Paper Reference(s) 9CH0/01
Pearson Edexcel Level 3 GCE

Total Marks

Chemistry

Advanced

PAPER 1: Advanced Inorganic and Physical Chemistry

Monday 10 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

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 atomic structure.

(a) Look at the table for Question 1(a) in the Diagram Booklet. Complete the table.
(3 marks)

(b) A sample of sulfur was found to contain only four isotopes.

(i) Look at the table for Question 1(b)(i) in the Diagram Booklet. Complete the table to show the percentage abundance of ^{34}S.
(1 mark)

(continued on the next page)

1(b) continued.

(ii) Calculate the relative atomic mass (A_r) of the sulfur in this sample using the data in the table. Give your answer to TWO decimal places.
(2 marks)

(Total for Question 1 = 6 marks)

2 This question is about the formation of ions.

(a) Look at the table for Question 2(a) in the Diagram Booklet. Explain the trend in the values of the first electron affinities of the elements shown.
(4 marks)

Answer space continues on the next page.

2(a) continued.

(continued on the next page)

2 continued.

(b) Which of these isoelectronic ions has the SMALLEST ionic radius?
(1 mark)

☐ A S^{2-}

☐ B Cl^{-}

☐ C K^{+}

☐ D Ca^{2+}

(continued on the next page)

2 continued.

(c) Look at the table for Question 2(c) in the Diagram Booklet. Some series of successive ionisation energies in kJ mol^{-1} are shown.
The letters do not refer to the symbols of the elements.

(i) Which element in the table could be in Group 4?
(1 mark)

☐ **A**

☐ **B**

☐ **C**

☐ **D**

(continued on the next page)

2(c) continued.

(ii) Which element in the table could be described as an s-block element?
(1 mark)

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

(Total for Question 2 = 7 marks)

3 This question is about compounds and their chemical analysis.

Three containers of soluble white solids have lost their labels but are known to be calcium bromide, calcium iodide and potassium sulfate.

(a) (i) Describe how to carry out a flame test on these samples.
(3 marks)

Answer space continues on the next page.

3(a)(i) continued.

(continued on the next page)

3(a) continued.

(ii) Give the expected observation for each of the flame tests.
(2 marks)

calcium bromide

_____

_____

calcium iodide

_____

_____

potassium sulfate

_____

_____

(continued on the next page)

3 continued.

(b) Separate aqueous solutions of calcium bromide and of calcium iodide reacted with acidified silver nitrate to produce a precipitate. Concentrated aqueous ammonia was added to each precipitate.

Look at the table for Question 3(b) in the Diagram Booklet. Complete the table.
(2 marks)

(continued on the next page)

3 continued.

(c) Describe a chemical test for the sulfate ion giving the positive result.
(2 marks)

(continued on the next page)

3 continued.

(d) What mass of potassium sulfate (K_2SO_4) would be needed to prepare 250 cm^3 of a solution of concentration 0·0450 mol dm^{-3}?

The molar mass of K_2SO_4 is 174·3 g mol^{-1}
(1 mark)

☐ A 1·96 g

☐ B 7·84 g

☐ C 19·6 g

☐ D 31·4 g

(Total for Question 3 = 10 marks)

4 This question is about acids, bases and buffers.

(a) State what is meant by a Brønsted–Lowry acid.
(1 mark)

_____

_____

_____

(continued on the next page)

4 continued.

(b) Look at the graphs for Question 4(b) in the Diagram Booklet. Which could be the titration curve when $0{\cdot}100\,mol\,dm^{-3}$ NaOH(aq) is added to $25{\cdot}0\,cm^3$ of $0{\cdot}100\,mol\,dm^{-3}$ $CH_3COOH(aq)$? (1 mark)

☐ Graph A

☐ Graph B

☐ Graph C

☐ Graph D

(continued on the next page)

4 continued.

(c) Look at the table for Question 4(c) in the Diagram Booklet. Some information about acids in aqueous solution is given.

Comment on these pH values. No calculations are required.
(4 marks)

Answer space continues on the next 2 pages.

4(c) continued.

4(c) continued.

(continued on the next page)

4 continued.

(d) One of the systems controlling the pH of blood is the carbonic acid–hydrogencarbonate buffer system.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

(i) Write the expression for the acid dissociation constant, K_a, for carbonic acid.
State symbols are not required.
(1 mark)

(continued on the next page)

4(d) continued.

(ii) A blood sample taken from an individual was analysed.

Calculate the pH of the blood sample.

Use your expression for K_a and the values shown.

K_a for carbonic acid = $4{\cdot}50 \times 10^{-7}\,\text{mol}\,\text{dm}^{-3}$

$[HCO_3^-] = 0{\cdot}0240\,\text{mol}\,\text{dm}^{-3}$
$[H_2CO_3] = 0{\cdot}00200\,\text{mol}\,\text{dm}^{-3}$

(3 marks)

Answer space continues on the next page.

4(d)(ii) continued.

(continued on the next page)

4 continued.

(e) The relevant equilibria that maintain the pH of blood are shown.

Equilibrium 1 $CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$

Equilibrium 2 $H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$

(i) When a person exercises vigorously the concentration of carbon dioxide (aq) in the blood increases.

Explain how this increase in the concentration of carbon dioxide affects the pH of the blood.
Refer to the equilibria in your answer.
No calculation is required.
(2 marks)

Answer space continues on the next page.

4(e)(i) continued.

(continued on the next page)

4(e) continued.

(ii) Explain how the carbonic acid–hydrogencarbonate buffer system in Equilibrium 2 acts to restore the pH of the blood after a person has exercised. (2 marks)

(Total for Question 4 = 14 marks)

5 This question is about 'Direct Ethanol Fuel Cells' which are being developed to power small electronic devices.

The overall reaction in these fuel cells is shown.

$$C_2H_5OH(l) + 3O_2(g) \longrightarrow 3H_2O(l) + 2CO_2(g)$$

(continued on the next page)

5 continued.

(a) Look at the data for Question 5(a) in the Diagram Booklet. Calculate the enthalpy change for the reaction using the mean bond enthalpy data. (3 marks)

Enthalpy change = _____ kJ mol^{-1}

(continued on the next page)

5 continued.

(b) (i) Look at the diagram for Question 5(b)(i) in the Diagram Booklet. Complete the enthalpy cycle for the overall reaction in the Direct Ethanol Fuel Cell. Include labels.
(2 marks)

Substance	$\Delta_f H^{\ominus}$ / kJ mol^{-1}
$C_2H_5OH(l)$	−277
$CO_2(g)$	−394
$H_2O(l)$	−286

(continued on the next page)

5(b) continued.

(ii) Calculate a value for the enthalpy change of the Direct Ethanol Fuel Cell reaction, using your cycle.
(1 mark)

Enthalpy change = _____ kJ mol^{-1}

(continued on the next page)

5 continued.

(c) Give TWO reasons for the difference between your calculated values in (a) and (b).
(2 marks)

(continued on the next page)

5 continued.

(d) In the Direct Ethanol Fuel Cell under acidic conditions, at one electrode the ethanol is oxidised in the presence of water to produce carbon dioxide, hydrogen ions and electrons.

At the other electrode, the hydrogen ions and electrons combine with oxygen to form water.

Write the two ionic half-equations for this process. State symbols are not required.
(2 marks)

Answer space continues on the next page.

Oxidation half-equation

5(d) continued.

Reduction half-equation

(Total for Question 5 = 10 marks)

*6 Explain why aqueous solutions of Cu^{2+} ions and Fe^{2+} ions are coloured but have different colours, whereas aqueous solutions of Zn^{2+} ions are colourless. Include any relevant electronic configurations. (6 marks)

Answer space continues on the next 5 pages.

6 continued.

6 continued.

6 continued.

6 continued.

6 continued.

(Total for Question 6 = 6 marks)

7 This question is about vanadium.

The contact process is used in the manufacture of sulfuric acid. In the second stage, sulfur dioxide is converted into sulfur trioxide by passing sulfur dioxide and air over a solid V_2O_5 catalyst.

The equation for the second stage is shown.

$$SO_2(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons SO_3(g) \quad \Delta H = -196\,kJ\,mol^{-1}$$

(a) (i) What are the expression and the units for the equilibrium constant (K_p) for this reaction? (1 mark)

	Expression	Units
☐ A	$\dfrac{p(SO_3)}{p(SO_2)\,p(O_2)^{1/2}}$	atm^2
☐ B	$\dfrac{p(SO_2)\,p(O_2)^{1/2}}{p(SO_3)}$	$atm^{1/2}$
☐ C	$\dfrac{p(SO_2)\,p(O_2)^{1/2}}{p(SO_3)}$	$atm^{-1/2}$
☐ D	$\dfrac{p(SO_3)}{p(SO_2)\,p(O_2)^{1/2}}$	$atm^{-1/2}$

(continued on the next page)

7(a) continued.

(ii) Which variable affects the value of K_p ? (1 mark)

☐ A pressure

☐ B temperature

☐ C surface area of the catalyst

☐ D concentration of $O_2(g)$

(continued on the next page)

7 continued.

(b) Write TWO equations that show the conversion of SO_2 and O_2 into SO_3 by using V_2O_5 as the catalyst. State symbols are not required.
(2 marks)

(continued on the next page)

7 continued.

(c) Which row of the table shows the correct colour of the solution and oxidation number of vanadium in the aqueous ions shown?
(1 mark)

	Aqueous ion	Colour of solution	Oxidation number of vanadium
☐ A	VO_2^+	yellow	+3
☐ B	VO^{2+}	green	+4
☐ C	VO_2^+	yellow	+5
☐ D	VO^{2+}	blue	+5

(continued on the next page)

7 continued.

(d) What is the value of the cell potential for the reaction of Zn and VO_2^+?
Use your Data Booklet.
(1 mark)

$$2VO_2^+(aq) + 4H^+(aq) + Zn(s) \longrightarrow 2VO^{2+}(aq) + 2H_2O(l) + Zn^{2+}(aq)$$

☐ A +1·76 V

☐ B +0·24 V

☐ C −0·24 V

☐ D −1·76 V

(Total for Question 7 = 6 marks)

8 This question is about ionic compounds.

(a) Draw dot-and-cross diagrams of the ions in magnesium hydroxide, showing the outer shell electrons only.

Use ✕ for magnesium electrons, ● for oxygen electrons and △ for each hydrogen electron.
(2 marks)

(continued on the next page)

8 continued.

(b) Which definition correctly describes the enthalpy change of solution, $\Delta_{sol}H$?
(1 mark)

	Enthalpy change of solution, $\Delta_{sol}H$
☐ A	The enthalpy change when 1 mol of gaseous ions dissolves in sufficient water to give an infinitely dilute solution.
☐ B	The enthalpy change when 1 mol of an ionic substance dissolves in water to give an infinitely dilute solution.
☐ C	The enthalpy change when 1 mol of gaseous ions dissolves in sufficient water to give a solution of concentration 1 mol dm^{-3}
☐ D	The enthalpy change when 1 mol of an ionic substance dissolves in water to give a solution of concentration 1 mol dm^{-3}

(continued on the next page)

8 continued.

(c) The table shows the information needed to calculate the standard enthalpy change of formation of magnesium fluoride.

Label	Description	Value / kJ mol^{-1}
A	enthalpy change of formation of magnesium fluoride	
B	lattice energy of magnesium fluoride	−2957
C	enthalpy change of atomisation of magnesium	+148
D	1st ionisation energy of magnesium	+738
E	2nd ionisation energy of magnesium	+1451
F	enthalpy change of atomisation of fluorine	+79
G	1st electron affinity of fluorine	−328

(continued on the next page)

8(c) continued.

(i) Look at the diagram for Question 8(c)(i) in the Diagram Booklet. Complete the Born–Haber cycle for magnesium fluoride with formulae, state symbols, electrons and correctly labelled arrows.
The cycle is not drawn to scale.
(4 marks)

(continued on the next page)

8(c) continued.

(ii) Calculate the value of $\Delta_f H^{\ominus}[MgF_2(s)]$.
(1 mark)

(continued on the next page)

8(c) continued.

(iii) Look at the table for Question 8(c)(iii) in the Diagram Booklet. The experimental and theoretical values of the lattice energy for MgF_2 and MgI_2 are given in the table.

Explain the differences in these values. (4 marks)

Answer space continues on the next page.

8(c)(iii) continued.

(Total for Question 8 = 12 marks)

9 Sodium hydrogencarbonate is used as a raising agent in baking as carbon dioxide gas is released when it undergoes thermal decomposition.

Look at the table for Question 9(a) in the Diagram Booklet.

(a) Show that the reaction below is NOT feasible at 298 K by calculating ΔG. Use the table in the Diagram Booklet to support your answer. (3 marks)

$$2NaHCO_3(s) \longrightarrow Na_2CO_3(s) + CO_2(g) + H_2O(l)$$

$$\Delta_r H = +91{\cdot}6\ kJ\,mol^{-1}$$

9 continued.

(b) Calculate the minimum temperature, in degrees Celsius (°C), at which an oven should be set for this reaction to be thermodynamically feasible. (2 marks)

Minimum temperature = _____ °C

(Total for Question 9 = 5 marks)

10 Vitamin C has the molecular formula $C_6H_8O_6$

The label on a bottle of vitamin C tablets stated that a 2·50 g tablet contained 6% of vitamin C by mass. The tablet was analysed to check the accuracy of the label. The procedure involved a series of steps.

(a) Step 1 Dissolving the tablet.

A 2·50 g vitamin C tablet was crushed and dissolved to make an aqueous solution of volume 250·0 cm^3

Describe how to make this solution from the crushed tablet.
(3 marks)

Answer space continues on the next page.

10(a) continued.

(continued on the next page)

10 continued.

(b) Step 2 Producing a known amount of iodine.

Iodine was produced by reacting 25·0 cm^3 of 0·0100 mol dm^{-3} potassium iodate with excess potassium iodide and hydrochloric acid in a conical flask.

(i) Complete the ionic equation for the formation of the iodine from 1 mol of IO_3^- ions.
(1 mark)

$$IO_3^- + ____ I^- + ____ H^+ \longrightarrow 3I_2 + _____$$

(continued on the next page)

10(b) continued.

(ii) Show, by calculation, that $7{\cdot}50 \times 10^{-4}$ moles of iodine were produced in the flask.
(2 marks)

(continued on the next page)

10 continued.

(c) Step 3 Titrating with sodium thiosulfate solution.

$10{\cdot}0\,cm^3$ of the vitamin C tablet solution from Step 1 was added to the conical flask from Step 2 to react with the iodine produced, as shown in the equation.

$$C_6H_8O_6(aq) + I_2(aq) \longrightarrow C_6H_6O_6(aq) + 2HI(aq)$$

The unreacted iodine in the conical flask was titrated with a solution of $0{\cdot}100\,mol\,dm^{-3}$ sodium thiosulfate, $Na_2S_2O_3(aq)$.

The mean titre was $14{\cdot}40\,cm^3$

$$2S_2O_3^{2-}(aq) + I_2(aq) \longrightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

(continued on the next page)

10(c) continued.

(i) State the indicator used in this titration, giving the colour change that would be observed at the end-point.
(2 marks)

_____

_____

_____

_____

_____

_____

(continued on the next page)

10(c) continued.

(ii) Deduce, by calculation, whether the label on the bottle of vitamin C tablets is correct.
(6 marks)

Answer space continues on the next page.

10(c)(ii) continued.

(Total for Question 10 = 14 marks)

TOTAL FOR PAPER = 90 MARKS
END OF PAPER