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

Chemistry

Total Marks

Advanced

PAPER 1: Advanced Inorganic and Physical Chemistry

Monday 12 June 2023 – 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					

Q71912A

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 d-block elements.

(a) Look at the graph for Question 1(a) in the Diagram Booklet. Which of the labels 1–4 identifies a d-block element in Period 4?
(1 mark)

☐ **A** 1

☐ **B** 2

☐ **C** 3

☐ **D** 4

(continued on the next page)

1 continued.

(b) State what is meant by the term d-block element.
(1 mark)

(Total for Question 1 = 2 marks)

2 Chemists often use the term ‘orbital’ when considering atomic structure.

(a) State what is meant by the term orbital.
(2 marks)

(continued on the next page)

2 continued.

(b) Look at the table for Question 2(b) in the Diagram Booklet. Draw diagrams to show the shape of an s and a p orbital.
(2 marks)

(c) What is the electronic configuration of a copper atom?
(1 mark)

☐ **A** $[Ar]4s^1 3d^{10}$

☐ **B** $[Ar]4s^2 3d^9$

☐ **C** $[Ar]4s^2 4p^1 3d^8$

☐ **D** $[Ar]4s^2 4p^2 3d^7$

(Total for Question 2 = 5 marks)

3 This question is about compounds containing elements from Group 7.

(a) Which change occurs when concentrated sulfuric acid is added to potassium bromide? (1 mark)

☐ **A** bromide ions oxidise sulfuric acid forming sulfur

☐ **B** bromide ions oxidise sulfuric acid forming sulfur dioxide

☐ **C** bromide ions reduce sulfuric acid forming sulfur

☐ **D** bromide ions reduce sulfuric acid forming sulfur dioxide

(continued on the next page)

3 continued.

(b) Chemists can test for the presence of bromide ions in solution by adding a small amount of acidified silver nitrate solution. The solubility of the precipitate in aqueous ammonia is then tested.

(i) Which statement is correct for bromide ions? (1 mark)

☐ A a white precipitate forms that dissolves in concentrated ammonia only

☐ B a white precipitate forms that dissolves in both dilute and concentrated ammonia

☐ C a cream precipitate forms that dissolves in concentrated ammonia only

☐ D a cream precipitate forms that dissolves in both dilute and concentrated ammonia

(continued on the next page)

3(b) continued.

(ii) Give a reason why the silver nitrate must be acidified.
(1 mark)

_____

_____

_____

(continued on the next page)

3(b) continued.

(iii) Explain which acid needs to be used to acidify the silver nitrate solution and why other acids are unsuitable.
(2 marks)

(continued on the next page)

3 continued.

(c) Look at the chemical equation for Question 3(c) in the Diagram Booklet.

Iodine trichloride forms a dimer, I_2Cl_6, in the solid state.
When molten, it is suggested that it breaks down as shown.

(continued on the next page)

3(c) continued.

(i) Draw a labelled diagram of a simple experiment to confirm this dissociation has occurred, stating the positive result.
(2 marks)

Result

_____

_____

(continued on the next page)

3(c) continued.

(ii) What is the shape of the ICl_4^- ion?
(1 mark)

☐ A octahedral

☐ B square planar

☐ C tetrahedral

☐ D trigonal bipyramidal

(iii) The equilibrium position for the dissociation of molten I_2Cl_6 lies to the left.

$$I_2Cl_6 \rightleftharpoons ICl_2^+ + ICl_4^-$$

What is the most likely numerical value of K_c for this equilibrium?
(1 mark)

☐ A $1{\cdot}0 \times 10^{6}$

☐ B $5{\cdot}0 \times 10^{3}$

☐ C $1{\cdot}0$

☐ D $5{\cdot}0 \times 10^{-3}$

(Total for Question 3 = 9 marks)

4 **Look at the graph for Question 4 in the Diagram Booklet. It shows the melting temperatures of some elements in Period 3.**

Explain the variations in melting temperature across the period in terms of the structure and bonding in these elements.
(6 marks)

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 the decomposition of dinitrogen tetroxide.
The reaction eventually reaches equilibrium.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

colourless brown

(a) The table shows values of ΔG at different temperatures for this reaction.

Temperature / K	ΔG / kJ mol^{-1}
350	–4·0
400	–13
450	–22
500	–31
550	–40

(i) Look at the grid for Question 5(a)(i) in the Diagram Booklet. Plot a graph of ΔG against temperature.
(2 marks)

(continued on the next page)

5(a) continued.

(ii) Calculate the entropy change of the system, ΔS_{system}, in $J\,K^{-1}\,mol^{-1}$, using your straight line from the graph in (a)(i) and the equation shown.
(3 marks)

$$\Delta G = -T\Delta S_{system} + \Delta H$$

(continued on the next page)

5(a) continued.

(iii) What feature of the graph in (a)(i) gives the enthalpy change of the reaction?
(1 mark)

- ☐ **A** intercept of the x-axis
- ☐ **B** (intercept of the x-axis) × –1
- ☐ **C** intercept of the y-axis
- ☐ **D** (intercept of the y-axis) × –1

(continued on the next page)

5 continued.

(b) What happens to the position of the equilibrium and the colour of the mixture when the pressure is increased?

The volume of the system remains constant.
(1 mark)

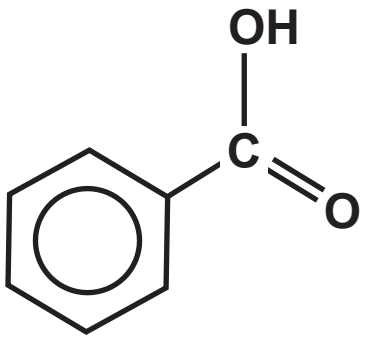
$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

colourless **brown**

	Position of equilibrium	Change in colour
☐ A	moves to the right	mixture gets lighter
☐ B	moves to the right	mixture gets darker
☐ C	moves to the left	mixture gets lighter
☐ D	moves to the left	mixture gets darker

(Total for Question 5 = 7 marks)

6 Benzoic acid is a weak acid found in cranberries.



C_6H_5COOH – benzoic acid

(a) Which of these answers identifies the types of species present when benzoic acid is mixed with nitric acid?
(1 mark)

[K_a of benzoic acid = $6{\cdot}3 \times 10^{-5}$ mol dm^{-3};
K_a of nitric acid = 40 mol dm^{-3}]

$$C_6H_5COOH + HNO_3 \rightleftharpoons C_6H_5COOH_2^+ + NO_3^-$$

☐	A	acid	base	acid	base
☐	B	acid	base	base	acid
☐	C	base	acid	base	acid
☐	D	base	acid	acid	base

(continued on the next page)

6 continued.

(b) The ionic salts sodium benzoate and potassium benzoate are both used as food preservatives.

Explain why the melting temperature of sodium benzoate is higher than the melting temperature of potassium benzoate.
(2 marks)

Answer space continues on the next page.

6(b) continued.

(c) The value of K_a for benzoic acid = $6{\cdot}28 \times 10^{-5}\,mol\,dm^{-3}$.

(i) Write the expression for the acid dissociation constant, K_a, of benzoic acid.
(1 mark)

(continued on the next page)

6(c) continued.

(ii) Calculate the mass of benzoic acid needed to prepare 250 cm^3 of a solution with a pH = 3·51 (4 marks)

Answer space continues on the next page.

6(c)(ii) continued.

(d) Weak acids such as benzoic acid can be neutralised by sodium hydroxide solution.

$C_6H_5COOH(aq) + NaOH(aq) \longrightarrow$

$C_6H_5CO_2Na(aq) + H_2O(l)$

(i) Which of these could be used to show the end-point of a titration of benzoic acid with sodium hydroxide solution?
(1 mark)

☐ A bromothymol blue

☐ B litmus

☐ C methyl orange

☐ D phenolphthalein

(continued on the next page)

6(d) continued.

(ii) Another weak acid found in cranberries is quinic acid, $C_6H_7(OH)_4COOH$.
It is neutralised by sodium hydroxide solution in a similar way to benzoic acid.

A 25·0 cm^3 sample of 0·500 mol dm^{-3} quinic acid solution was neutralised under standard conditions in a polystyrene cup using 25·0 cm^3 of 0·800 mol dm^{-3} of sodium hydroxide solution.
This resulted in a temperature rise of 2·9 °C.

Calculate the standard enthalpy change of neutralisation, $\Delta_{neut}H^{\ominus}$, of quinic acid in kJ mol^{-1}.
(3 marks)

[Assume the density of both solutions is 1·0 g cm^{-3}.
specific heat capacity of solution formed = 4·18 J g^{-1} $°C^{-1}$]

Answer space continues on the next page.

6(d)(ii) continued.

(continued on the next page)

6(d) continued.

(iii) The standard enthalpy change of neutralisation of the weak acid HCN by sodium hydroxide is $-11{\cdot}7\,kJ\,mol^{-1}$ while that of the strong acid HCl is $-57{\cdot}9\,kJ\,mol^{-1}$.

Explain the difference between these values. (2 marks)

(Total for Question 6 = 14 marks)

7 This question is about chromium and chromium compounds.

(a) Naturally occurring chromium has four isotopes, ^{50}Cr, ^{52}Cr, ^{53}Cr and ^{54}Cr.

State what is meant by the term isotopes.
(2 marks)

_____

_____

_____

(b) Both chromium and calcium can form ions with a +2 charge.

(i) Complete the electronic configuration of a Cr^{2+} ion.
(1 mark)

$1s^2$ _____

_____

(continued on the next page)

7(b) continued.

(ii) Look at the table for Question 7(b)(ii) in the Diagram Booklet. Explain which of chromium or calcium most easily forms a +2 ion using all of the data in the table.
(3 marks)

Answer space continues on the next page.

7(b)(ii) continued.

(c) Chromium(III) sulfate, $Cr_2(SO_4)_3$, dissolves in water to form the complex ion $[Cr(H_2O)_6]^{3+}(aq)$.

(i) State the colour of this complex ion.
(1 mark)

(continued on the next page)

7(c) continued.

(ii) Explain why the aqueous solution of this complex ion has an acidic pH by considering the interaction between the metal ion and the ligands.
(2 marks)

(continued on the next page)

7 continued.

(d) A student researching the role of dichromate(VI) ions, $Cr_2O_7^{2-}$, as an oxidising agent made the statement shown.

'Standard electrode potential data shows that it is never feasible for a 1·00 mol dm^{-3} solution of potassium dichromate(VI) to oxidise the chloride ions in hydrochloric acid.'

Look at the chemical equations for Question 7(d) in the Diagram Booklet. Comment on this statement using the data and equilibria shown. (4 marks)

Answer space continues on the next 2 pages.

7(d) continued.

7(d) continued.

(Total for Question 7 = 13 marks)

*8 Transition metals and their compounds can act as catalysts in many reactions such as the ones shown:

- platinum, Pt, in the catalytic converters of vehicles
- manganese(II) ions, $Mn^{2+}(aq)$, in the oxidation of ethanedioate ions, $C_2O_4^{2-}(aq)$, by manganate(VII) ions, $MnO_4^-(aq)$.

Compare and contrast the role of the catalysts in these reactions.
(6 marks)

Answer space continues on the next 5 pages.

8 continued.

8 continued.

8 continued.

8 continued.

8 continued.

(Total for Question 8 = 6 marks)

9 This question is about silver compounds.

(a) Look at the diagram for Question 9(a) in the Diagram Booklet. It shows a Born–Haber cycle for the formation of silver(I) oxide, Ag_2O.
All quantities are measured in $kJ\,mol^{-1}$.

(i) Complete the diagram by adding appropriate species and state symbols to the empty boxes.
(2 marks)

(ii) Explain why the value for the first electron affinity of oxygen is negative and the value for the second electron affinity is positive.
(3 marks)

Answer space continues on the next page.

9(a)(ii) continued.

(continued on the next page)

9(a) continued.

(iii) Calculate a value for the standard enthalpy change of atomisation of silver, $\Delta_{at}H^{\ominus}$, using the Born–Haber cycle.
(3 marks)

Answer space continues on the next page.

9(a)(iii) continued.

(continued on the next page)

9 continued.

(b) Look at the table for Question 9(b) in the Diagram Booklet. Another silver compound is silver chloride, AgCl. Values for its lattice energy can be found by experiment or by theoretical calculation.

(i) Give TWO assumptions used in the model to calculate the theoretical lattice energy. (2 marks)

(continued on the next page)

9(b) continued.

(ii) Explain the difference in the two values for the lattice energy of silver chloride by considering the possible bonding models.
(3 marks)

Answer space continues on the next page.

9(b)(ii) continued.

(Total for Question 9 = 13 marks)

10 Manganese compounds can be used to determine the amounts of dissolved molecular oxygen in water samples.

(a) Draw the dot-and-cross diagram for an oxygen molecule, O_2.
Show outer shell electrons only.
(1 mark)

(continued on the next page)

10 continued.

(b) The solubility of oxygen in water under standard conditions is $1{\cdot}22 \times 10^{-3}$ mol dm^{-3}.

Comment on this value by considering the type and strength of the intermolecular forces in

- pure water
- pure oxygen
- a mixture of water and oxygen.

Detailed descriptions of the forces involved are not required.
(4 marks)

Answer space continues on the next page.

10(b) continued.

(continued on the next page)

10 continued.

(c) The amount of dissolved oxygen in a sample of river water was found using the process outlined.

- excess alkaline manganese(II) sulfate, $MnSO_4$, was added to a 150 cm^3 sample of river water
- the Mn^{2+} ions reacted with the dissolved oxygen forming a precipitate of manganese(IV) oxide hydroxide

$$2Mn^{2+}(aq) + O_2(aq) + 4OH^-(aq) \longrightarrow 2MnO(OH)_2(s)$$

- the precipitate was then dissolved using excess sulfuric acid, forming $Mn^{4+}(aq)$ ions

$$MnO(OH)_2(s) + 4H^+(aq) \longrightarrow Mn^{4+}(aq) + 3H_2O(l)$$

- excess potassium iodide solution was then added, forming iodine

$$Mn^{4+}(aq) + 2I^-(aq) \longrightarrow Mn^{2+}(aq) + I_2(aq)$$

- the liberated iodine was then titrated with sodium thiosulfate solution, $Na_2S_2O_3(aq)$, of concentration 0·00518 mol dm^{-3}

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

- the mean volume of the titre of $Na_2S_2O_3(aq)$ was 34·20 cm^3.

(continued on the next page)

10(c) continued.

(i) Calculate the concentration of dissolved oxygen in the sample of river water, in g dm^{-3}. (5 marks)

Answer space continues on the next page.

10(c)(i) continued.

(continued on the next page)

10(c) continued.

(ii) The concentration of oxygen in water is often expressed in parts per million (ppm), where 1 ppm equals 1 g of solute dissolved in 1×10^6 g of solvent.

Calculate the concentration of the oxygen in the sample of river water in ppm. Assume the density of the river water is $1{\cdot}00\,g\,cm^{-3}$.
(1 mark)

(continued on the next page)

10 continued.

(d) Look at the table for Question 10(d) in the Diagram Booklet. Some data is shown for electrode systems involving the $Mn^{3+}(aq)$ ion.

Explain why Mn^{3+} ions are unstable in aqueous solution.
Include an equation and the type of reaction that occurs.
(4 marks)

Answer space continues on the next page.

10(d) continued.

(Total for Question 10 = 15 marks)

TOTAL FOR PAPER = 90 MARKS
END OF PAPER