Please write clearly in block capitals.

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

Surname ______________________________

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	
3	
4	
5	
6	
7	
8	
9	
Section B	
TOTAL	

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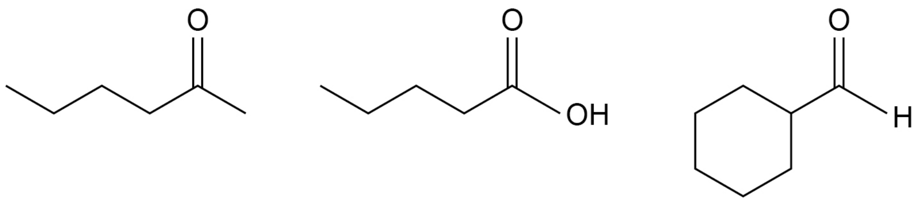
Section A

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 ____________________

Observation with **A** ____________________

____

Observation with **B** ____________________

____

0 1 . 2 Compounds **A** and **C**

[3 marks]

Reagent ____________________

Observation with **A** ____________________

____

Observation with **C** ____________________

____

6

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0 2 Bromoethane reacts with potassium cyanide to form compound **D**.

$$CH_3CH_2Br + KCN \rightarrow CH_3CH_2CN + KBr$$

Compound **D**

0 2 . 1 Outline the mechanism for this reaction.

[2 marks]

0 2 . 2 Give the IUPAC name of **D**.

[1 mark]

____

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]

% atom economy ______________________

5

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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 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 J K^{-1} g^{-1}
The relative molecular mass (M_r) of cyclohexane = 84.0

[4 marks]

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Final temperature of the water ______________________ °C

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

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]

____

____

____

Question 3 continues on the next page

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0 3 . 3 **Table 2** gives some values of standard enthalpies of combustion ($\Delta_c H^\ominus$).

Table 2

Substance	C(s)	H_2(g)	C_6H_{12}(l)
Standard enthalpy of combustion, $\Delta_c H^\ominus$ / kJ mol^{-1}	–394	–286	–3920

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

$$6C(s) + 6H_2(g) \rightarrow C_6H_{12}(l)$$

[3 marks]

Enthalpy change ______________________ kJ mol^{-1}

8

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0 4 This question is about fossil fuels.

0 4 . 1 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 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.

$$CaO + SO_2 \rightarrow CaSO_3$$

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]

Mass of calcium oxide ____________________ kg

4

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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]

Do not write outside the box

0 5 . 3 Methanol is made by the reaction of carbon monoxide with hydrogen.

$$CO + 2H_2 \rightleftharpoons CH_3OH \qquad \Delta H = -91 \text{ kJ mol}^{-1}$$

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]

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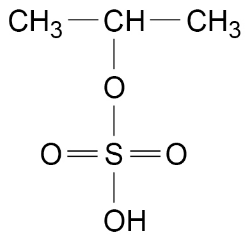
10

Turn over ►

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 ______________________________

Mechanism

Do not write outside the box

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]

8

Turn over for the next question

Do not write outside the box

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 cm^3 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]

Do not write outside the box

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

[2 marks]

Mass of propanedioic acid ______________________ mg

9

Turn over ►

Do not write outside the box

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

$$3CH_3CH_2CH_2OH + Cr_2O_7^{2-} + 8H^+ \rightarrow 3CH_3CH_2CHO + 2Cr^{3+} + 7H_2O$$

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]

Minimum volume ________________________ cm^3

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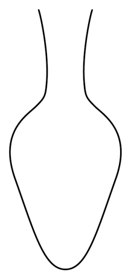
0 8 . 2 The reaction is done in a pear-shaped flask.

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

Label the diagram.

[3 marks]



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There are no questions printed on this page

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ANSWER IN THE SPACES PROVIDED

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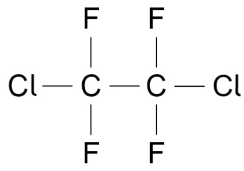
0 9 The compound 1,2-dichlorotetrafluoroethane is a CFC that was previously used in refrigerators as a coolant.



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

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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 J K^{-1} 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]

Volume of butane gas ____________________________________ cm^3

Do not write outside the box

Volume of liquid butane ____________________ cm^3

Expansion factor ____________________

9

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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 cm^3 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 cm^3 of blood?

[1 mark]

A 0.00017

B 0.0017

C 0.017

D 1.7

Do not write outside the box

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.

$$NH_3(g) \rightleftharpoons \frac{1}{2}N_2(g) + \frac{3}{2}H_2(g)$$

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

[1 mark]

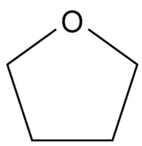
A 1.5 ⬭

B 2.0 ⬭

C 2.5 ⬭

D 3.0 ⬭

1 3 Which compound is **not** an isomer of the following compound?



[1 mark]

A $CH_3CH_2COCH_3$ ⬭

B $CH_3CH{=}CHCH_2OH$ ⬭

C $(CH_3)_2CHCHO$ ⬭

D $CH_2{=}CHCH_2CHO$ ⬭

Turn over ►

Do not write outside the box

1 4 How many isomers are there of C_3H_9N?

[1 mark]

A 2

B 3

C 4

D 5

1 5 Which equation represents a propagation step?

[1 mark]

A $\bullet CH_2Cl + Cl\bullet \rightarrow CH_2Cl_2$

B $\bullet CH_3 + \bullet CH_3 \rightarrow C_2H_6$

C $Cl_2 \rightarrow Cl\bullet + Cl\bullet$

D $CH_3Cl + Cl\bullet \rightarrow \bullet CH_2Cl + HCl$

1 6 Which compound can react with ammonia to produce propylamine?

[1 mark]

A $CH_3CH{=}CH_2$

B $CH_3CH_2CH_2OH$

C $CH_3CH_2CH_2Br$

D $CH_3CH_2CH_3$

1 7 Which statement is **not** correct about $CH_2{=}C(CH_3)CH_2Br$?

[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 $(CH_3)_2CHCOCH_3$?

[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 ►

Do not write outside the box

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 $CH_3CH_2CH_2Br$ ⬭

B $CH_3CH_2CH_2F$ ⬭

C CH_3CH_2CHO ⬭

D CH_3CH_2COOH ⬭

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 ⬭

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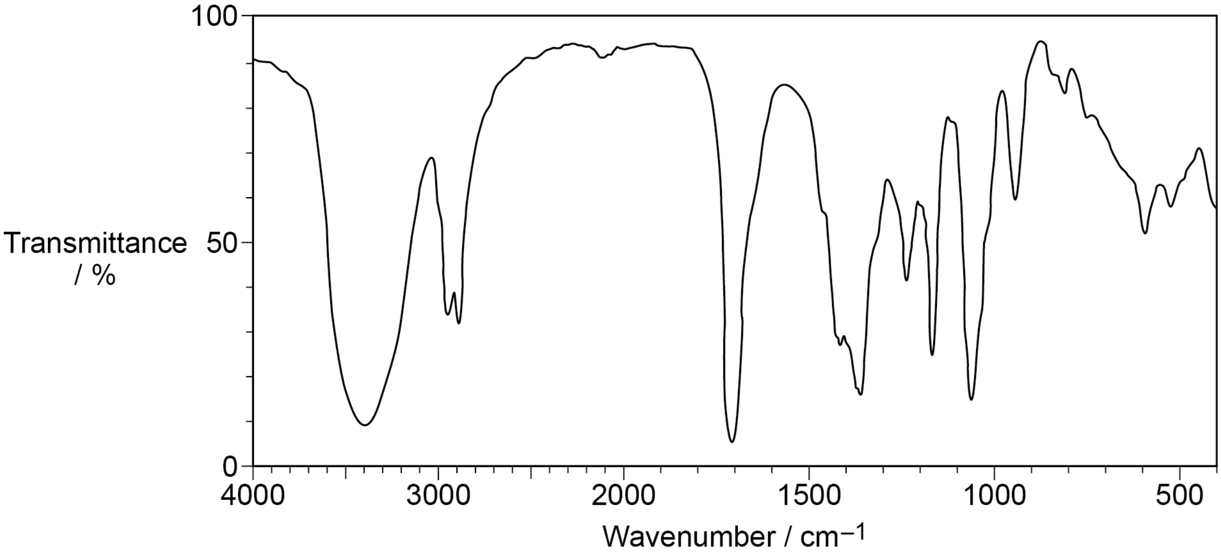
2 3 The infrared spectrum of an organic compound is shown.



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

Do not write outside the box

2 4 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 $L = 6.022 \times 10^{23}$ mol^{-1})

[1 mark]

A 2.28×10^{-18} J

B 4.95×10^{-20} J

C 2.28×10^{-21} J

D 4.95×10^{-23} J

15

END OF QUESTIONS