Paper Reference(s) 9CH0/03

Pearson Edexcel Level 3 GCE

Total Marks

Chemistry

Advanced

PAPER 3: General and Practical Principles in Chemistry

Friday 20 June 2025 – Morning

Time: 2 hours 30 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 120.

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.

Write your answers in the spaces provided.

1 This question is about ionisation energies.

Look at the table for Question 1 in the Diagram Booklet. It shows the first four ionisation energies of three elements in the same group of the Periodic Table. The letters used are not the symbols of the elements.

(a) State what is meant by the term 'FIRST ionisation energy'.

(2 marks)

Answer space continues on the next page.

1(a) continued.

(continued on the next page)

1 continued.

(b) Explain to which group the elements **X**, **Y** and **Z** belong.

(2 marks)

(continued on the next page)

1 continued.

(c) Explain which of the elements **X**, **Y** and **Z** has the highest atomic number.

(3 marks)

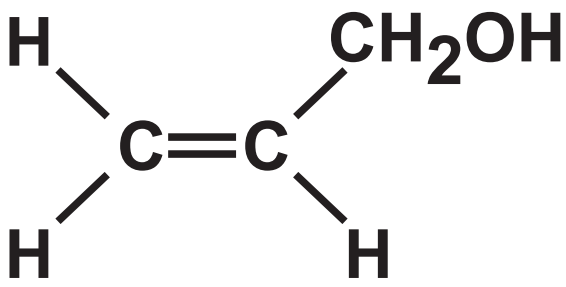
Answer space continues on the next page.

1(c) continued.

(Total for Question 1 = 7 marks)

2 This question is about compounds that contain both an alkene and an alcohol functional group.

(a) **Prop-2-en-1-ol**, present in garlic, has the structure shown.



(i) Describe a test, and the positive result, that confirms the presence of a C=C group.
(2 marks)

Answer space continues on the next page.

Test

2(a)(i) continued.

Result

(continued on the next page)

2(a) continued.

(ii) **Prop-2-en-1-ol** reacts with hydrogen bromide to form **3-bromopropan-1-ol** as one of the products.

Look at the diagram for Question 2(a)(ii) in the Diagram Booklet. Draw a mechanism for this reaction.
Include curly arrows, and relevant lone pairs and dipoles.
(3 marks)

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2 continued.

(b) **Prop-2-en-1-ol** can polymerise to form an addition polymer.

Write a balanced equation for this polymerisation.

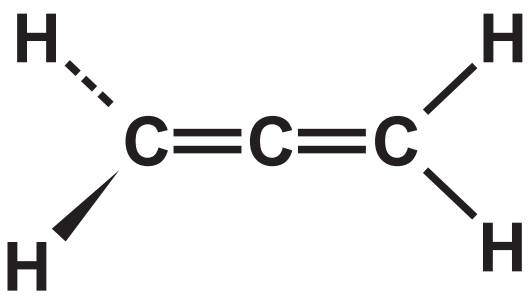
(2 marks)

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2 continued.

(c) **Prop-2-en-1-ol** can form the alkene propadiene, which has two adjacent C═C bonds, as shown.

propadiene



Explain why the CH_2 groups at each end of the molecule are at right angles to each other.
Use your knowledge of how orbitals overlap to form π-bonds.
(2 marks)

Answer space continues on the next page.

2(c) continued.

(continued on the next page)

2 continued.

(d) Look at the diagram for Question 2(d) in the Diagram Booklet. The compound bombykol is a pheromone secreted by female silk moths.
Like **prop-2-en-1-ol**, it can also be classified as both an alkene and an alcohol.

Bombykol can exist as a number of geometric isomers.

(i) Give the number of different geometric isomers of bombykol.
(1 mark)

(continued on the next page)

2(d) continued.

(ii) Give the reason why **prop-2-en-1-ol** does NOT exhibit geometric isomerism.

(1 mark)

(continued on the next page)

2(d) continued.

(iii) Explain the expected solubilities in water of bombykol and prop-2-en-1-ol.

(3 marks)

Answer space continues on the next page.

2(d)(iii) continued.

(Total for Question 2 = 14 marks)

*3 A student carries out a series of qualitative tests to identify the contents of three unlabelled bottles. The bottles are known to contain the following solutions.

- ammonium carbonate, $(NH_4)_2CO_3(aq)$
- potassium carbonate, $K_2CO_3(aq)$
- potassium sulfate, $K_2SO_4(aq)$

The student has access to just test tubes and a water bath, plus ONLY the reagents shown.

red litmus paper

blue litmus paper

$AgNO_3(aq)$ $BaCl_2(aq)$ $Ca(OH)_2(aq)$ $CuSO_4(aq)$

$HCl(aq)$ $HNO_3(aq)$ $MgCl_2(aq)$ $NaOH(aq)$

The student carries out qualitative tests to POSITIVELY identify either an anion or a cation in each compound and so identify the contents of each bottle.

Describe the qualitative tests carried out, the expected observations and appropriate deductions.
(6 marks)

Answer space begins and continues on the next 5 pages.

3 continued.

3 continued.

3 continued.

3 continued.

3 continued.

(Total for Question 3 = 6 marks)

4 This question is about the kinetics of the reaction between iodine and propanone under acidic conditions.

The equation for the reaction is shown.

$$CH_3COCH_3 + I_2 \xrightarrow{H^+} CH_3COCH_2I + HI$$

An experiment is carried out to determine the order of the reaction with respect to iodine.

Step 1 $50{\cdot}0\,cm^3$ of $0{\cdot}0200\,mol\,dm^{-3}$ iodine solution, $I_2(aq)$, is added from a burette to a conical flask.

Step 2 $25{\cdot}0\,cm^3$ of $2{\cdot}00\,mol\,dm^{-3}$ sulfuric acid, $H_2SO_4(aq)$, is added to the conical flask using a pipette.

Step 3 $25{\cdot}0\,cm^3$ of $2{\cdot}00\,mol\,dm^{-3}$ propanone solution, $CH_3COCH_3(aq)$, is added to the conical flask using a pipette.

The flask is swirled and a timer is started.

Step 4 After 2 minutes, a $10{\cdot}0\,cm^3$ sample of the reaction mixture is removed and quenched.

(continued on the next page)

4 continued.

Step 5 The quenched sample is then titrated using $0{\cdot}0100\,\text{mol}\,\text{dm}^{-3}$ sodium thiosulfate solution, $Na_2S_2O_3(aq)$

Step 6 Steps 4 and 5 are repeated every two minutes, until six titres have been determined.

(continued on the next page)

4 continued.

(a) Before carrying out Step 2, a student noticed droplets of an unknown colourless aqueous solution in the pipette.

Describe how the pipette should be treated before it is used in Step 2

Justify your answer.

(2 marks)

(continued on the next page)

4 continued.

(b) Samples from the reaction mixture are quenched in Step 4

(i) Explain why quenching is necessary.
(2 marks)

(continued on the next page)

4(b) continued.

(ii) State a compound which can be added to the reaction mixture to quench the reaction. Include an equation for the reaction that takes place during the quenching process. State symbols are not required.
(2 marks)

Compound

Equation

(continued on the next page)

4 continued.

(c) One of the products of the reaction, iodopropanone (CH_3COCH_2I) is corrosive, strongly irritating to the eyes and can cause breathing difficulties.

Explain why a risk assessment for this experiment says it does NOT have to be carried out in a fume cupboard.
(2 marks)

(continued on the next page)

4 continued.

(d) Show, by calculating the initial quantities of the reactants involved, that this experiment provides evidence for the order with respect to iodine ONLY. (4 marks)

Answer space continues on the next page.

4(d) continued.

(continued on the next page)

4 continued.

(e) The results of the experiment are shown.

Time / min	Titre / cm^3
2	17·00
4	15·60
6	14·00
8	12·50
10	11·00
12	9·40

(i) Look at the grid for Question 4(e)(i) in the Diagram Booklet. Plot a graph of titre against time.

(2 marks)

(continued on the next page)

4(e) continued.

(ii) Give the reason why it is not necessary to calculate the concentration of iodine so that the order can be deduced.
(1 mark)

(continued on the next page)

4(e) continued.

(iii) Deduce the order with respect to iodine.

Justify your answer.

(2 marks)

(Total for Question 4 = 17 marks)

5 This question is about cobalt complexes.

(a) A sample of cobalt(II) chloride was dissolved in aqueous ammonia, $NH_3(aq)$. During the process, a stream of oxygen was gently bubbled through the solution to oxidise the cobalt(II) ion.

Look at the table for Question 5(a) in the Diagram Booklet. A coloured solid, R, was extracted from the solution. A pure sample of this solid was found to contain the masses of the elements shown and had a molar mass of $233{\cdot}4\,g\,mol^{-1}$

(i) Show that the empirical formula AND the molecular formula of R is $CoN_4H_{12}Cl_3$

You must show your working.

(2 marks)

Answer space continues on the next page.

5(a)(i) continued.

(continued on the next page)

5(a) continued.

(ii) 1·00 g of R was dissolved in water forming a coloured solution of the complex ion, Q

The solution was reacted with excess silver nitrate solution, forming 0·614 g of silver chloride, AgCl(s)

Calculate the number of moles of chloride ions released when 1 mol of R dissolves.
(2 marks)

(continued on the next page)

5(a) continued.

(iii) Draw the three-dimensional shape of the complex ion, **Q**, using your answer to (a)(ii) to help deduce the formula and overall charge.
(3 marks)

Answer space continues on the next page.

5(a)(iii) continued.

(continued on the next page)

5 continued.

(b) An aqueous solution of cobalt(II) chloride contains the complex ion $[Co(H_2O)_6]^{2+}$

Look at the equations for Question 5(b) in the Diagram Booklet. The dynamic equilibria shown occur when $NH_3(aq)$ and $EDTA^{4-}(aq)$ are each added to separate solutions of this complex ion.

(i) State what is meant by the term 'dynamic equilibrium'.

(2 marks)

Answer space continues on the next page.

5(b)(i) continued.

(continued on the next page)

5(b) continued.

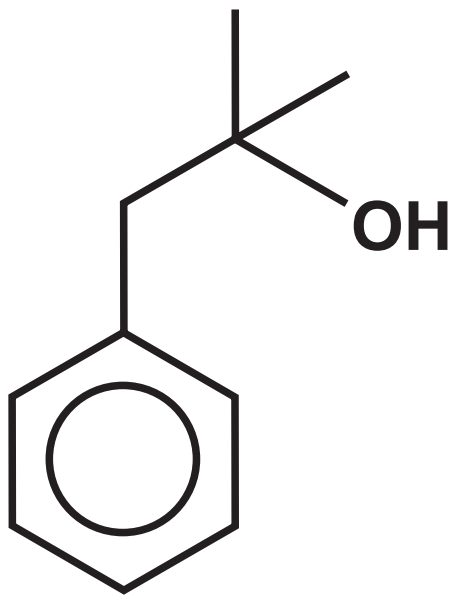
(ii) Explain, in terms of equilibria and entropy, which of the three complex ions is the most stable.
(3 marks)

Answer space continues on the next page.

5(b)(ii) continued.

(Total for Question 5 = 12 marks)

6 The compound **2-methyl-1-phenylpropan-2-ol** is found in small amounts in cocoa beans and has the structure shown.



(a) Look at the diagram for Question 6(a) in the Diagram Booklet. A proposed synthesis of **2-methyl-1-phenylpropan-2-ol** from phenylmethanol and propanone is shown.

Complete the diagram to show the structures of compounds **A**, **B** and **C** and the formula of reagent **D**.

(4 marks)

(continued on the next page)

6 continued.

(b) Look at the diagram for Question 6(b) in the Diagram Booklet.

2-Methyl-1-phenylpropan-2-ol can be converted to compound **S**. When considering the ^{1}**H NMR** spectrum of **S**, the hydrogen atoms of the benzene have been assumed to be a single environment, labelled **J**.

The other hydrogen environments have been labelled **K**, **L**, **M** and **N**.

Look at the table for Question 6(b) in the Diagram Booklet. Complete the table for each of the environments **K** to **N** in the high resolution ^{1}**H NMR** spectrum of **S**.

(5 marks)

(Total for Question 6 = 9 marks)

7 A laboratory technician analysed a sample of an alcoholic drink to determine the concentration of ethanol, in $g\,dm^{-3}$

$20{\cdot}00\,cm^3$ of the alcoholic drink was added to a $250\,cm^3$ volumetric flask and made up to the mark with deionised water.

Look at the diagram for Question 7 in the Diagram Booklet. The ethanol in $5{\cdot}00\,cm^3$ of the diluted sample was oxidised in the equipment shown.

The sample was suspended in an open beaker in a sealed conical flask over $10{\cdot}00\,cm^3$ of acidified sodium dichromate(VI), of concentration $0{\cdot}0780\,mol\,dm^{-3}$

The apparatus was left in a warm place for 24 hours for the acidified sodium dichromate(VI) to oxidise the ethanol.

Excess potassium iodide solution was then added to the REMAINING acidified sodium dichromate(VI) in the conical flask, forming iodine.

(continued on the next page)

7 continued.

All of this iodine was then titrated using $0{\cdot}0220\,mol\,dm^{-3}$ sodium thiosulfate solution, $Na_2S_2O_3(aq)$

The volume of $Na_2S_2O_3(aq)$ required in the titration was $32{\cdot}70\,cm^3$

Look at the equations for Question 7 in the Diagram Booklet. The equations for the reactions that take place during the experiment are shown.

(a) Explain why the apparatus was left in a WARM room and for 24 HOURS.
(2 marks)

Answer space continues on the next page.

7(a) continued.

(continued on the next page)

7 continued.

(b) (i) Calculate the number of moles of ethanol in $5\,cm^3$ of the DILUTED drink.

(5 marks)

Answer space continues on the next page.

7(b)(i) continued.

(continued on the next page)

7(b) continued.

(ii) Calculate the concentration of ethanol in the alcoholic drink in $g\,dm^{-3}$

(3 marks)

(continued on the next page)

7 continued.

(c) It was suggested that the TITRATION as described might lead to an unreliable result.

State TWO ways the procedure could be amended to counter this suggestion.
(2 marks)

Answer space continues on the next page.

7(c) continued.

(continued on the next page)

7 continued.

(d) Another technician suggested that it was unnecessary to suspend the drink sample above the acidified sodium dichromate(VI) solution and proposed a change to the procedure.

The proposal was that the drink sample should be mixed with the acidified sodium dichromate(VI) solution and then heated under reflux to allow the ethanol to be oxidised.

Give ONE reason to support this change and ONE reason to leave the method unchanged.
In each case justify your answer.
(2 marks)

Answer space continues on the next page.

Reason to support this change

7(d) continued.

Reason to leave the method unchanged

(Total for Question 7 = 14 marks)

8 This question is about weak acids.

(a) An aqueous solution of a weak acid, $HA(aq)$, with a concentration of $0{\cdot}0712\,mol\,dm^{-3}$, has a $pH = 3{\cdot}25$ at room temperature.

Calculate the value of K_a for the weak acid $HA(aq)$

(2 marks)

(continued on the next page)

8 continued.

(b) The value of K_a may be determined from experimental data, using a titration curve.

Ethanoic acid, $CH_3COOH(aq)$, with a concentration of $0{\cdot}0500\,mol\,dm^{-3}$, has a pH of $3{\cdot}03$ at room temperature.

A $20{\cdot}0\,cm^3$ sample of the acid was titrated with sodium hydroxide solution, $NaOH(aq)$, with a concentration of $0{\cdot}0500\,mol\,dm^{-3}$

During the experiment, $40{\cdot}0\,cm^3$ of sodium hydroxide solution was slowly added to the ethanoic acid.

A pH probe connected to a data logger was used to monitor the pH throughout the experiment.

(continued on the next page)

8(b) continued.

(i) Calculate the pH of the sodium hydroxide solution.
Give your answer to one decimal place.
(1 mark)

$[K_w = 1{\cdot}00 \times 10^{-14}\,mol^2\,dm^{-6}]$

(continued on the next page)

8(b) continued.

(ii) Look at the diagram for Question 8(b)(ii) in the Diagram Booklet. Draw a titration curve, on the axes shown, to show the change in pH throughout the experiment.
(3 marks)

(iii) Give an estimate of the pH value at the half-equivalence point.
Show your working on the titration curve.
(1 mark)

(continued on the next page)

8(b) continued.

(iv) Calculate a value for K_a of ethanoic acid using your answer to (b)(iii).
You MUST show your working.
(3 marks)

(continued on the next page)

8 continued.

(c) Another method used to monitor the titration is to use a pH meter without a data logger. The pH is measured and recorded after the addition of each $1{\cdot}00\,cm^3$ portion of NaOH(aq)

A student assessed the two methods and concluded that using the data logger was a more effective way to carry out the experiment.

Give THREE reasons that support this conclusion. (3 marks)

Answer space continues on the next page.

8(c) continued.

(continued on the next page)

8 continued.

(d) A solution containing propanoic acid and sodium propanoate forms a buffer.

(i) $2{\cdot}30\,g$ of sodium propanoate is dissolved in propanoic acid solution. This forms a buffer with $pH = 4{\cdot}2$ and a volume of exactly $100\,cm^3$

Calculate the concentration of the propanoic acid, in $mol\,dm^{-3}$, in this buffer.
(4 marks)

[K_a (propanoic acid) = $1{\cdot}34 \times 10^{-5}\,mol\,dm^{-3}$

$M_r(CH_3CH_2CO_2Na) = 96{\cdot}0$]

Answer space continues on the next page.

8(d)(i) continued.

[K_a (propanoic acid) = $1{\cdot}34 \times 10^{-5}$ mol dm^{-3}

$M_r(CH_3CH_2CO_2Na) = 96{\cdot}0$]

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8(d) continued.

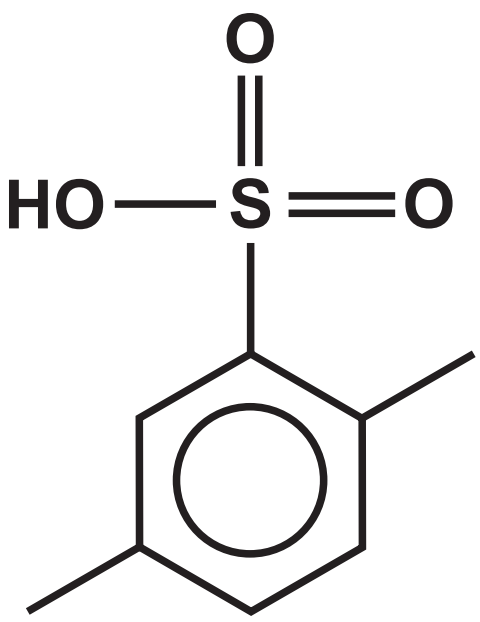
(ii) Explain why there is no significant change in pH when a small amount of hydrochloric acid, HCl(aq), is added to this buffer.
(3 marks)

Answer space continues on the next page.

8(d)(ii) continued.

(Total for Question 8 = 20 marks)

9 This question is about the compound **2,5-dimethylbenzenesulfonic** acid, which has the structure shown.



It is used to analyse levels of cholesterol in blood plasma. It can be synthesised by the reaction of **1,4-dimethylbenzene** with concentrated sulfuric acid.

The electrophile in this reaction is sulfur trioxide.

(a) Look at the diagram for Question 9(a) in the Diagram Booklet. Complete a possible mechanism for this reaction by adding curly arrows, and any relevant dipoles, charges and lone pairs.

(3 marks)

(continued on the next page)

9 continued.

(b) The 2,5-dimethylbenzenesulfonic acid formed can be purified by recrystallisation using hot water as a solvent.

PROCEDURE

Step 1 Dissolve impure 2,5-dimethylbenzenesulfonic acid in the minimum volume of hot water.

Step 2 Allow the solution to cool until 2,5-dimethylbenzenesulfonic acid has crystallised.

Step 3 Separate the 2,5-dimethylbenzenesulfonic acid by filtering under reduced pressure.

Step 4 Rinse the 2,5-dimethylbenzenesulfonic acid using a small amount of ice-cold water.

Step 5 Dry the 2,5-dimethylbenzenesulfonic acid between two pieces of filter paper.

(continued on the next page)

9(b) continued.

(i) Explain how recrystallisation reduces the amount of SOLUBLE impurities.
(3 marks)

(continued on the next page)

9(b) continued.

(ii) A student carrying out this procedure noticed some INSOLUBLE impurities in their sample.

Describe how the procedure should be amended to remove these insoluble impurities. (2 marks)

(continued on the next page)

9 continued.

(c) The hydrated form of the acid has the formula $C_6H_3(CH_3)_2SO_3H \bullet nH_2O$

An experiment was carried out to determine the number of moles of water of crystallisation, n, in this formula.

The method involves adding excess sodium hydroxide to a known mass of the hydrated 2,5-dimethylbenzenesulfonic acid. The amount of unreacted sodium hydroxide is then determined by titration.

PROCEDURE

Step 1 $10{\cdot}0\,cm^3$ of $1{\cdot}00\,mol\,dm^{-3}$ NaOH(aq) was added to $1{\cdot}60\,g$ of hydrated 2,5-dimethylbenzenesulfonic acid in a small conical flask.

Step 2 The solution formed was diluted to give a volume of exactly $100\,cm^3$

(continued on the next page)

9(c) continued.

Step 3 20·0 cm^3 samples of the diluted solution required a mean titre of 22·40 cm^3 of 0·02500 $mol\,dm^{-3}$ HCl(aq) to neutralise the unreacted sodium hydroxide present in the sample.

(i) Describe how to make the diluted solution, in Step 2

(4 marks)

Answer space continues on the next 2 pages.

9(c)(i) continued.

9(c)(i) continued.

(continued on the next page)

9(c) continued.

(ii) Calculate the relative formula mass of hydrated 2,5-dimethylbenzenesulfonic acid and hence deduce the value of n.
(5 marks)

Answer space continues on the next 2 pages.

9(c)(ii) continued.

9(c)(ii) continued.

(continued on the next page)

9 continued.

(d) Look at the diagram for Question 9(d) in the Diagram Booklet. A student carrying out this experiment used a funnel as shown to try to ensure the acid was added safely to the burette during the titration.

(i) Give ONE change to this technique that would reduce the risk to this student.
(1 mark)

(continued on the next page)

9(d) continued.

(ii) The student forgot to remove the funnel from the burette and during the titration five drops of acid from the funnel dripped into the burette.

Explain what effect, if any, this error will have on the final value for **n**.

(3 marks)

Answer space continues on the next page.

9(d)(ii) continued.

(Total for Question 9 = 21 marks)

TOTAL FOR PAPER = 120 MARKS

END OF PAPER