Paper Reference(s) 9CH0/01

Pearson Edexcel Level 3 GCE

Chemistry

Total Marks

Advanced

PAPER 1: Advanced Inorganic and Physical Chemistry

Tuesday 10 June 2025 – Morning

Time: 1 hour 45 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 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 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.

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 Look at the table for Question 1 in the Diagram Booklet. It shows data for the three stable isotopes of argon.

(a) State what is meant by the term 'relative isotopic mass'.
(2 marks)

(continued on the next page)

1 continued.

(b) State what is meant by the term ‘isotope’. Illustrate your answer by referring to the numbers of sub-atomic particles in these isotopes of argon. (2 marks)

(continued on the next page)

1 continued.

(c) Calculate the relative atomic mass of argon.
Give your answer to TWO decimal places.
(2 marks)

Answer space continues on the next page.

1(c) continued.

(Total for Question 1 = 6 marks)

2 This question is about some trends in properties of elements and compounds.

(a) Look at the graph for Question 2(a) in the Diagram Booklet. The trend in the first ionisation energies for some of the first eleven elements is shown.

Complete the graph by including the points for nitrogen, oxygen, and sodium.
(3 marks)

(b) Explain why the first ionisation energy of beryllium is higher than the first ionisation energy of both lithium and boron.
(4 marks)

Answer space continues on the next 2 pages.

2(b) continued.

2(b) continued.

(continued on the next page)

2 continued.

(c) Write the equation for the SECOND ionisation energy of beryllium.
Include state symbols.
(1 mark)

(d) Which orbital is an electron removed from during the second ionisation of calcium?
(1 mark)

☐ A 3s

☐ B 3p

☐ C 4s

☐ D 4p

(continued on the next page)

2 continued.

(e) Which of these isoelectronic ions has the LARGEST ionic radius?
(1 mark)

☐ A S^{2-}

☐ B Cl^{-}

☐ C K^{+}

☐ D Ca^{2+}

(continued on the next page)

2 continued.

(f) Look at the table for Question 2(f) in the Diagram Booklet. Discuss the reasons for the differences between the boiling temperatures of the compounds in the table.
Refer to intermolecular forces in your answer.
Detailed descriptions of how these forces arise are not required.
(6 marks)

Answer space continues on the next 5 pages.

2(f) continued.

2(f) continued.

2(f) continued.

2(f) continued.

2(f) continued.

(Total for Question 2 = 16 marks)

3 A student carried out an investigation to determine indirectly the enthalpy change for the thermal decomposition of calcium carbonate. The reaction equation is shown.

Reaction 1:

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g) \qquad \Delta_r H_1$$

(a) State why the enthalpy change for the thermal decomposition of calcium carbonate cannot be determined directly.
(1 mark)

(continued on the next page)

3 continued.

(b) The student placed a known mass of calcium carbonate in a polystyrene cup. $30{\cdot}0\,cm^3$ of hydrochloric acid of concentration $3{\cdot}00\,mol\,dm^{-3}$ was added.
The mixture was stirred, and the highest temperature reached was recorded.

The equation for the reaction is shown.

Reaction 2:

$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

(i) Look at the table for Question 3(b)(i) in the Diagram Booklet. Complete the missing data in the table for Reaction 2
(1 mark)

(continued on the next page)

3(b) continued.

(ii) **0·041 mol of $CaCO_3(s)$ was used in the experiment.**

Show, by calculation, that the hydrochloric acid is in excess for Reaction 2

(2 marks)

(continued on the next page)

3(b) continued.

(iii) Calculate the enthalpy change, $\Delta_r H_2$, for Reaction 2 in $kJ\,mol^{-1}$

Include a sign in your answer.

(3 marks)

[Assume the specific heat capacity of the solution = $4{\cdot}18\ J\ g^{-1}\,°C^{-1}$ and the mass of the solution = $30\ g$]

(continued on the next page)

3(b) continued.

(iv) The student carried out a similar procedure with calcium oxide.

The enthalpy change, $\Delta_r H_3$, calculated for Reaction 3 was $-176{\cdot}3\ kJ\ mol^{-1}$

Reaction 3:

$$CaO(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l)$$

Look at the diagram for Question 3(b)(iv) in the Diagram Booklet. Complete the enthalpy cycle. Include the correct substances with state symbols in the lower box.
Add an appropriately labelled arrow.
(2 marks)

(continued on the next page)

3(b) continued.

(v) Calculate a value for the enthalpy change $\Delta_r H_1$ for the thermal decomposition of calcium carbonate by using your cycle.
(1 mark)

(continued on the next page)

3 continued.

(c) A data book value for the thermal decomposition of calcium carbonate, $\Delta_r H^{\ominus}$ (Reaction 1), under standard conditions is $+178{\cdot}2\,kJ\,mol^{-1}$

(i) Look at the table for Question 3(c)(i) in the Diagram Booklet. Deduce the feasibility of the thermal decomposition of calcium carbonate at $298\,K$ using the data in the table.
(3 marks)

(continued on the next page)

3(c) continued.

(ii) Calculate the MINIMUM temperature, in °C, at which thermal decomposition would occur. Give your answer to 3 significant figures.
(2 marks)

(continued on the next page)

3 continued.

(d) Explain why magnesium carbonate undergoes thermal decomposition at a LOWER temperature than calcium carbonate.

(3 marks)

Answer space continues on the next page.

3(d) continued.

(Total for Question 3 = 18 marks)

4 Ethanol is made industrially by the reaction of ethene and steam.

The equation is shown.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$$

$$\Delta H = -45{\cdot}0\,kJ\,mol^{-1}$$

The catalyst used is phosphoric acid, H_3PO_4, which is bound to a solid silicon dioxide support.

$90{\cdot}0\,mol$ of ethene and $54{\cdot}0\,mol$ of steam are mixed in a sealed reactor at $500\,K$

At equilibrium, the total pressure is $60{\cdot}0\,atm$ and $5\,\%$ of the ethene has been converted into ethanol.

(a) Calculate the value of K_p at this temperature. Include the expression for K_p and units as appropriate.

(5 marks)

Answer space continues on the next 2 pages.

4(a) continued.

4(a) continued.

(continued on the next page)

4 continued.

(b) (i) It is proposed to increase the pressure in the reactor to 70·0 atm

Explain the effect this change would have on the yield of ethanol by referring to the equilibrium.
(2 marks)

(continued on the next page)

4(b) continued.

(ii) Which of these factors would change the value of K_p?
(1 mark)

☐ **A** using a different catalyst

☐ **B** increasing the pressure

☐ **C** decreasing the temperature

☐ **D** increasing the volume of the reaction vessel

(Total for Question 4 = 8 marks)

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5 This question is about acids and bases.

(a) The reaction of nitric acid with water can be represented by the equation shown.

$$HNO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + NO_3^-(aq)$$

Which is a conjugate acid–base pair for the reaction?

(1 mark)

	Acid	Conjugate base
☐ A	HNO_3	H_2O
☐ B	NO_3^-	HNO_3
☐ C	H_3O^+	H_2O
☐ D	H_2O	H_3O^+

(continued on the next page)

5 continued.

(b) State the expression that defines the pH of a solution.

(1 mark)

(continued on the next page)

5 continued.

(c) What is the concentration of $OH^-(aq)$ ions, in $mol\,dm^{-3}$, in a solution of $Ba(OH)_2(aq)$ with $pH = 9{\cdot}50$ at $298\,K$?

(1 mark)

☐ **A** $3{\cdot}16 \times 10^{-10}$

☐ **B** $3{\cdot}16 \times 10^{-5}$

☐ **C** $6{\cdot}32 \times 10^{-5}$

☐ **D** $3{\cdot}16 \times 10^{4}$

(Total for Question 5 = 3 marks)

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6 This question is about transition metals.

(a) (i) Which pair of electronic configurations is correct?

(1 mark)

	Cr	Cr^{3+}
☐ A	[Ar] $3d^4 4s^2$	[Ar] $3d^1 4s^2$
☐ B	[Ar] $3d^5 4s^1$	[Ar] $3d^1 4s^2$
☐ C	[Ar] $3d^4 4s^2$	[Ar] $3d^3$
☐ D	[Ar] $3d^5 4s^1$	[Ar] $3d^3$

(continued on the next page)

6(a) continued.

(ii) State why chromium is classified as a transition metal.
(1 mark)

_____

_____

_____

(continued on the next page)

6 continued.

(b) (i) Draw the structure of the complex ion, $[Cr(H_2O)_6]^{3+}(aq)$, showing clearly its 3-dimensional shape, and the bonds between the chromium ion and the water ligands.
(2 marks)

(continued on the next page)

6(b) continued.

(ii) Name the SHAPE of the $[Cr(H_2O)_6]^{3+}(aq)$ complex ion.

(1 mark)

_____

_____

(continued on the next page)

6 continued.

(c) Write TWO IONIC equations which demonstrate the amphoteric nature of chromium(III) hydroxide $[Cr(OH)_3(H_2O)_3]$

Include state symbols.

(3 marks)

(continued on the next page)

6 continued.

(d) Name the type of reaction that occurs when chromium(III) hydroxide reacts with excess aqueous ammonia.
(1 mark)

_____

_____

(continued on the next page)

6 continued.

(e) (i) Explain why aqueous solutions of $[Cr(H_2O)_6]^{3+}$ are coloured.

(4 marks)

Answer space continues on the next page.

6(e)(i) continued.

(continued on the next page)

6(e) continued.

(ii) Give the reason why the solutions of $[Cr(H_2O)_6]^{3+}$ and $[CrCl_4]^-$ are DIFFERENT colours.

(1 mark)

(continued on the next page)

6 continued.

(f) Look at the equations for Question 6(f) in the Diagram Booklet. The standard electrode potentials for two half-cell reactions are shown.

(i) Write the overall equation for the reaction of chromium(III) hydroxide with hydrogen peroxide in alkaline conditions to form chromate(VI) ions.
State symbols are not required.
(2 marks)

(continued on the next page)

6(f) continued.

(ii) Calculate the $E^{\ominus}_{cell}$ for this reaction.
Include a reason whether or not the reaction is thermodynamically feasible.
(2 marks)

Answer space continues on the next page.

6(f)(ii) continued.

(continued on the next page)

6(f) continued.

(iii) Which is a correct statement about $E^{\ominus}_{cell}$?
(1 mark)

☐ **A** $E^{\ominus}_{cell}$ **is directly proportional to** $\ln K$

☐ **B** $E^{\ominus}_{cell}$ **is directly proportional to** ΔS_{system}

☐ **C** $E^{\ominus}_{cell}$ **is directly proportional to** $\ln \Delta S_{total}$

☐ **D** $E^{\ominus}_{cell}$ **is directly proportional to** K

(Total for Question 6 = 19 marks)

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7 This question is about lattice energy.

(a) Which statement defines the lattice energy of an ionic solid?

(1 mark)

☐ **A** the energy absorbed when 1 mol of an ionic substance is formed from its gaseous ions

☐ **B** the energy change when 1 mol of an ionic substance is formed from its elements in their standard states

☐ **C** the energy change when 1 mol of an ionic substance is formed from its gaseous ions

☐ **D** the energy absorbed when 1 mol of an ionic substance is formed from its elements in their standard states

(continued on the next page)

7 continued.

(b) Which substance has the lattice energy with the most exothermic value?
(1 mark)

☐ A NaCl

☐ B NaI

☐ C KCl

☐ D KI

(continued on the next page)

7 continued.

(c) Which ionic solid would have the greatest difference between the theoretical and experimental lattice energies?
(1 mark)

☐ **A** NaCl

☐ **B** NaI

☐ **C** KCl

☐ **D** KI

(Total for Question 7 = 3 marks)

*8 Look at the table for Question 8 in the Diagram Booklet. Compare and contrast the mechanisms of the catalysts in the table.
Illustrate your answer with equations that demonstrate the redox reactions involved.
(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 Some hand sanitisers contain hydrogen peroxide (H_2O_2) as an active ingredient.

The World Health Organization recommends that the concentration of H_2O_2 is between $3{\cdot}0\,\%$ and $6{\cdot}0\,\%$ by mass.

A higher concentration results in the hand sanitiser being caustic.

A lower concentration means the sanitiser would not be effective.

A sample of a colourless hand sanitiser of density $0{\cdot}82\,g\,cm^{-3}$ was analysed.

$10{\cdot}00\,cm^3$ of the sanitiser was dissolved in deionised water to give a total volume of $250{\cdot}0\,cm^3$

An acidified solution of potassium manganate(VII) with a concentration of $0{\cdot}0200\,mol\,dm^{-3}$ was titrated against a $25{\cdot}00\,cm^3$ sample of the diluted hand sanitiser solution.

(a) Look at the table for Question 9(a) in the Diagram Booklet. The results of four titrations are shown in the table.

Complete the table by calculating the missing values. (1 mark)

(continued on the next page)

9 continued.

(b) The mean titre was calculated to be $15{\cdot}60\,cm^3$

State how this value was determined.

(1 mark)

(continued on the next page)

9 continued.

(c) The ionic equation for the titration reaction is shown.

$$2MnO_4^- + 5H_2O_2 + 6H^+ \longrightarrow 2Mn^{2+} + 5O_2 + 8H_2O$$

State the colour change that would be seen in the FLASK at the end-point of this titration.
(2 marks)

From

_____

to

_____

(continued on the next page)

9 continued.

(d) Deduce by calculation whether the concentration of hydrogen peroxide in the hand sanitiser is within World Health Organization guidelines. (5 marks)

Answer space continues on the next 2 pages.

9(d) continued.

9(d) continued.

(continued on the next page)

9 continued.

(e) The uncertainty in the pipette volume is $\pm 0{\cdot}04\,cm^3$

The uncertainty in each burette reading is $\pm 0{\cdot}05\,cm^3$

Calculate the percentage uncertainties for the pipette volume of $25{\cdot}00\,cm^3$ and the burette volume of $15{\cdot}55\,cm^3$ for titre 2

(2 marks)

Answer space continues on the next page.

9(e) continued.

(Total for Question 9 = 11 marks)

TOTAL FOR PAPER = 90 MARKS

END OF PAPER