Paper Reference(s) 9CH0/02

Pearson Edexcel Level 3 GCE

Total Marks

Chemistry

Advanced

PAPER 2: Advanced Organic and Physical Chemistry

Monday 16 June 2025 – Morning

Time: 1 hour 45 minutes

Question Paper

THIS DOCUMENT MUST BE RETURNED TO PEARSON AT THE END OF THE EXAMINATION

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

Surname					
Other names					
Centre Number					
Candidate Number					

Pearson

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 how 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 question is about mass spectrometry.

(a) Which molecule would NOT give a molecular ion peak with $m/z = 74$?

(1 mark)

☐ **A** C_2H_5COOH

☐ **B** $CHOCOOH$

☐ **C** $CH_2(OH)COOH$

☐ **D** CH_3COOCH_3

(continued on the next page)

1 continued.

(b) The fragmentation pattern in a mass spectrum can be used to distinguish between structural isomers.

Which m/z peak would be present in the mass spectrum of propanal, CH_3CH_2CHO, but NOT in the mass spectrum of propanone, CH_3COCH_3? (1 mark)

☐ A 15

☐ B 29

☐ C 43

☐ D 59

(Total for Question 1 = 2 marks)

2 Intermolecular forces affect the physical properties of compounds.

(a) Which of these isomers, with the formula C_8H_{18}, will have the LOWEST boiling temperature? (1 mark)

☐ **A** $(CH_3)_2CHCH_2C(CH_3)_3$

☐ **B** $(CH_3)_2CHCH_2CH(CH_3)CH_2CH_3$

☐ **C** $CH_3CH_2CH_2C(CH_3)_2CH_2CH_3$

☐ **D** $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

(continued on the next page)

2 continued.

(b) Pentan-1-ol and hexane have the same number of electrons but pentan-1-ol is much less volatile than hexane.

Explain this difference in volatility.
(2 marks)

Answer space continues on the next page.

2(b) continued.

(continued on the next page)

2 continued.

(c) Iodine is a solid at room temperature but on gentle heating it vaporises.

What bonds or forces are being broken?
(1 mark)

☐ A covalent bonds

☐ B ionic bonds

☐ C London forces

☐ D permanent dipole-dipole forces

(continued on the next page)

2 continued.

(d) The boiling temperature of boron trichloride is 13 °C while that of phosphorus trichloride is 76 °C

Explain, in terms of the shapes of the molecules, why phosphorus trichloride has a much higher boiling temperature, although both compounds have polar bonds.

Do not consider differences in London forces.
(4 marks)

Answer space continues on the next page.

2(d) continued.

(Total for Question 2 = 8 marks)

3 Look at the diagram for Question 3 in the Diagram Booklet. Sodium stearate is a constituent of soap and can be made from the hydrolysis of stearin as shown.

(a) Look at the table for Question 3(a) in the Diagram Booklet. What is the atom economy, by mass, for the production of sodium stearate in this reaction? (1 mark)

☐ A 32·9%

☐ B 34·4%

☐ C 90·9%

☐ D 98·7%

(continued on the next page)

3 continued.

(b) What is the IUPAC name for glycerol?
(1 mark)

☐ A 1,2,3-trihydroxypropane

☐ B propanetriol

☐ C 2,3-dihydroxypropan-1-ol

☐ D propane-1,2,3-triol

(Total for Question 3 = 2 marks)

4 Covalent bonds can break by either heterolytic fission or homolytic fission.

(a) The reaction of butane and chlorine involves homolytic bond fission of the chlorine molecule, using ultraviolet radiation.

(i) The energy of ultraviolet radiation can be calculated using the formula shown.

$$\text{Energy of one photon} = \frac{h \times c}{\lambda}$$

Planck constant, $h = 6{\cdot}626 \times 10^{-34}\ \text{J s}$

Speed of light, $c = 3{\cdot}00 \times 10^{8}\ \text{m s}^{-1}$

Avogadro constant, $L = 6{\cdot}02 \times 10^{23}\ \text{mol}^{-1}$

Wavelength, λ in metres

The mean C—H bond energy is $413\ \text{kJ mol}^{-1}$ compared to $243\ \text{kJ mol}^{-1}$ for the Cl—Cl bond.

(continued on the next page)

4(a)(i) continued.

Show, by calculation, that ultraviolet radiation, with the wavelength 315 nm, can break the Cl—Cl bond but not the C—H bond.

(4 marks)

Answer space continues on the next page.

4(a)(i) continued.

(continued on the next page)

4(a) continued.

(ii) In the reaction of chlorine with butane, the propagation stage produces two different butyl radicals.

Write the structural formulae of these two radicals.
(2 marks)

(continued on the next page)

4(a) continued.

(iii) The reaction of chlorine with butane produces 2-chlorobutane (72%) and 1-chlorobutane (28%)

Explain, by application of your knowledge of the stability of carbocations, why there is a higher yield of 2-chlorobutane.
(2 marks)

(continued on the next page)

4 continued.

(b) Water molecules can undergo either heterolytic fission to form a hydroxide ion or homolytic fission to form a hydroxyl radical.

Look at the page for Question 4(b) in the Diagram Booklet. Draw dot-and-cross diagrams of these two species.

Use crosses (×) for oxygen electrons and dots (●) for hydrogen electrons.
(2 marks)

(continued on the next page)

4 continued.

(c) Which process does NOT involve heterolytic fission?
(1 mark)

☐ **A** the formation of the cyanide nucleophile from **KCN**

☐ **B** the formation of propanenitrile from bromoethane

☐ **C** hydroxide ion attack on bromopropane in ethanol

☐ **D** aqueous silver nitrate in ethanol reacting with iodoethane

(Total for Question 4 = 11 marks)

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5 Look at the diagram for Question 5 in the Diagram Booklet. The kinetics of the reactions of hydrochloric acid with metal carbonates were investigated using the apparatus shown.

The equation for the reaction is shown below.

$$XCO_3(s) + 2HCl(aq) \longrightarrow XCl_2(aq) + CO_2(g) + H_2O(l)$$

(a) One student used $0{\cdot}355\,g$ of calcium carbonate.

Calculate the minimum volume, in cm^3, of $0{\cdot}100\,mol\,dm^{-3}$ hydrochloric acid that would completely react with this mass of calcium carbonate.
Give your answer to an appropriate number of significant figures.
(4 marks)

[Calcium carbonate molar mass = $100{\cdot}1\,g\,mol^{-1}$]

Answer space begins on the next page.

5(a) continued.

[Calcium carbonate molar mass = $100{\cdot}1\,g\,mol^{-1}$]

(continued on the next page)

5 continued.

(b) State why powdered metal carbonate reacts faster than large lumps.

(1 mark)

_____

_____

_____

_____

_____

(continued on the next page)

5 continued.

(c) A second student used $4{\cdot}19 \times 10^{-3}$ mol of magnesium carbonate and suggested heating up the apparatus to speed up the rate of reaction.

(i) If the use of heat means that the carbon dioxide gas is at a temperature of $74{\cdot}0\,°C$, then the apparatus shown would NOT give a measurable result.

Justify this comment by calculating the volume of carbon dioxide gas at this temperature using the ideal gas equation.

Assume that the pressure remains at $100\,kPa$ throughout the experiment.
(4 marks)

Answer space continues on the next page.

5(c)(i) continued.

(continued on the next page)

5(c) continued.

(ii) Look at the diagram for Question 5(c)(ii) in the Diagram Booklet. The student suggested that the Maxwell–Boltzmann distribution of molecular energies for a reaction mixture at a particular temperature is shown in a graph.

Explain, by adding another line to the graph AND by annotating the graph, how heating the reaction mixture results in a faster reaction rate.
(3 marks)

Answer space continues on the next page.

5(c)(ii) continued.

(continued on the next page)

5 continued.

(d) Look at the graph for Question 5(d) in the Diagram Booklet. A third student, in order to obtain the rate of reaction, measured the volume of gas produced at various times and used their data to plot the graph shown.

Determine the initial rate of this reaction.
You MUST show your working on the graph.
Include units in your answer.
(2 marks)

Answer space continues on the next page.

5(d) continued.

(Total for Question 5 = 14 marks)

6 This question is about benzaldehyde and some related compounds.

***(a) Benzaldehyde (C_6H_5CHO) can be distinguished from phenylethanone ($C_6H_5COCH_3$) and benzoic acid (C_6H_5COOH) using CHEMICAL tests.**

Describe a series of CHEMICAL tests which could be used to distinguish each of these compounds, giving the relevant tests and their positive results.

Do NOT use tests which give positive results for more than one of these compounds.

Detailed information of the laboratory equipment is not required.
(6 marks)

Answer space continues on the next 6 pages.

6(a) continued.

6(a) continued.

6(a) continued.

6(a) continued.

6(a) continued.

6(a) continued.

(continued on the next page)

6 continued.

(b) Look at the diagram for Question 6(b) in the Diagram Booklet. The reaction of **2,4-dinitrophenylhydrazine (2,4-DNPH)** with a general aldehyde, **RCHO**, is shown.

(i) What is this type of reaction?
(1 mark)

☐ A addition

☐ B condensation

☐ C hydrolysis

☐ D polymerisation

(continued on the next page)

6(b) continued.

(ii) Draw the structure of the organic product of the reaction of 2,4-DNPH with benzaldehyde. (1 mark)

(Total for Question 6 = 8 marks)

7 This question is about amines.

(a) Aliphatic amines may be prepared from halogenoalkanes or from nitriles.

Assess these two methods for the preparation of butylamine.
Consider the reagents, the conditions needed, atom economy and the type of reaction.
Include equations.
(7 marks)

Answer space continues on the next 2 pages.

7(a) continued.

7(a) continued.

(continued on the next page)

7 continued.

(b) Preparation of the aromatic amine, **benzene-1,3-diamine**, requires different conditions.

(i) Write an equation for the preparation of **benzene-1,3-diamine** from the corresponding dinitro-compound and include necessary conditions.
(3 marks)

Answer space continues on the next page.

7(b)(i) continued.

Conditions

_____

_____

(continued on the next page)

7(b) continued.

(ii) Explain the factors affecting the basicity of **benzene-1,3-diamine** and **propane-1,3-diamine**.

Look at the table for Question 7(b)(ii) in the Diagram Booklet. Include reference to information given in the table.
(4 marks)

K_{b1} is the equilibrium constant for the first protonation reaction.

The equation is shown below.

$$RNH_2 + H_2O \rightleftharpoons RNH_3^+ + OH^-$$

Answer space continues on the next 2 pages.

7(b)(ii) continued.

$$RNH_2 + H_2O \rightleftharpoons RNH_3^+ + OH^-$$

7(b)(ii) continued.

(continued on the next page)

7 continued.

(c) Look at the diagram for Question 7(c) in the Diagram Booklet. Methylamine reacts with ethanoyl chloride to produce an amide.
An incomplete outline of the mechanism is shown.

Add curly arrows to show the movement of the electrons in the mechanism.
(3 marks)

(Total for Question 7 = 17 marks)

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8 Look at the diagram for Question 8 in the Diagram Booklet. The flavour of aniseed and liquorice is mainly due to anethole, which has the structure shown.

(a) Give the molecular formula of anethole.

(1 mark)

_____

_____

(b) Draw the stereoisomer of anethole.

(1 mark)

(continued on the next page)

8 continued.

(c) Look at the diagram for Question 8(c) in the Diagram Booklet. A structural isomer of anethole is estragole, which has the structure shown.

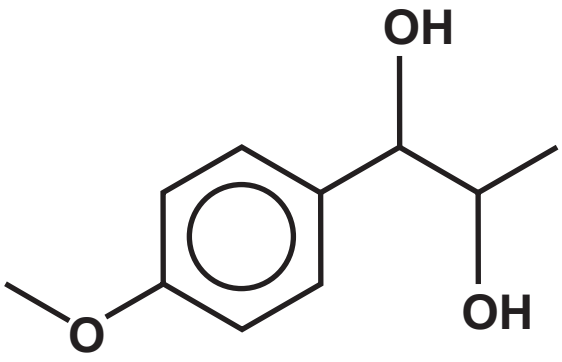
Give a reason why anethole shows stereoisomerism but estragole does NOT.
(1 mark)

(continued on the next page)

8 continued.

(d) What is the reagent required to convert anethole to the diol shown below?

(1 mark)



☐ A acidified potassium manganate(VII)

☐ B aqueous sodium hydroxide

☐ C ethanolic potassium hydroxide

☐ D steam with an acid catalyst

(continued on the next page)

8 continued.

(e) Look at the diagrams for Question 8(e) in the Diagram Booklet. The structure of anethole can be drawn with a delocalised model of the benzene ring or with the Kekulé benzene ring structure as shown.

(i) Describe how the orbitals of carbon atoms overlap to form the σ-bonds and the π-bonds in the delocalised model of the benzene ring. You may include a labelled diagram in your answer.
(3 marks)

Answer space continues on the next page.

8(e)(i) continued.

(continued on the next page)

8(e) continued.

(ii) Explain why the delocalised model of the benzene ring is the preferred representation rather than the Kekulé cyclic triene.
Refer to ONE physical and ONE thermodynamic measurement in your answer.
(4 marks)

Answer space continues on the next page.

8(e)(ii) continued.

(continued on the next page)

8 continued.

(f) Anethole is also present in some alcoholic drinks such as the Greek liquor, ouzo.

The anethole is responsible for the so-called 'ouzo effect'. This effect is the transparent ouzo liquor turning milky when water is added. The addition of water causes the anethole to form oily droplets which result in a stable milky emulsion.

Look at the diagram for Question 8(f) in the Diagram Booklet. Deduce the solubility of anethole in ethanol and in water from the 'ouzo effect'. Justify your answer with reference to the anethole structure shown, but detailed descriptions of intermolecular forces are not required.
(3 marks)

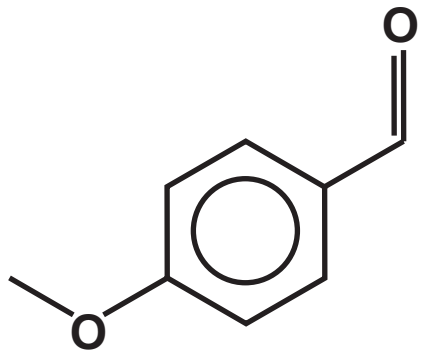
Answer space continues on the next page.

8(f) continued.

(continued on the next page)

8 continued.

(g) A derivative of anethole is anisaldehyde, which has the structure shown below.



What is the number of peaks in the ^{13}C NMR spectrum of anisaldehyde?
(1 mark)

☐ A 5

☐ B 6

☐ C 7

☐ D 8

(Total for Question 8 = 15 marks)

9 Halogenoalkanes are hydrolysed to form alcohols.

(a) The rate constant for the reaction of 1-bromopropane with aqueous sodium hydroxide was determined at five temperatures.

(i) Look at the table for Question 9(a)(i) in the Diagram Booklet. Some of the results are given in the table. Complete the table of data. (2 marks)

(continued on the next page)

9(a) continued.

(ii) Look at the grid for Question 9(a)(ii) in the Diagram Booklet. Plot a graph of $\ln k$ against $1/T$ and use it to determine the activation energy, E_a, for this reaction in $kJ\,mol^{-1}$

You must show your working on the graph and include the value of the gradient of the line and its units.

(5 marks)

The Arrhenius equation can be expressed as

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

Answer space continues on the next 2 pages.

9(a)(ii) continued.

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

9(a)(ii) continued.

Gradient

_____

_____

Activation energy

_____

_____

(continued on the next page)

9(a) continued.

(iii) The rate constant for the reaction of **1-bromopropane** with aqueous potassium hydroxide has the units of $dm^3 mol^{-1} s^{-1}$

Explain why it can be deduced that the reaction is second order overall.

Assume that the units of the rate of reaction are $mol\, dm^{-3} s^{-1}$

(2 marks)

Answer space continues on the next page.

9(a)(iii) continued.

(continued on the next page)

9 continued.

(b) The rate of reaction for the hydrolysis of **2-bromo-2-methylpropane** by aqueous hydroxide ions is independent of the concentration of hydroxide ions.

(i) Draw the S_N1 reaction mechanism for this hydrolysis.
Include curly arrows and any relevant dipoles and lone pairs of electrons.
(3 marks)

Answer space continues on the next page.

9(b)(i) continued.

(continued on the next page)

9(b) continued.

(ii) State how your mechanism is consistent with the rate of reaction being independent of hydroxide ion concentration.
(1 mark)

(Total for Question 9 = 13 marks)

TOTAL FOR PAPER = 90 MARKS

END OF PAPER