of **F**.

[1 mark]



0 6 . 3

Explain why more of isomer **E** than isomer **F** is formed in this reaction.

[2 marks]

E is formed via a secondary (2°) carbocation, but F is formed via a primary (1°) carbocation.

The secondary carbocation is more stable than the primary carbocation (it has more alkyl groups attached to the positive carbon), so E is formed more readily.

8

Turn over for the next question

Turn over ►



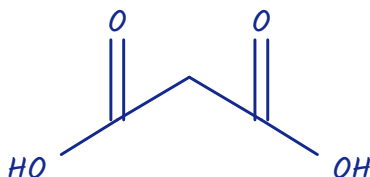
0 7

Propanedioic acid contains two carboxylic acid groups. It is a solid organic acid that is soluble in water.

0 7 . 1

Draw the skeletal formula of propanedioic acid.

[1 mark]



0 7 . 2

Describe how to prepare 250 cm³ of an aqueous standard solution of propanedioic acid containing an accurately measured mass of the acid. Include essential practical details in your answer.

[6 marks]

Place a weighing bottle on a balance and weigh out an accurately measured mass of propanedioic acid into it, recording the mass.

Tip the solid into a beaker, then reweigh the empty weighing bottle, so the exact mass of acid transferred is found by difference.

Add about 100 cm³ of distilled (deionised) water to the beaker and stir with a glass rod until all of the solid has dissolved.

Pour the solution into a 250 cm³ volumetric flask through a funnel.

Rinse the beaker, glass rod and funnel with distilled water and add all of the washings to the volumetric flask.

Add distilled water until the bottom of the meniscus is on the 250 cm³ graduation mark, adding the last few drops with a dropping pipette and reading at eye level.

Finally, stopper the flask and invert it (shake) several times so the solution is thoroughly mixed and homogeneous.



0	7	.	3
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Calculate the mass, in mg, of propanedioic acid ($M_r = 104.0$) needed to prepare 250 cm^3 of a $0.00500 \text{ mol dm}^{-3}$ solution.

[2 marks]

$$\text{Moles} = 0.00500 \times 250 \div 1000 = 0.00125 \text{ mol}$$

$$\text{Mass} = 0.00125 \times 104.0 = 0.130 \text{ g}$$

$$= 0.130 \times 1000 = 130 \text{ mg}$$

Mass of propanedioic acid 130 mg

9

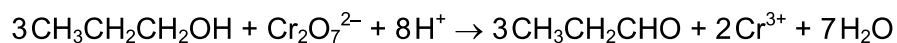
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0 8

Propanal can be prepared by the oxidation of propan-1-ol with acidified potassium dichromate(VI).

An ionic equation for this reaction is



0 8 . 1

Calculate the minimum volume, in cm^3 , of 0.40 mol dm^{-3} potassium dichromate(VI) solution needed to oxidise 6.0 cm^3 of propan-1-ol to propanal.

M_r of propan-1-ol = 60.0

Density of propan-1-ol = 0.80 g cm^{-3}

[3 marks]

$$\text{Mass of propan-1-ol} = 6.0 \times 0.80 = 4.8 \text{ g}$$

$$\text{Moles of propan-1-ol} = 4.8 \div 60.0 = 0.080 \text{ mol}$$

$$\text{Moles of } \text{Cr}_2\text{O}_7^{2-} = 0.080 \div 3 = 0.0267 \text{ mol}$$

$$\text{Volume} = 0.0267 \div 0.40 \times 1000 = 66.7 \text{ cm}^3$$

$$= 67 \text{ cm}^3 \text{ (2 s.f.)}$$

Minimum volume 67 cm^3



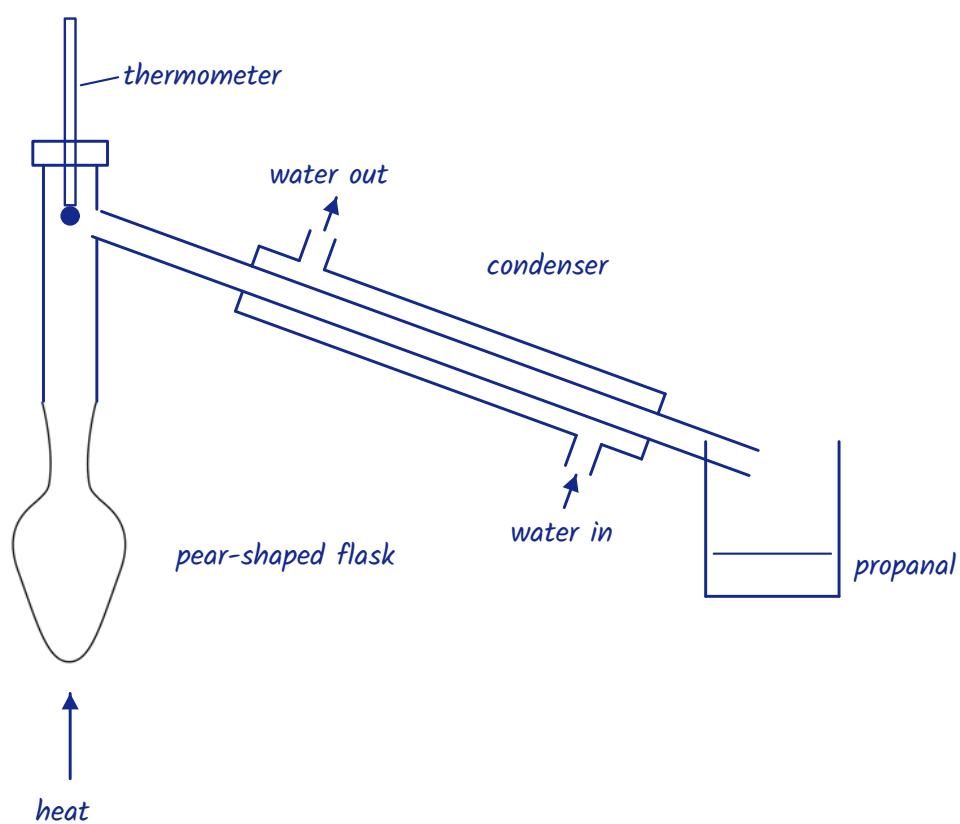
0 8 . 2

The reaction is done in a pear-shaped flask.

Complete the diagram to show the assembled apparatus needed to prepare propanal from propan-1-ol in this way.

Label the diagram.

[3 marks]



Turn over for the next question

Turn over ►



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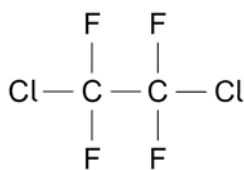
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ANSWER IN THE SPACES PROVIDED**



0 9

The compound 1,2-dichlorotetrafluoroethane is a CFC that was previously used in refrigerators as a coolant.



0 9 . 1

Molecules of 1,2-dichlorotetrafluoroethane can break down in the upper atmosphere to form chlorine radicals.

Give an equation to show the breakdown of one molecule of 1,2-dichlorotetrafluoroethane to form one chlorine radical and one other species.

[1 mark]



0 9 . 2

Give **two** equations to show how chlorine radicals catalyse the decomposition of ozone.

[2 marks]



Question 9 continues on the next page

Turn over ►



0 9 . 3

Butane can be used as a replacement for CFCs in refrigerators.

During its use, the butane is repeatedly converted from liquid to gas and then back to liquid. Liquid butane expands as it turns into a gas.

- Calculate the volume, in cm^3 , of 38.8 g of butane gas at 272 K and 101 kPa (the gas constant $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$) (M_r of butane = 58.0)
- Calculate the volume, in cm^3 , of 38.8 g of liquid butane. (density of liquid butane = 0.60 g cm^{-3})
- Use your answers to calculate the factor by which butane expands in volume when it changes from a liquid to a gas.

Show your working.

[6 marks]

$$\text{Moles of butane} = 38.8 \div 58.0 = 0.669 \text{ mol}$$

$$pV = nRT, \text{ so } V = nRT \div p$$

$$V = (0.669 \times 8.31 \times 272) \div 101\,000$$

$$= 0.0150 \text{ m}^3 \text{ (0.014971 m}^3\text{)}$$

$$= 0.0150 \times 10^6 \text{ cm}^3 = 15\,000 \text{ cm}^3$$

Volume of butane gas 15 000 cm^3



$$\text{Volume} = \text{mass} \div \text{density}$$

$$= 38.8 \div 0.60 = 64.7 \text{ cm}^3$$

Volume of liquid butane 64.7 cm³

$$\text{Expansion factor} = \text{volume of gas} \div \text{volume of liquid}$$

$$= 15\,000 \div 64.7 = 232$$

Expansion factor 232

9

Turn over ►



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

A 'drink-driving' offence is committed if the blood alcohol level of a driver is over 80 mg of ethanol per 100 cm³ of blood.What is the concentration, in mol dm⁻³, of ethanol if there are 80 mg of ethanol ($M_r = 46.0$) per 100 cm³ of blood?

[1 mark]

A 0.00017

☐

B 0.0017

☐

C 0.017

☒

D 1.7

☐

1 1

Which statement is correct for the distribution curve of molecular energies in a gas?

[1 mark]

A The curve is symmetrical about the maximum.

☐

B There are always some molecules with zero energy.

☐

C The position of the maximum of the curve is not dependent on the temperature.

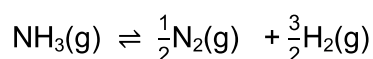
☐

D The mean energy of the molecules is greater than the most probable energy of the molecules.

☒

1 2

When one mole of ammonia is heated to a given temperature, 50 % of it dissociates and the following equilibrium is established.



What is the total amount, in moles, of gas in this equilibrium mixture?

[1 mark]

A 1.5

☒

B 2.0

☐

C 2.5

☐

D 3.0

☐

1 3

Which compound is **not** an isomer of the following compound?

[1 mark]

A $\text{CH}_3\text{CH}_2\text{COCH}_3$ ☐B $\text{CH}_3\text{CH}=\text{CHCH}_2\text{OH}$ ☐C $(\text{CH}_3)_2\text{CHCHO}$ ☐D $\text{CH}_2=\text{CHCH}_2\text{CHO}$ ☒

Turn over ►



1 4How many isomers are there of C₃H₉N?**[1 mark]****A** 2☐**B** 3☐**C** 4☒**D** 5☐**1 5**

Which equation represents a propagation step?

[1 mark]**A** $\cdot\text{CH}_2\text{Cl} + \text{Cl}\cdot \rightarrow \text{CH}_2\text{Cl}_2$ ☐**B** $\cdot\text{CH}_3 + \cdot\text{CH}_3 \rightarrow \text{C}_2\text{H}_6$ ☐**C** $\text{Cl}_2 \rightarrow \text{Cl}\cdot + \text{Cl}\cdot$ ☐**D** $\text{CH}_3\text{Cl} + \text{Cl}\cdot \rightarrow \cdot\text{CH}_2\text{Cl} + \text{HCl}$ ☒**1 6**

Which compound can react with ammonia to produce propylamine?

[1 mark]**A** $\text{CH}_3\text{CH}=\text{CH}_2$ ☐**B** $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$ ☐**C** $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ ☒**D** $\text{CH}_3\text{CH}_2\text{CH}_3$ ☐

1 7

Which statement is **not** correct about $\text{CH}_2=\text{C}(\text{CH}_3)\text{CH}_2\text{Br}$?

[1 mark]

- A It displays *E-Z* isomerism.
- B It forms an addition polymer.
- C It reacts with electrophiles.
- D It decolourises bromine water.

☒☐☐☐

1 8

Which compound can be oxidised to form $(\text{CH}_3)_2\text{CHCOCH}_3$?

[1 mark]

- A 2-methylpropan-1-ol
- B 2,2-dimethylpropanol
- C 2-methylbutan-2-ol
- D 3-methylbutan-2-ol

☐☐☐☒

1 9

Which species can act as a nucleophile?

[1 mark]

- A NH_4^+
- B CH_3OH
- C CH_4
- D H^+

☐☒☐☐

Turn over ►



2 0

Which alcohol forms a mixture of alkenes when dehydrated?

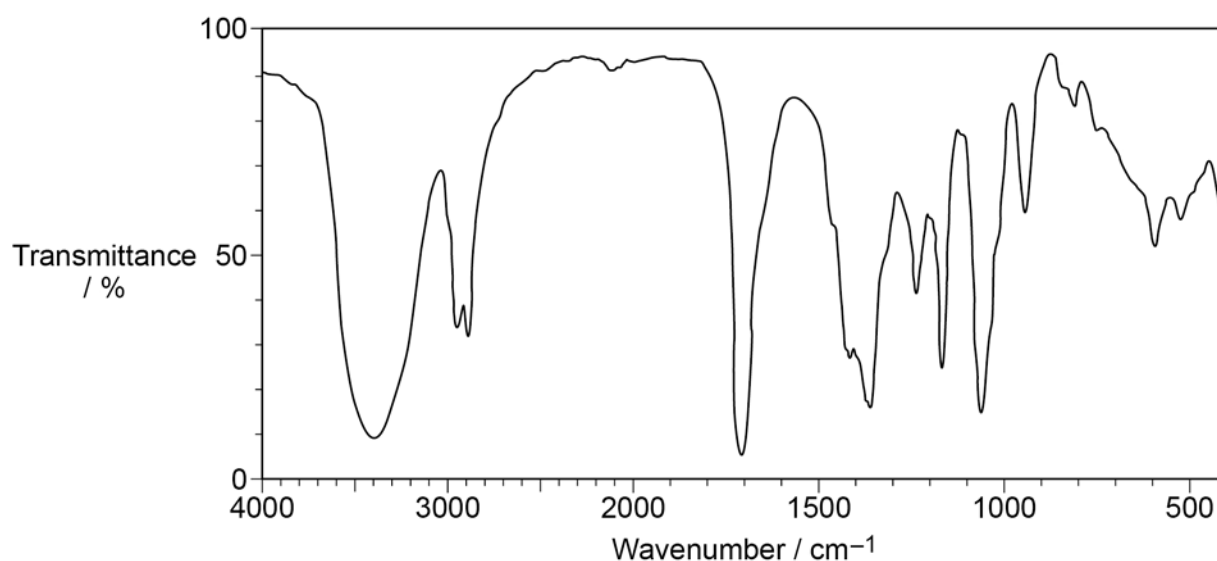
[1 mark]**A** propan-1-ol☐**B** propan-2-ol☐**C** pentan-1-ol☐**D** pentan-2-ol☒**2 1**

Which compound has the highest boiling point?

[1 mark]**A** $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ ☐**B** $\text{CH}_3\text{CH}_2\text{CH}_2\text{F}$ ☐**C** $\text{CH}_3\text{CH}_2\text{CHO}$ ☐**D** $\text{CH}_3\text{CH}_2\text{COOH}$ ☒**2 2**Which compound could **not** be produced by reacting 2-bromo-3-methylbutane with sodium hydroxide?**[1 mark]****A** 2-methylbut-1-ene☒**B** 3-methylbut-1-ene☐**C** 2-methylbut-2-ene☐**D** 3-methylbutan-2-ol☐

2 3

The infrared spectrum of an organic compound is shown.



Which compound produces this spectrum?

[1 mark]**A** ethanoic acid☐**B** 4-hydroxybutanone☒**C** propan-1-ol☐**D** prop-2-en-1-ol☐**Turn over for the next question****Turn over ►**

2	4
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The heat released when 1.00 g of ethanol ($M_r = 46.0$) undergoes complete combustion is 29.8 kJ

What is the heat released by each molecule, in joules, when ethanol undergoes complete combustion?

(the Avogadro constant $L = 6.022 \times 10^{23} \text{ mol}^{-1}$)

[1 mark]

A $2.28 \times 10^{-18} \text{ J}$

☒

B $4.95 \times 10^{-20} \text{ J}$

☐

C $2.28 \times 10^{-21} \text{ J}$

☐

D $4.95 \times 10^{-23} \text{ J}$

☐

15

END OF QUESTIONS

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2 8



1 9 6 A 7 4 0 4 / 2