

Chemistry

Advanced

PAPER 3: General and Practical Principles in Chemistry

Time: 2 hours 30 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 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 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 Relative atomic mass is an important concept in chemistry.

**(a) Define the term relative atomic mass.
(2 marks)**

(continued on the next page)

1 continued.

(b) Look at the table for Question 1(b) in the Diagram Booklet. A sample of neon consisted of three isotopes.

Calculate the relative atomic mass of neon in this sample.

**Give your answer to three significant figures.
(2 marks)**

(Total for Question 1 = 4 marks)

Turn over

2 Ammonium cobalt(II) sulfate is made by mixing aqueous solutions of ammonium sulfate and excess cobalt(II) sulfate.

(a) Dry crystals of ammonium cobalt(II) sulfate, $(\text{NH}_4)_2\text{SO}_4 \cdot \text{CoSO}_4 \cdot 6\text{H}_2\text{O}$, are obtained by the procedure shown.

Step 1 The reaction mixture is transferred to an evaporating basin, heated gently and then left to crystallise.

Step 2 The crystals are separated by gravity filtration.

Step 3 The crystals are then RINSED with a small amount of ICE-COLD water.

Step 4 The rinsed crystals are placed in a WARM OVEN for 30 minutes.

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2 continued.

- (i) The colour of the cobalt(II) sulfate solution used is pink due to the complex cobalt(II) ion, $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$.**

**Explain why the solution is coloured.
(4 marks)**

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2 continued.

- (ii) Explain the shape of the cobalt(II) ion, $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$, using electron-pair repulsion theory.
(3 marks)**

2 continued.

(iii) Give the reasons for carrying out Steps 3 and 4 of the procedure, referring particularly to the words in CAPITALS. (3 marks)

[illegible]

2 continued.

(b) The percentage yield of this reaction is 70·0%.

Give TWO possible reasons, other than an incomplete reaction, why the yield is less than 100%.

(2 marks)

(Total for Question 2 = 12 marks)

- 3 A group of students design and carry out experiments to deduce the formulae of two salts, **X** and **Y**.

X contains one cation and one anion.

Y contains water of crystallisation.

- (a) (i) A flame test is carried out on **X**.

Describe how to carry out a flame test.
(3 marks)

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3 continued.

(ii) The colour of the flame is yellow.

**Give the FORMULA of the metal ion present
in salt X.
(1 mark)**

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3 continued.

- (b) A sample of X is placed in a test tube and dissolved in deionised water.
The solution is acidified with hydrochloric acid and barium chloride solution is added.**

A white precipitate forms.

- (i) Give the FORMULA of the anion present in X.
(1 mark)**

- (ii) Deduce the FORMULA of X, using your answers to (a)(ii) and (b)(i).
(1 mark)**

(continued on the next page)

3 continued.

- (c) Y is identified as hydrated potassium carbonate, $K_2CO_3 \cdot nH_2O$.**

Look at the diagram for Question 3(c) in the Diagram Booklet. Two of the students were asked to determine the number of moles of water of crystallisation, n , in Y using the procedure shown:

- weigh a sample of hydrated Y into a pre-weighed crucible**
 - place a lid loosely on the crucible and heat it for five minutes to remove the water of crystallisation**
 - allow the crucible and lid to cool, remove the lid and then reweigh the crucible with its contents.**
- (i) The first student carried out the experiment but forgot to use the lid.**

**Explain how this mistake would affect the calculated value of n .
(2 marks)**

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3 continued.

- (ii) The second student carried out the experiment but heated the apparatus for only ONE minute.**

**Explain how this mistake would affect the calculated value of n .
(2 marks)**

3 continued.

(iii) In an accurate experiment, Y is found to consist of 71.9% K_2CO_3 by mass.

**Calculate the value of n.
(3 marks)**

(Total for Question 3 = 13 marks)

- 4 This question is about the white solid barium carbonate.**

Look at the equation and table for Question 4 in the Diagram Booklet.

- (a) Barium carbonate decomposes under suitable conditions to form barium oxide and carbon dioxide.**

Standard molar entropy data related to this reaction are shown.

- (i) Show that barium carbonate is thermally stable at 298 K, using the data in the equation and in the table.
(5 marks)**

4 continued.

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4 continued.

- (ii) Calculate the lowest temperature, in °C, at which it is thermodynamically feasible for barium carbonate to decompose. Give your answer to three significant figures. (3 marks)**

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4 continued.

- (b) Explain whether magnesium carbonate is more or less thermally stable than barium carbonate.
(3 marks)**

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4 continued.

- (c) A white solid was thought to be barium carbonate. A student suggested that the presence of the carbonate ion could be tested for by adding a small amount of sulfuric acid.**

**Explain whether or not this suggestion is valid.
(2 marks)**

(Total for Question 4 = 13 marks)

- * 5 Explain the difference in the reactivity of bromine with benzene and with phenol.**

Include the type of reaction, the products that form, and any conditions required.

Mechanisms for the reactions are NOT required.

(6 marks)

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(Total for Question 5 = 6 marks)

6 An ester Q has the molecular formula $C_8H_{16}O_2$

- (a) When burned in excess oxygen, 1.879 g of Q formed 4.594 g of carbon dioxide and 1.879 g of water.**

**Show that the empirical formula of Q is C_4H_8O .
(4 marks)**

6 continued.

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6 continued.

- (b) Look at the table for Question 6(b) in the Diagram Booklet. Data from the high resolution ^1H (proton) NMR spectrum of the ester Q are shown in the table.**

Part of the structure of Q is shown.

Look at the diagram for Question 6(b) in the Diagram Booklet. Complete the structure of Q.

**Justify your answer by linking the proton environments in your structure to the relative peak areas and the splitting pattern of the peaks.
(7 marks)**

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6 continued.

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6 continued.

(Total for Question 6 = 11 marks)

7 This question is about some reactions of carbonyl compounds.

(a) Look at the diagram for Question 7(a) in the Diagram Booklet. Methyl methacrylate is the monomer used to make the polymer perspex. It can be synthesised from propanone using the reaction scheme shown.

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7 continued.

- (i) Draw the mechanism for the reaction in Step 1.
Include curly arrows and any relevant lone pairs and dipoles.
(4 marks)**

7 continued.

(ii) Look at the table for Question 7(a)(ii) in the Diagram Booklet. Complete the table to show the information missing from the reaction scheme.

(6 marks)

(iii) Look at the diagram for Question 7(a)(iii) in the Diagram Booklet. Complete the equation for the formation of the polymer from methyl methacrylate.

(2 marks)

(b) Propanone can be formed from the fermentation of polysaccharides such as starch. The propanone can be separated from the fermentation mixture by distillation.

Using the space provided in the Diagram Booklet for Question 7(b), draw the apparatus used in the laboratory for distillation of propanone from the reaction mixture.

(3 marks)

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7 continued.

- (c) Carbonyl compounds, such as propanone, react with 2,4-dinitrophenylhydrazine in solution (Brady's reagent) to form a precipitate which can be used to identify the compound.**

The precipitate can be purified by recrystallisation.

Details of the recrystallisation process are shown.

- Step 1 Dissolve the precipitate in the minimum volume of hot ethanol.**
- Step 2 Warm a filter paper and funnel in an oven for use in Step 3.**
- Step 3 Filter the solution whilst still warm to remove any undissolved solids, using gravity filtration.**
- Step 4 Allow the filtrate to cool and recrystallise.**
- Step 5 Filter the crystals under reduced pressure.**
- Step 6 Rinse the crystals with a small amount of ice-cold ethanol.**
- Step 7 Dry the crystals between filter papers and leave in a desiccator.**

7 continued.

- (i) Explain why the filter paper and funnel are warmed in an oven before Step 3.
(2 marks)**

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7 continued.

- (ii) Explain how Steps 4 and 5 remove impurities from the crystalline product.
(2 marks)**

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7 continued.

- (iii) State how the purified crystals can be used to identify the carbonyl compound that reacts with 2,4-dinitrophenylhydrazine.**

Detailed descriptions of practical procedures are not required.

(2 marks)

(Total for Question 7 = 21 marks)

Turn over

8 This question is about acids and bases.

- (a) Devise an experiment to determine the acid dissociation constant, K_a , for a solution of ethanoic acid, CH_3COOH , of unknown concentration.**

Assume you have access to a pH meter and a solution of sodium hydroxide of similar concentration to the acid.

**Include how to determine K_a from your results.
(5 marks)**

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(b) 500 cm^3 of a buffer solution of $\text{pH} = 4.70$ is required.

Calculate the volume of 0.800 mol dm^{-3} sodium ethanoate solution and of 0.800 mol dm^{-3} ethanoic acid needed to make this buffer.
(3 marks)

$[\text{K}_a \text{ for ethanoic acid} = 1.74 \times 10^{-5}\text{ mol dm}^{-3}]$

8 continued.

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8 continued.

- (c) Calculate the pH of the solution formed when 51.2 cm^3 of $0.927 \text{ mol dm}^{-3}$ NaOH(aq) is mixed with 40.4 cm^3 of $0.370 \text{ mol dm}^{-3}$ $\text{H}_2\text{SO}_4\text{(aq)}$.
(6 marks)

[Ionic product of water

$$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}]$$

8 continued.

(Total for Question 8 = 14 marks)

- 9 Pineapple juice contains the weak acids citric acid ($\text{C}_6\text{H}_8\text{O}_7$) and ascorbic acid ($\text{C}_6\text{H}_8\text{O}_6$). The amount of each compound in a sample of 150 cm^3 of pineapple juice can be determined by titration.

- (a) Experiment 1 is designed to determine the total amount of acid.

10.0 cm^3 samples of pineapple juice are transferred to separate conical flasks and titrated with a solution of sodium hydroxide of known concentration.

The total amount of acid in the 150 cm^3 sample of pineapple juice is $8.00 \times 10^{-3}\text{ mol}$.

- (i) Give a reason why methyl orange would NOT be a suitable indicator to use in this titration.
(1 mark)

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9 continued.

- (ii) A student did not notice an air bubble in the tip of the burette BEFORE carrying out one of their accurate titrations. During this titration, the air bubble escaped.**

Explain the effect this mistake would have on the value of this titre.

(2 marks)

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9 continued.

- (b) Experiment 2 is carried out to determine the amount of ascorbic acid ($\text{C}_6\text{H}_8\text{O}_6$) in the pineapple juice.**

An outline procedure for this experiment is given.

Step 1 5.00 cm³ of the pineapple juice is added to a conical flask.

Step 2 Deionised water, a small amount of HCl(aq), a few crystals of potassium iodide, KI, and 3 drops of starch solution are also added to the flask.

Step 3 The contents of the flask are swirled to ensure the KI dissolves fully.

Step 4 The resultant mixture is titrated with a solution of potassium iodate(V), $\text{KIO}_3(\text{aq})$, of concentration 0.00100 mol dm⁻³.

The reactions that take place are on page 17 in the Diagram Booklet.

Only the ascorbic acid reacts with the iodine.

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9 continued.

- (i) The end-point of the titration is when the starch changes colour.**

Explain how this occurs, including the colour change.

(3 marks)

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9 continued.

- (ii) The TOTAL amount of acid in the 150 cm^3 sample is $8.00 \times 10^{-3}\text{ mol}$.**

The mean titre in Experiment 2 using 5.00 cm^3 of pineapple juice is 9.50 cm^3 .

**Calculate the mass of CITRIC ACID in the 150 cm^3 sample.
(5 marks)**

9 continued.

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9 continued.

- (c) Look at the diagram for Question 9(c) in the Diagram Booklet. While doing background research for the experiment, a student found that three other compounds, D, E and F, are often present in pineapple juice.**

Predict which one of these compounds is most likely to affect the result of Experiment 1 and hence predict the effect on the mass of citric acid calculated in (b)(ii).

Justify your answer.

(3 marks)

(continued on the next page)

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9 continued.

(Total for Question 9 = 14 marks)

- 10 The progress of the reaction between iodine and propanone with an acid catalyst can be followed in an experiment using a titrimetric method.**

Procedure

- Step 1** Mix 25 cm^3 of 1 mol dm^{-3} aqueous propanone with 25 cm^3 of 1 mol dm^{-3} sulfuric acid in a beaker. Both these reactants are in excess.
- Step 2** Start the stop clock as 50 cm^3 of 0.02 mol dm^{-3} iodine solution is added to the beaker. Mix the reactants thoroughly.
- Step 3** Withdraw a 10.0 cm^3 sample of the reaction mixture, using a pipette, and transfer it to a conical flask.
- Step 4** Add a spatula measure of sodium hydrogencarbonate, noting the exact time.
- Step 5** Titrate the iodine present in the 10.0 cm^3 sample with 0.01 mol dm^{-3} sodium thiosulfate solution, using starch indicator.
- Step 6** Continue to withdraw 10.0 cm^3 samples about every two minutes, repeating Steps 4 and 5 with each sample.

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10 continued.

- (a) (i) Explain why sodium hydrogencarbonate is added in Step 4.
(2 marks)**

(continued on the next page)

10 continued.

- (ii) Write the IONIC equation for the reaction that takes place during Step 4. State symbols are not required.
(1 mark)**

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10 continued.

(b) Some data from the experiment are shown.

Time sodium hydrogencarbonate is added / min	2·0	5·0	6·5	8·0	10·5	12·0
Volume of sodium thiosulfate / cm ³	19·2	15·5	14·0	12·1	9·5	7·2

- (i) Look at the grid for Question 10(b)(i) in the Diagram Booklet. Plot a graph of the volume of sodium thiosulfate against the time the sodium hydrogencarbonate is added.
(2 marks)
- (ii) Explain how the graph of volume of thiosulfate against time confirms the reaction is zero order with respect to iodine, I₂.
(3 marks)

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10 continued.

(continued on the next page)

10 continued.

- (c) The overall rate equation for the reaction is
 $\text{rate} = k[\text{H}^+(\text{aq})][\text{CH}_3\text{COCH}_3(\text{aq})]$.**

**Look at the diagram for Question 10(c) in the
Diagram Booklet. A student researching the
mechanism for the reaction found this example.**

- (i) Predict which of the three steps is the
rate-determining step.
Justify your answer.
(2 marks)**

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10 continued.

(ii) The student stated that

‘The hydrogen ions cannot be acting as a catalyst.

One hydrogen ion is a reactant in Step 1 but two hydrogen ions are formed as products in Steps 1 and 3.’

**Explain whether or not this statement is valid.
(2 marks)**

(Total for Question 10 = 12 marks)

**TOTAL FOR PAPER = 120 MARKS
END OF PAPER**