

Chemistry

Advanced

PAPER 2: Advanced Organic and Physical Chemistry

Time: 1 hour 45 minutes

In the boxes below, write your name, centre number and candidate number.

Surname					
Other names					
Centre Number					
Candidate Number					

YOU MUST HAVE

Scientific calculator, Data Booklet, ruler

YOU WILL BE GIVEN

Diagram Booklet, Periodic Table

INSTRUCTIONS

Answer ALL questions.

Answer the questions in the spaces provided in this Question Paper or in the separate Diagram Booklet – there may be more space than you need.

INFORMATION

The total mark for this paper is 90.

The marks for EACH question are shown in brackets – use this as a guide as to how much time to spend on each question.

For the question marked with an ASTERISK (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.

A Periodic Table is provided as a separate insert.

There may be spare copies of some diagrams.

ADVICE

Read each question carefully before you start to answer it.

Show all your working in calculations and include units where appropriate.

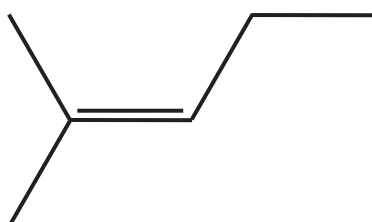
Check your answers if you have time at the end.

Answer ALL questions.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 This is a question about polymers.

(a) An addition polymer is formed from 2-methylpent-2-ene.



Look at the diagram for Question 1(a) in the Diagram Booklet. What is the repeat unit for poly(2-methylpent-2-ene)?
(1 mark)

- ☐ A Structure A
- ☐ B Structure B
- ☐ C Structure C
- ☐ D Structure D

(continued on the next page)

Turn over

1 continued.

**(b) Which is NOT a use of waste poly(alkenes)?
(1 mark)**

- ☐ **A feedstock for cracking**
- ☐ **B generation of biodegradable materials**
- ☐ **C incineration to release energy**
- ☐ **D make new materials by recycling**

(c) A condensation polymer can be made from ethane-1,2-diol and butanedioic acid.

**Look at the diagram for Question 1(c) in the Diagram Booklet. Which is the repeat unit for this polymer?
(1 mark)**

- ☐ **A Structure A**
- ☐ **B Structure B**
- ☐ **C Structure C**
- ☐ **D Structure D**

(continued on the next page)

Turn over

1 continued.

**(d) Which approach used by chemists would NOT contribute to a more sustainable use of materials over the life cycle of a polymer?
(1 mark)**

- ☐ **A make more efficient use of energy**
- ☐ **B make more efficient use of resources**
- ☐ **C use catalysts for a faster reaction rate**
- ☐ **D use a higher temperature for a faster reaction rate**

(Total for Question 1 = 4 marks)

2 This is a question about hydrocarbons.

**(a) State what is meant by the term HYDROCARBON.
(1 mark)**

(continued on the next page)

2 continued.

- (b) Explain why 2,2-dimethylpropane has a much lower boiling temperature than its isomer pentane. Detailed descriptions of the forces involved are not required.
(2 marks)**

(continued on the next page)

2 continued.

(c) The HETEROLYTIC bond fission of a sigma (σ) bond in an alkane would produce (1 mark)

- ☐ **A only carbocations**
- ☐ **B only free radicals**
- ☐ **C free radicals and ions**
- ☐ **D ions**

(Total for Question 2 = 4 marks)

3 This is a question about dihalogenoalkanes.

(a) Dihalogenoalkanes are formed when alkenes react with halogens.

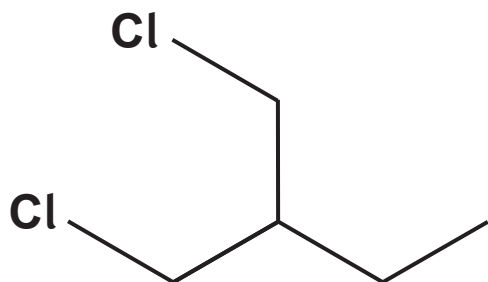
(i) Look at the diagram for Question 3(a) in the Diagram Booklet. Complete the mechanism for the production of a dihalogenoalkane from 2-methylbut-1-ene and chlorine. Include curly arrows and any relevant lone pairs. (3 marks)

(ii) Give the name of the dihalogenoalkane produced. (1 mark)

(continued on the next page)

3 continued.

(b) What is the classification of the dihalogenoalkane shown?
(1 mark)



- ☐ A primary
- ☐ B secondary
- ☐ C tertiary
- ☐ D primary and secondary

(Total for Question 3 = 5 marks)

4 This question is about nitrogen and some nitrogen compounds.

(a) A study of one brand of crisps found that each packet contained 0.420 g of nitrogen gas at a pressure of 120 kPa and a temperature of 20 °C.

**(i) Calculate the volume of nitrogen gas, in cm³, in one packet of crisps.
(4 marks)**

$$[R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}]$$

4 continued.

- (ii) Give a possible reason why nitrogen gas and not air is used in packets of crisps.
(1 mark)**

(continued on the next page)

4 continued.

- (b) Draw dot-and-cross diagrams for a molecule of nitrogen gas and for the nitride ion, N^{3-} , in sodium nitride, Na_3N .**

Use dots (●) for nitrogen electrons and crosses (X) for electrons from sodium.

(2 marks)

Nitrogen molecule

Nitride ion

4 continued.

(c) Ammonia accepts a proton to form an ammonium ion.



Explain why the ammonia molecule and the ammonium ion have different shapes and different bond angles.

(4 marks)

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Turn over

4 continued.

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4 continued.

(d) Butylamine, $\text{C}_4\text{H}_9\text{NH}_2$, reacts with ethanoyl chloride.



Explain how this equation illustrates that butylamine acts as a nucleophile and as a base.

(4 marks)

(continued on the next page)

Turn over

4 continued.

(Total for Question 4 = 15 marks)

- 5 Ice has a density of 0.92 g cm^{-3} and water has a density of 1.00 g cm^{-3} .

- (a) About 200 cm^3 of water and 200 cm^3 of cooking oil were placed in a large beaker and two layers formed. The cooking oil formed the upper layer.

An ice cube made from water with a water-soluble blue food dye was added.

Initially the ice cube floated on top of the cooking oil but on melting the blue-coloured water sank into the bottom layer of water.

Give a possible value for the density of the cooking oil. Justify your answer.
(2 marks)

(continued on the next page)

Turn over

5 continued.

(continued on the next page)

5 continued.

- (b) Calculate how many MORE molecules there are in 5.00 cm^3 of water compared to 5.00 cm^3 of ice.
(3 marks)**

(Total for Question 5 = 5 marks)

Turn over

6 Aldehydes and ketones are carbonyl compounds.

(a) Look at the diagram for Question 6(a) in the Diagram Booklet. Which of these compounds does NOT contain a ketone functional group?

(1 mark)

☐ **A Structure A**

☐ **B Structure B**

☐ **C Structure C**

☐ **D Structure D**

(b) Look at the diagram for Question 6(b) in the Diagram Booklet. Which of these compounds has both an aldehyde functional group AND a ketone functional group?

(1 mark)

☐ **A Structure A**

☐ **B Structure B**

☐ **C Structure C**

☐ **D Structure D**

(continued on the next page)

Turn over

6 continued.

(c) Propanal can be produced from the oxidation of propan-1-ol.

(i) Look at the diagram for Question 6(c)(i) in the Diagram Booklet. A student assembled the apparatus shown for this oxidation.

**Explain why the use of this apparatus would give a very low yield of propanal.
(2 marks)**

(continued on the next page)

6 continued.

(ii) The oxidising agent is acidified $\text{Na}_2\text{Cr}_2\text{O}_7$.

State the oxidation number of chromium
in $\text{Na}_2\text{Cr}_2\text{O}_7$.
(1 mark)

(iii) Complete the ionic half-equation for the oxidation
of propan-1-ol.
(1 mark)



(continued on the next page)

6 continued.

- (iv) State how the use of anti-bumping granules gives smoother boiling.
(1 mark)**

(continued on the next page)

6 continued.

(v) Another student used the correct apparatus for this oxidation.

1.50 g of propan-1-ol produced 0.609 g of propanal.

Calculate the percentage yield of propanal by mass.

(3 marks)

6 continued.

(continued on the next page)

6 continued.

(d) Look at the table for Question 6(d) in the Diagram Booklet. It contains data on propanone and ethanoic acid.

**(i) Explain, by reference to the data and any intermolecular forces involved, the difference in the boiling temperatures.
(4 marks)**

6 continued.

(continued on the next page)

6 continued.

- (ii) Explain, with the aid of a diagram, why propanone is completely miscible with water. (2 marks)**

(Total for Question 6 = 16 marks)

Turn over

7 Organic compounds containing nitrogen include amides, amines, amino acids and nitriles.

(a) Propylamine, $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$, may be formed from either a nitrile or a halogenoalkane.

(i) Give the reagent and essential condition for the formation of propylamine from a nitrile. Include an equation for the reaction. (2 marks)

(continued on the next page)

7 continued.

- (ii) Give the reagent and essential conditions for the formation of propylamine from a halogenoalkane. Include an equation for the reaction. (3 marks)**

7 continued.

- (b) A compound produced a peak due to an N—H stretching vibration in its infrared spectrum with a wavenumber of 3220 cm^{-1} .

This compound could be
(1 mark)

- ☐ A an amide
- ☐ B an amine
- ☐ C either an amide or an amine
- ☐ D neither an amide nor an amine

(continued on the next page)

7 continued.

***(c) Look at the table for Question 7(c) in the Diagram Booklet. Alanine and glycine are amino acids.**

Compare and contrast the structures, optical activity and reactions with acids and bases of alanine and glycine.

Include diagrams, structures and equations to illustrate your answer.

(6 marks)

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Turn over

7 continued.

[illegible]

(continued on the next page)

Turn over

7 continued.

[illegible]

(continued on the next page)

Turn over

7 continued.

[illegible]

(continued on the next page)

Turn over

7 continued.

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7 continued.

- (d) Look at the table for Question 7(d) in the Diagram Booklet. Lysine and serine are two more amino acids.**

Explain the difference in the volumes of $0.010 \text{ mol dm}^{-3}$ hydrochloric acid required to completely react with separate 10.0 cm^3 samples of aqueous lysine and of aqueous serine, both of concentration $0.010 \text{ mol dm}^{-3}$.

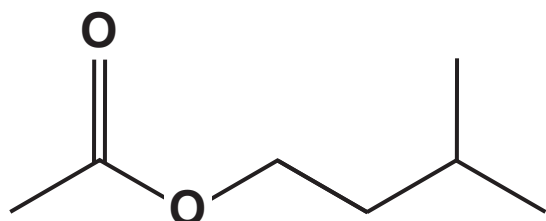
(2 marks)

(Total for Question 7 = 14 marks)

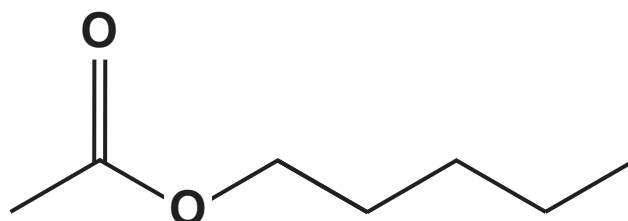
Turn over

- 8 Esters have many uses due to their characteristic aromas and often have common names. For example, isoamyl acetate is referred to as banana oil and amyl acetate has a scent similar to apples.

isoamyl acetate



amyl acetate



- (a) What is the number of peaks in a ^{13}C NMR spectrum of isoamyl acetate and of amyl acetate? (1 mark)

	isoamyl acetate	amyl acetate
<input type="checkbox"/> A	5	6
<input type="checkbox"/> B	6	6
<input type="checkbox"/> C	6	7
<input type="checkbox"/> D	7	7

(continued on the next page)

8 continued.

**(b) State the molecular formula of amyl acetate.
(1 mark)**

**(c) Deduce the structural formula of the
carboxylic acid that could be used to form both
isoamyl acetate and amyl acetate.
(1 mark)**

**(d) Deduce the NAME of the alcohol that forms
isoamyl acetate.
(1 mark)**

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8 continued.

**(e) Give the systematic name for amyl acetate.
(1 mark)**

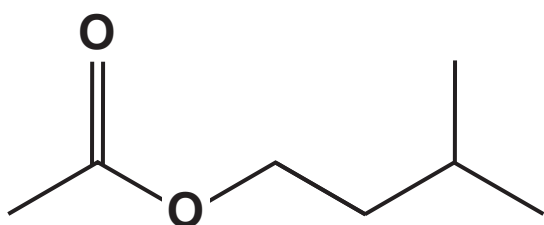
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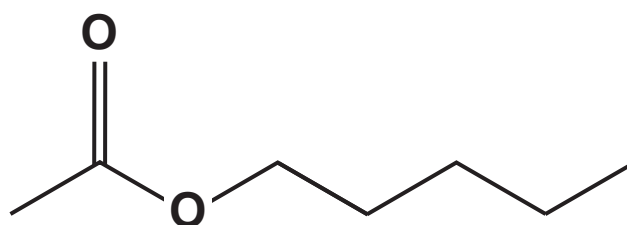
- (f) The carboxylic acid used to make isoamyl acetate and amyl acetate can also be used to make five further ester isomers.

The structures of isoamyl acetate and amyl acetate are shown below.

isoamyl acetate

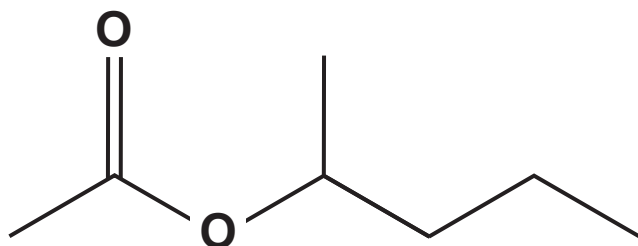


amyl acetate

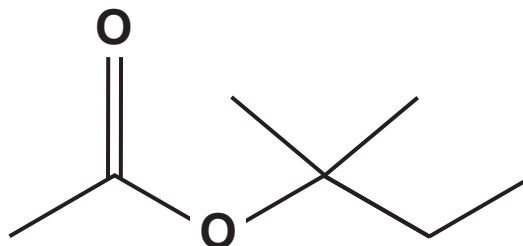


The structures of two of the further five ester isomers, **A** and **B**, are shown below.

ester **A**



ester **B**



- (i) Look at the diagram for Question 8(f)(i) in the Diagram Booklet. Complete the **SKELETAL** formulae of the three remaining esters. Names are NOT required.
(3 marks)

8 continued.

- (ii) Write an equation to show the formation of ester **A** from an acyl chloride and an alcohol.
(2 marks)**

(continued on the next page)

8 continued.

(g) Esters can be hydrolysed by heating under reflux with aqueous acid or alkali.

Compare and contrast these two methods of hydrolysis for amyl acetate.

(4 marks)

(continued on the next page)

Turn over

8 continued.

(Total for Question 8 = 14 marks)

- 9 At high temperatures, ethanal decomposes to form methane and carbon monoxide.

The reaction is second order with respect to ethanal and second order overall.



- (a) Write the rate equation for this reaction.
(1 mark)

- (b) Deduce the units of the rate constant given that the units of rate are $\text{mol dm}^{-3} \text{ s}^{-1}$.
(1 mark)

(continued on the next page)

9 continued.

- (c) Look at the table for Question 9(c) in the Diagram Booklet. It shows the concentration of ethanal in a sample at different times.**

Calculate average values for the rate of reaction between 0 and 420 seconds and between 420 and 1260 seconds.

Give your answers to an appropriate number of significant figures.

(2 marks)

0 s – 420 s _____

420 s – 1260 s _____

9 continued.

- (d) Explain why the data given and your answers in (c) show that the reaction is NEITHER zero order NOR first order.
(2 marks)**

(continued on the next page)

9 continued.

- (e) The rate constant for the reaction was determined at five temperatures.**

Look at the table and grid for Question 9(e) in the Diagram Booklet. The results are given in the table. Determine the activation energy, E_a , in kJ mol^{-1} , by completing the data in the table and plotting a graph of $\ln k$ against $1/T$ in the Diagram Booklet. (7 marks)

You should include the value of the gradient of the line and its units.

The Arrhenius equation can be expressed as

$$\ln k = -\frac{E_a}{R} \times \frac{1}{T} + \text{constant}$$

(Total for Question 9 = 13 marks)

TOTAL FOR PAPER = 90 MARKS
END OF PAPER