Paper Reference(s) 9CH0/02
Pearson Edexcel Level 3 GCE

Total Marks

Chemistry

Advanced

PAPER 2: Advanced Organic and Physical Chemistry

Tuesday 18 June 2024 – Morning

Time: 1 hour 45 minutes

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, writing and drawing equipment

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 question is about organic compounds that contain a halogen atom or a nitrogen atom.

(a) Equal amounts of four bromoalkanes were added to separate test tubes containing $2\,cm^3$ of a silver nitrate solution.
The mixtures were heated in a water bath.

Which bromoalkane would be the FIRST to form a precipitate?
(1 mark)

☐ **A 1-bromobutane**

☐ **B 2-bromobutane**

☐ **C 1-bromo-2-methylpropane**

☐ **D 2-bromo-2-methylpropane**

(continued on the next page)

1 continued.

(b) Which pair of reactants will form an **N**-substituted amide?
(1 mark)

☐ A CH_3COCl and NH_3

☐ B CH_3CH_2OH and NH_3

☐ C CH_3COCl and CH_3NH_2

☐ D CH_3CH_2OH and CH_3NH_2

(continued on the next page)

1 continued.

(c) Ammonia reacts with bromoethane as shown.

$$2NH_3 + CH_3CH_2Br \longrightarrow NH_4Br + CH_3CH_2NH_2$$

(i) Explain, by referring to the reaction mechanism, the roles of ammonia in the formation of each of the products of this reaction.
(3 marks)

(continued on the next page)

1(c) continued.

(ii) What conditions are needed for this reaction? (1 mark)

	Method of heating	Solvent
☐ A	heat in a sealed tube	ethanol
☐ B	heat under reflux	ethanol
☐ C	heat in a sealed tube	water
☐ D	heat under reflux	water

(continued on the next page)

1 continued.

(d) The halogenoalkane, 1-bromobutane, can be formed by the reaction of butan-1-ol with sodium bromide and sulfuric acid.

$$CH_3CH_2CH_2CH_2OH + NaBr + H_2SO_4 \longrightarrow CH_3CH_2CH_2CH_2Br + NaHSO_4 + H_2O$$

Calculate the atom economy, by mass, for the formation of 1-bromobutane.
Give your answer to ONE decimal place.
(2 marks)

[A_r values: H = 1·0 C = 12·0 O = 16·0 Na = 23·0 S = 32·1 Br = 79·9]

Answer space continues on the next page.

1(d) continued.

(Total for Question 1 = 8 marks)

2 This question is about Grignard reagents.

A Grignard reagent is formed by reacting bromoethane with magnesium under reflux.

$$CH_3CH_2Br + Mg \longrightarrow CH_3CH_2MgBr$$

(a) The most suitable solvent for this reaction is (1 mark)

- ☐ **A cyclohexane**
- ☐ **B ether**
- ☐ **C ethyl ethanoate**
- ☐ **D hexane**

(continued on the next page)

2 continued.

(b) State the use of Grignard reagents in organic synthesis.
(1 mark)

_____

_____

_____

(continued on the next page)

2 continued.

(c) In their reactions, the Grignard reagent is best described as
(1 mark)

- ☐ **A** a carbocation
- ☐ **B** an electrophile
- ☐ **C** a nucleophile
- ☐ **D** a radical

(continued on the next page)

2 continued.

(d) Grignard reagents must be kept dry.

Predict the ORGANIC product that forms when CH_3CH_2MgBr reacts with water. Justify your answer by considering the polarity of both CH_3CH_2MgBr and water.
(2 marks)

(continued on the next page)

2 continued.

(e) Which compound will form a TERTIARY alcohol when it reacts with a Grignard reagent, followed by acid hydrolysis?
(1 mark)

☐ **A** CO_2

☐ **B** $HCHO$

☐ **C** CH_3CHO

☐ **D** CH_3COCH_3

(Total for Question 2 = 6 marks)

3 This question is about hydrogen peroxide, H_2O_2

(a) On the blank page for Question 3(a) in the Diagram Booklet, draw a dot-and-cross diagram of a molecule of hydrogen peroxide.
(1 mark)

(b) Hydrogen peroxide decomposes to form water and oxygen.

$$2H_2O_2(aq) \longrightarrow 2H_2O(l) + O_2(g)$$

Explain, using oxidation numbers, why the decomposition of hydrogen peroxide is classified as a disproportionation reaction.
(3 marks)

Answer space continues on the next page.

3(b) continued.

(continued on the next page)

3 continued.

(c) The decomposition of hydrogen peroxide is catalysed by iodide ions, $I^-(aq)$.

Look at the table for Question 3(c) in the Diagram Booklet. The kinetics of this reaction were investigated using different concentrations of hydrogen peroxide and iodide ions.
The results are shown in the table.

(i) Deduce the order of reaction with respect to hydrogen peroxide and to iodide ions.
(2 marks)

Order with respect to hydrogen peroxide

Order with respect to iodide ions

(continued on the next page)

3(c) continued.

(ii) Write the rate equation for the reaction using your answer to (c)(i).
(1 mark)

(continued on the next page)

3(c) continued.

(iii) Calculate the rate constant, k, using data from Experiment 3.
Include units in your answer.
(2 marks)

(continued on the next page)

3 continued.

(d) The breakdown of hydrogen peroxide with iodide ions as a catalyst is the basis of the demonstration 'Elephant's Toothpaste'.
The presence of a detergent results in a rapid eruption of foam as the oxygen gas is released.

(i) Describe the test and the positive result that confirms the gas produced is oxygen.
(1 mark)

(continued on the next page)

3(d) continued.

(ii) The foam produced often has a slight yellow / brown colour.

Explain what causes this colour, which is NOT caused by the detergent.
(2 marks)

(continued on the next page)

3 continued.

(e) Look at the graph for Question 3(e) in the Diagram Booklet. The effect of temperature on the rate of the decomposition of hydrogen peroxide without a catalyst was also investigated.
A graph of ln k against 1 / temperature (1 / T) was plotted.

(i) Determine the gradient of the graph. Include units in your answer. You must show your working on the graph.
(3 marks)

(continued on the next page)

3(e) continued.

(ii) Calculate the activation energy, E_a, of the reaction, in $kJ\,mol^{-1}$, using your answer to (e)(i) and the Arrhenius equation shown. (1 mark)

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

[Gas constant $(R) = 8{\cdot}31\,J\,mol^{-1}\,K^{-1}$]

(continued on the next page)

3 continued.

(f) Another way to write the Arrhenius equation is shown.

$$k = Ae^{-E_a/RT}$$

The constant A is often called the collision factor as it is linked to the orientation of the particles colliding in a reaction.

The decomposition of hydrogen peroxide is also catalysed by aluminium.

Calculate a value for A at $370\,K$, for the catalysed decomposition of hydrogen peroxide with an activation energy, E_a, of $5{\cdot}02 \times 10^4\,J\,mol^{-1}$ and a numerical value for the rate constant of $1{\cdot}60 \times 10^{-3}$

Units are NOT required.

(2 marks)

(Total for Question 3 = 18 marks)

***4 Discuss the role society, and chemists in particular, can play in order to contribute to a more sustainable use of polymers.**
(6 marks)

Your answer should consider

- **the different ways of dealing with waste polymers**
- **how chemists can limit the problems caused by the disposal of polymers.**

Answer space continues on the next 4 pages.

4 continued.

4 continued.

4 continued.

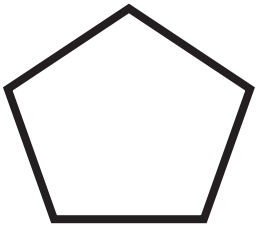
4 continued.

(Total for Question 4 = 6 marks)

5 This question is about cyclic compounds.

(a) The hydrocarbon cyclopentane is present in some fuels and is used in the manufacture of insulation for freezers.

cyclopentane



Look at the equation for Question 5(a) in the Diagram Booklet. Cyclopentane can be synthesised by passing 2-methylbutane over a hot platinum catalyst.

Name the type of reaction that takes place in this synthesis.
(1 mark)

_____

_____

(continued on the next page)

5 continued.

(b) The energy density of a fuel is defined as the energy released per dm^3 of the liquid fuel burned.

A sample of cyclopentane with a mass of $30{\cdot}0\,g$ releases $1{\cdot}41\,MJ$ of energy.

Calculate the energy density of cyclopentane. Include units in your answer.
(2 marks)

[Density of cyclopentane = $0{\cdot}751\,g\,cm^{-3}$]

(continued on the next page)

5 continued.

(c) Look at the equation for Question 5(c) in the Diagram Booklet. Under appropriate conditions, cyclopentane reacts with bromine to form bromocyclopentane.

(i) State the condition needed to initiate the reaction.
(1 mark)

_____

_____

(ii) Look at the table for Question 5(c)(ii) in the Diagram Booklet. Complete the table showing the steps of the mechanism of this reaction. Curly arrows are not required.
(3 marks)

(continued on the next page)

5(c) continued.

(iii) On the blank page for Question 5(c)(iii) in the Diagram Booklet, draw the structure of the organic product of an alternative termination step.
(1 mark)

(continued on the next page)

5 continued.

(d) Look at the equation for Question 5(d) in the Diagram Booklet. Bromocyclopentane forms cyclopentene when heated under reflux with a concentrated solution of potassium hydroxide in ethanol.

(i) Explain why the solvent ethanol is treated with anhydrous sodium sulfate before use in this reaction.
(2 marks)

(continued on the next page)

5(d) continued.

(ii) Give the name of the reaction shown in the equation.
(1 mark)

(iii) Look at the diagram for Question 5(d)(iii) in the Diagram Booklet. Predict the mechanism for the reaction by adding two curly arrows.
(1 mark)

(Total for Question 5 = 12 marks)

6 This question is about nuclear magnetic resonance (NMR) spectroscopy.

(a) Which part of the electromagnetic spectrum is used in NMR?
(1 mark)

☐ **A infrared**

☐ **B radio waves**

☐ **C ultraviolet**

☐ **D X-ray**

(continued on the next page)

6 continued.

(b) Explain why tetramethylsilane, TMS, is used in NMR spectroscopy.
(2 marks)

(continued on the next page)

6 continued.

(c) A secondary amine, **Q**, has the molecular formula $C_6H_{15}N$

The low resolution ^1H NMR spectrum of **Q** has three peaks.

(i) State what is meant by the term 'secondary amine'.
(1 mark)

_____

_____

_____

(continued on the next page)

6(c) continued.

(ii) On the blank page for Question 6(c)(ii) in the Diagram Booklet, Deduce the structure of Q (1 mark)

(continued on the next page)

6 continued.

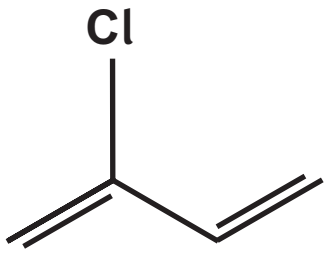
(d) Look at the diagram for Question 6(d) in the Diagram Booklet. Two cyclic alcohols have the structures shown.

Show that the ^{13}C NMR spectra of these compounds can be used to distinguish between the two alcohols, labelling the diagrams to justify your answer.
(2 marks)

(Total for Question 6 = 7 marks)

7 This question is about polymers, an example of which is neoprene, a synthetic rubber material.
It is formed by the polymerisation of chloroprene.

chloroprene



(a) What is the IUPAC name of chloroprene?
(1 mark)

- ☐ **A 3-chlorobuta-1,3-diene**
- ☐ **B 2-chlorobuta-2,4-diene**
- ☐ **C 3-chlorobuta-2,4-diene**
- ☐ **D 2-chlorobuta-1,3-diene**

(continued on the next page)

7 continued.

(b) Calculate the volume, in cm^3, occupied by 10·0 g of chloroprene in the gaseous phase, at 80·0 °C and 205 kPa

Give your answer to an appropriate number of significant figures.

(5 marks)

[Gas constant (R) = 8·31 $J\,mol^{-1}\,K^{-1}$]

Answer space continues on the next page.

7(b) continued.

(continued on the next page)

7 continued.

(c) Look at the diagram for Question 7(c) in the Diagram Booklet. Chloroprene is formed by first adding chlorine, Cl_2, to Compound A and then removing hydrogen chloride from the product of this reaction.

(i) Explain how chlorine, Cl_2, can act as an electrophile in Step 1 even though a chlorine molecule is symmetrical.
You may find it helpful to include a diagram on the blank page for Question 7(c)(i) in the Diagram Booklet.
(2 marks)

Answer space continues on the next page.

7(c)(i) continued.

(continued on the next page)

7(c) continued.

(ii) On the blank page for Question 7(c)(ii) in the Diagram Booklet, draw the mechanism for Step 1.
Include curly arrows, and any relevant lone pairs and dipoles.
(3 marks)

(iii) Look at the reaction for Question 7(c)(iii) in the Diagram Booklet. Chloroprene polymerises to form neoprene as shown.

Give the name of the type of reaction that occurs when chloroprene polymerises.
(1 mark)

_____

_____

(continued on the next page)

7 continued.

(d) Flexible and water-resistant materials can be made by combining neoprene with polyester fabric.

A polyester may be made by the reaction of benzene-1,4-dicarboxylic acid with ethane-1,2-diol.

(i) Explain why ethane-1,2-diol is soluble in water.
A detailed description of the forces involved is not required.
(2 marks)

(continued on the next page)

7(d) continued.

(ii) The molar mass of a polyester is $8400\,g\,mol^{-1}$

Calculate the number of polymer molecules in $4{\cdot}25\,mg$ of this polyester.
(2 marks)

[Avogadro constant (L) = $6{\cdot}02 \times 10^{23}\,mol^{-1}$]

Answer space continues on the next page.

7(d)(ii) continued.

(continued on the next page)

7(d) continued.

(iii) A student spilled a small amount of $0{\cdot}40\,mol\,dm^{-3}$ sodium hydroxide solution onto a polyester laboratory coat. A hole formed in the laboratory coat as the result of a chemical reaction.

What type of reaction occurred?
(1 mark)

☐ A dehydration

☐ B hydrolysis

☐ C neutralisation

☐ D redox

(Total for Question 7 = 17 marks)

8 This question is about amino acids and related compounds.

Look at the diagram for Question 8 in the Diagram Booklet. The structures of two amino acids are shown.

(a) Both amino acids contain a chiral carbon atom.

(i) State what is meant by the term 'chiral carbon atom'.
(1 mark)

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_____

_____

_____

_____

(ii) On the blank page for Question 8(a)(ii) in the Diagram Booklet, draw diagrams of the two stereoisomers of ALANINE, showing their three-dimensional shape.
(2 marks)

(continued on the next page)

8 continued.

(b) Look at the diagram for Question 8(b) in the Diagram Booklet. Draw the SKELETAL formulae of the two dipeptides that could form when serine and alanine react.
(2 marks)

(c) Look at the diagrams for Question 8(c) in the Diagram Booklet. Serine exists as a zwitterion.

What is the formula of this zwitterion?
(1 mark)

☐ Formula A

☐ Formula B

☐ Formula C

☐ Formula D

(continued on the next page)

8 continued.

(d) Look at the diagram for Question 8(d) in the Diagram Booklet. Alanine can be synthesised as shown.

(i) Sodium ethoxide, C_2H_5ONa, needed in Step 1, is formed by the reaction of sodium with ethanol.

Write the equation for this reaction.
State symbols are not required.
(1 mark)

(continued on the next page)

8(d) continued.

(ii) Name the TWO functional groups present in Compound Y.
(2 marks)

_____

_____

_____

(iii) Give the reagent needed and conditions required for Step 3.
(2 marks)

_____

_____

_____

(continued on the next page)

8(d) continued.

(iv) Calculate the mass of Compound **X** required to make **15·0 g** of alanine, assuming the overall yield of the synthesis is **55 %**
(3 marks)

(continued on the next page)

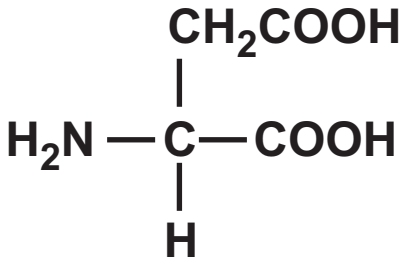
8 continued.

(e) Look at the diagram for Question 8(e) in the Diagram Booklet. A mixture of amino acids can be separated using a technique called paper electrophoresis. A simplified diagram is shown.

The movement of the amino acid on the paper depends on any charge on the amino acid, and this is determined by the pH of the buffer solution.

Amino acid Z has the structure shown.

amino acid Z

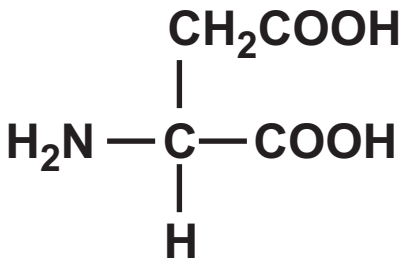


Explain in which direction, if any, amino acid Z would move when a current flows in the circuit with a buffer solution of pH = 9
(2 marks)

Answer space continues on the next page.

8(e) continued.

amino acid Z



(Total for Question 8 = 16 marks)

TOTAL FOR PAPER = 90 MARKS

END OF PAPER