OXFORD AQA
INTERNATIONAL QUALIFICATIONS

INTERNATIONAL A-LEVEL
CHEMISTRY (9620)
Unit 3: Inorganic 2 and Physical 2

Tuesday 14 January 2025   07:00 GMT   Time allowed: 1 hour 30 minutes

Materials
For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
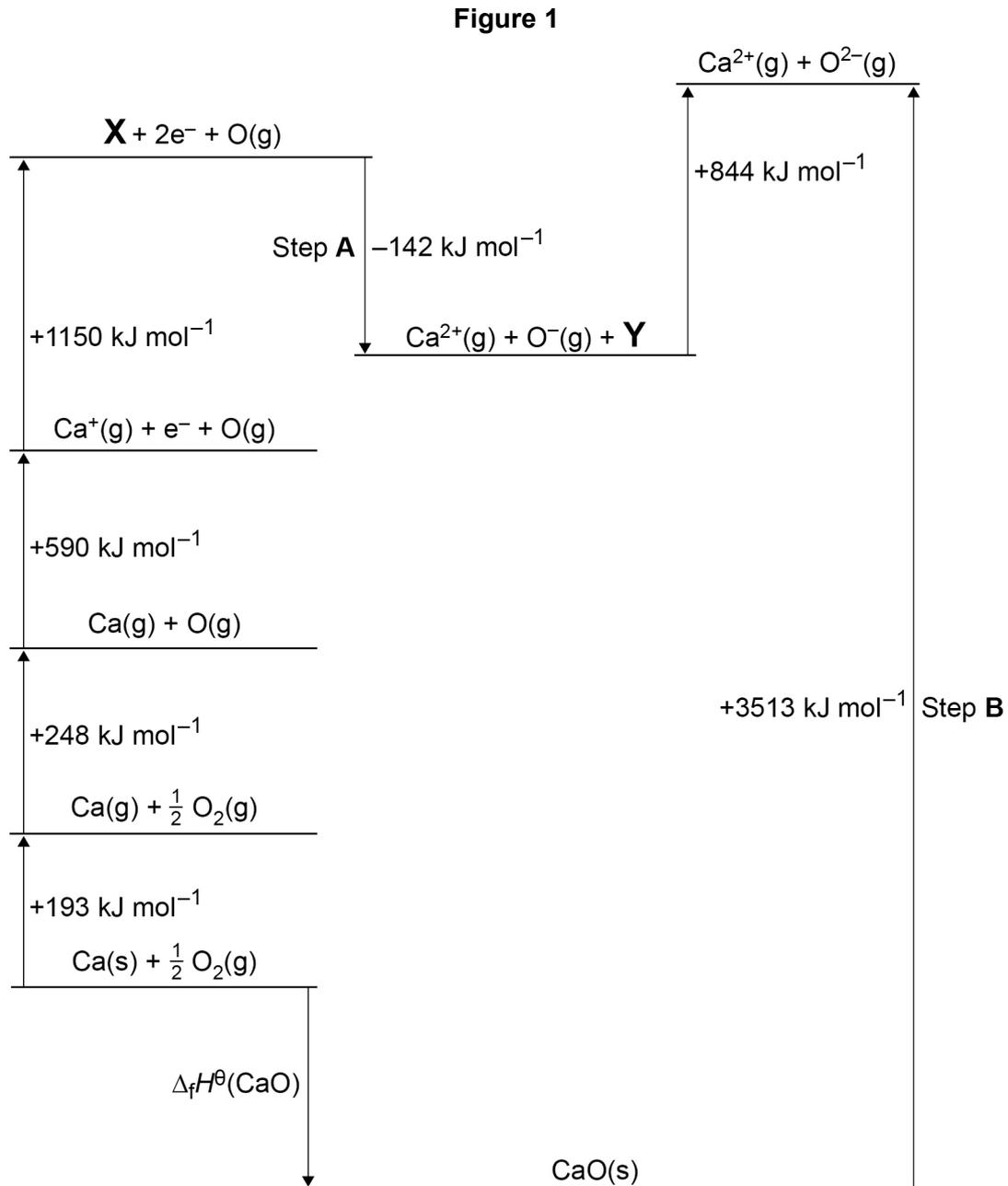- The maximum mark for this paper is 80.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
TOTAL	

Answer **all** questions in the spaces provided.

0 1 **Figure 1** shows the Born–Haber cycle for calcium oxide.

Figure 1

0 1 . 1 Identify species **X** and species **Y**.
Include state symbols where appropriate.

[1 mark]

Species **X** _____

Species **Y** _____

0 1 . 2 Give the names of the enthalpy changes represented by Step **A** and Step **B**.

[2 marks]

Step **A** _____

Step **B** _____

0 1 . 3 Use **Figure 1** to calculate the standard enthalpy of formation of calcium oxide.

[2 marks]

$\Delta_f H^\ominus(CaO)$ _____ kJ mol^{-1}

5

Turn over for the next question

Turn over ▶

0 2 A student does an experiment to determine the enthalpy of solution of magnesium chloride.

Method

- 25.0 cm^3 of distilled water are transferred into a plastic cup.
- 1.57 g of magnesium chloride are added to the water in the cup.
- The mixture is stirred so that the magnesium chloride dissolves.
- The temperature of the mixture is monitored using a thermometer.

The temperature rise is 14.2 °C

0 2 . 1 Calculate a value for the enthalpy of solution, in kJ mol^{-1}, of magnesium chloride.

The specific heat capacity of water = 4.18 J K^{-1} g^{-1}
Assume that the density of the solution = 1.00 g cm^{-3}

[3 marks]

Enthalpy of solution _____ kJ mol^{-1}

0 2 . 2 Explain why the enthalpy of solution of magnesium hydroxide cannot be determined using the same method.

[1 mark]

_____

_____

_____

Table 1 shows some enthalpy change data.

Table 1

	ΔH / kJ mol^{-1}
Enthalpy of hydration of magnesium ions	−1920
Enthalpy of hydration of chloride ions	−364
Lattice dissociation enthalpy of magnesium chloride	+2493

| 0 | 2 |.| 3 | Use the data in **Table 1** to calculate the enthalpy of solution, in kJ mol^{-1}, of magnesium chloride.
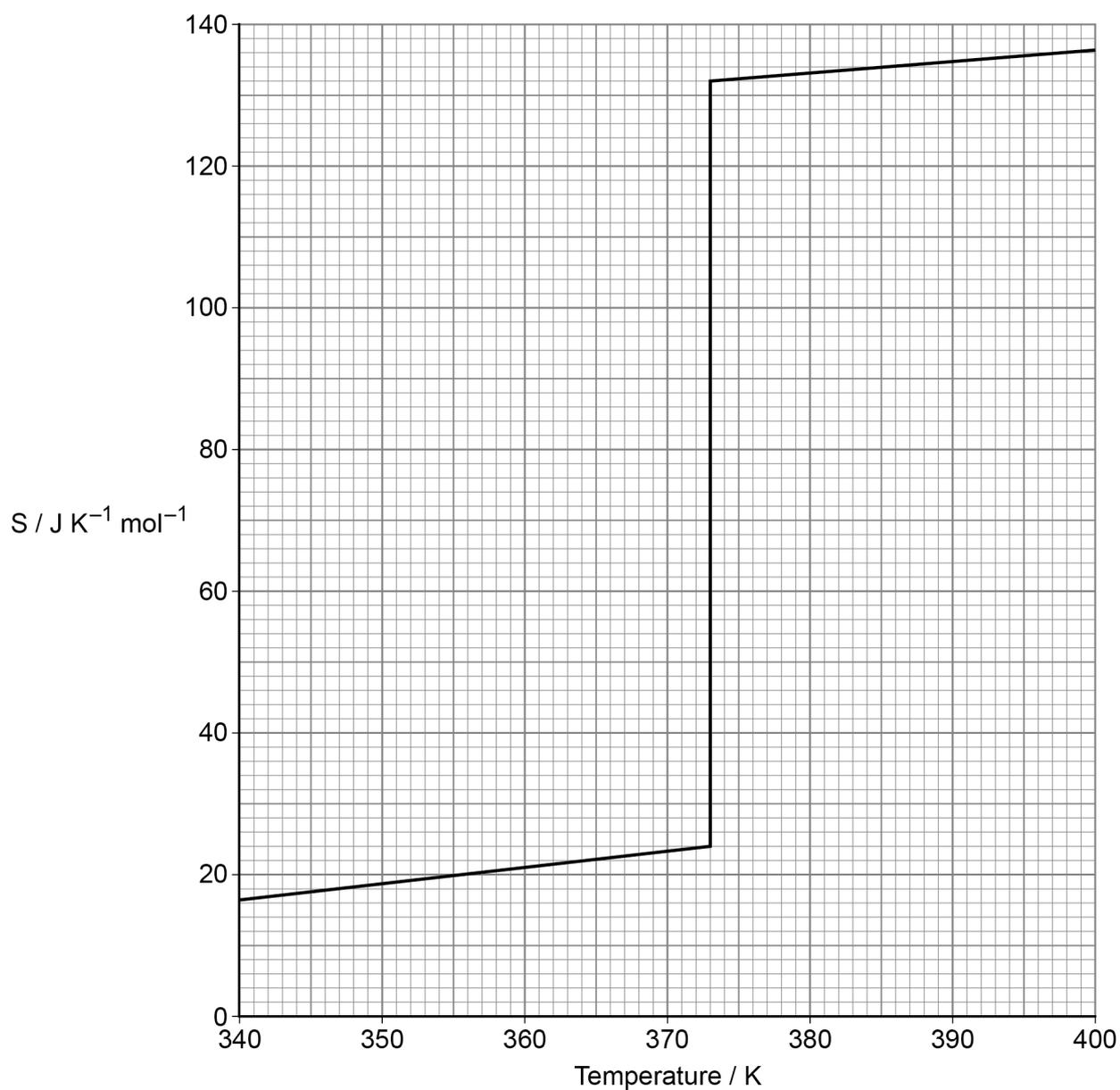
[2 marks]

Enthalpy of solution _____ kJ mol^{-1}

| **6** |

Turn over ▶

| 0 | 3 | | This question is about water.

| 0 | 3 | . | 1 | State why the entropy of water is zero at a temperature of 0 K

[1 mark]

Figure 2 shows how the entropy of a sample of water varies with temperature.

Figure 2

0 3 . 2 Use **Figure 2** to determine the entropy change, in J K^{-1} mol^{-1}, when water boils.

[1 mark]

Entropy change_____ J K^{-1} mol^{-1}

0 3 . 3 When a substance boils, the free-energy change, Δ*G*, is equal to zero.

Use your answer to Question **03.2** to determine the enthalpy change, in kJ mol^{-1}, when water boils.

(If you were unable to answer Question **03.2**, use entropy change = 65.0 J K^{-1} mol^{-1}
This is **not** the correct value.)

[2 marks]

Enthalpy change_____ kJ mol^{-1}

0 3 . 4 **Figure 2** shows the entropy change for water at 373 K
There is also an entropy change at 273 K

State why the entropy change at 373 K is much larger than the
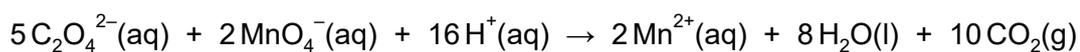entropy change at 273 K

[1 mark]

_____

_____

_____

Turn over ▶

5

0 4 $Na_2C_2O_4$ can be used to determine the concentration of a solution of $KMnO_4$

$$5\,C_2O_4^{\,2-}(aq) \;+\; 2\,MnO_4^{\,-}(aq) \;+\; 16\,H^+(aq) \;\rightarrow\; 2\,Mn^{2+}(aq) \;+\; 8\,H_2O(l) \;+\; 10\,CO_2(g)$$

Method

- 0.910 g of anhydrous $Na_2C_2O_4$ is dissolved in some distilled water and the solution is made up to 150 cm^3 using dilute sulfuric acid in a volumetric flask.

- 25.0 cm^3 of this solution are transferred to a conical flask and the solution is warmed to 60 °C

- $KMnO_4$ solution is added from a burette until there is a permanent colour change.

22.35 cm^3 of $KMnO_4$ solution are needed.

0 4 . 1 Determine the concentration, in mol dm^{-3}, of the $Na_2C_2O_4$ solution.
Calculate the concentration, in mol dm^{-3}, of the $KMnO_4$ solution.

[5 marks]

Concentration of $Na_2C_2O_4$ _____ mol dm^{-3}

Concentration of $KMnO_4$ _____ mol dm^{-3}

0 4 . 2 State the colour change at the end point.

[1 mark]

0 4 . 3 The solution in the conical flask is warmed to 60 °C before the $KMnO_4$ is added because the reaction is slow.

State why this reaction is slow.

[1 mark]

This reaction is an example of an autocatalysed reaction.

0 4 . 4 Write two equations to show how the reaction between $C_2O_4^{2-}$ ions and MnO_4^- ions is catalysed.

[2 marks]

Equation 1

Equation 2

Turn over for the next question

9

Turn over ▶

0 5 This question is about acids, bases and pH

0 5 . 1 Calculate the pH of the solution formed when 15.0 cm^3 of distilled water are added to 25.0 cm^3 of 0.150 mol dm^{-3} hydrochloric acid.
Give your answer to **two** decimal places.

[3 marks]

pH _____

0 5 . 2 Calculate the pH of a 0.650 mol dm^{-3} solution of barium hydroxide at 298 K
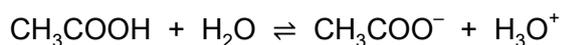Give your answer to **two** decimal places.

The ionic product of water, K_w = 1.00 × 10^{-14} mol^2 dm^{-6} at 298 K

[3 marks]

pH _____

Ethanoic acid is a weak acid and ionises in water as shown.

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$$

For ethanoic acid, the acid dissociation constant, $K_a = 1.76 \times 10^{-5}$ mol dm^{-3} at 298 K

0 5 . 3 What is the effect on the value of this K_a if the concentration of a solution of ethanoic acid is increased?

Tick ($\checkmark$) **one** box.

[1 mark]

Increases ☐

Remains constant ☐

Decreases ☐

0 5 . 4 Calculate the mass, in g, of sodium ethanoate (CH_3COONa) that needs to be dissolved in 25.0 cm^3 of 0.150 mol dm^{-3} ethanoic acid to produce a solution with pH = 4.50 at 298 K

[4 marks]

Mass of sodium ethanoate _____ g

11

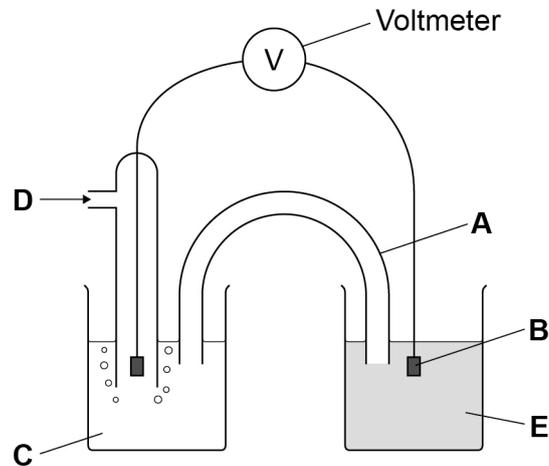**Turn over ▶**

0 6 **Figure 3** represents the cell used to measure the standard electrode potential for the $Cr_2O_7^{2-}(aq) / Cr^{3+}(aq)$ electrode.

Figure 3

0 6 . 1 Name the piece of equipment, **A**.

State the purpose of **A**.

[2 marks]

Name of **A** _____

Purpose of **A** _____

0 6 . 2 Name the substance used as **B**.

[1 mark]

_____

0 6 . 3 The cell is operated at 298 K

Complete **Table 2** to identify substances **C** and **D**.

Include **one** essential condition for each substance.

[2 marks]

Table 2

	Identity	Condition
C		
D		

0 6 . 4 A student suggested that solution **E** should be prepared by mixing equal volumes of 1.00 mol dm^{-3} aqueous acidified potassium dichromate(VI) solution and 1.00 mol dm^{-3} aqueous chromium(III) sulfate solution.

Describe how the mixture should be changed to allow the standard electrode potential for the $Cr_2O_7^{2-}(aq) / Cr^{3+}(aq)$ electrode to be measured.

Justify your answer.

[2 marks]

How mixture should be changed _____

_____

_____

Justification _____

_____

_____

The standard electrode potential, $E^{\ominus}$, for the $Cr_2O_7^{2-}(aq) / Cr^{3+}(aq)$ electrode is +1.33 V

0 6 . 5 Give the conventional representation for this cell.

[2 marks]

_____

0 6 . 6 Give the ionic equation that shows the overall reaction for this cell.

[1 mark]

_____

0 6 . 7 The electrode on the left in **Figure 3** is replaced by a Cl_2 / Cl^- electrode.
The reading on the voltmeter changes to –0.03 V

Calculate the standard electrode potential, $E^{\ominus}$, for the Cl_2 / Cl^- electrode.

[1 mark]

$E^{\ominus}$ for the Cl_2 / Cl^- electrode _____ V

11

Turn over ▶

0 7 This question is about complexes with bidentate ligands.

0 7 . 1 Explain what is meant by bidentate ligand.

[1 mark]

0 7 . 2 When an excess of sodium ethanedioate solution is added to an aqueous solution of cobalt(II) chloride, a pair of stereoisomers is formed.

Draw the displayed formula of each isomer.
Show clearly the charge on each complex.

[3 marks]

0 7 . 3 When an excess of ethane-1,2-diamine ($NH_2CH_2CH_2NH_2$) is added to a solution containing aqueous cobalt(II) ions, all the water ligands are replaced.

Write an equation for the reaction.

Explain the thermodynamic reasons why this reaction occurs.

[6 marks]

Equation

_____

Explanation

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10

Turn over for the next question

Turn over ▶

0 8 This question is about elements in Period 3.

0 8 . 1 Write equations, including state symbols, to show the reaction of phosphorus with excess oxygen and the reaction of phosphorus with excess chlorine.

State **one** observation that you would make in **both** reactions.

[3 marks]

Equation with oxygen

Equation with chlorine

Observation

0 8 . 2 Write an equation to show the reaction of aluminium oxide with hydrochloric acid.

[1 mark]

0 8 . 3 Aluminium oxide is added to an excess of water.

Describe what is observed.

[1 mark]

Do not write outside the box

0 8 . 4 Sulfuric acid can be used to test for barium compounds.
Phosphoric acid can be used in a similar way to test for barium compounds.

Write an equation for the reaction between barium hydroxide and phosphoric acid.

Suggest what you would observe in this reaction.

[2 marks]

Equation

_____

Observation _____

_____

_____

7

Turn over for the next question

Turn over ▶

0 9 This question is about the colours of transition metal ions.

0 9 . 1 Explain why an aqueous solution of copper(II) ions is blue.

[2 marks]

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$[Ti(H_2O)_6]^{3+}$ has a single d-orbital electron.

The energy needed to excite this electron is 3.79×10^{-19} J

0 9 . 2 Calculate the wavelength, in nm, of light that will be absorbed by this $[Ti(H_2O)_6]^{3+}$ complex.

Planck's constant, $h = 6.63 \times 10^{-34}$ J s
The speed of light, $c = 3.00 \times 10^8$ m s^{-1}

[2 marks]

Wavelength _____ nm

**0 9 . 3** Aqueous ammonia is added a drop at a time to an aqueous solution containing copper(II) ions until the ammonia is in excess.

Describe what is observed.
Write equations for any reactions that occur.

[4 marks]

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8

Turn over for the next question

Turn over ▶

1 0 This question is about the acidity of metal-aqua ions.

1 0.**1** Iron(III) compounds dissolve in water to form $[Fe(H_2O)_6]^{3+}$ ions.
The $[Fe(H_2O)_6]^{3+}$ ion dissociates as shown.

$$[Fe(H_2O)_6]^{3+} \rightleftharpoons [Fe(H_2O)_5(OH)]^{2+} + H^+$$
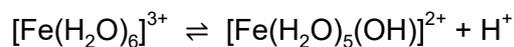
Write an expression for the acid dissociation constant, K_a, for the $[Fe(H_2O)_6]^{3+}$ ion.

Calculate the pH of a solution made when 1.35 g of iron(III) chloride are dissolved in water to make 750 cm^3 of aqueous solution.
Give your answer to **two** decimal places.

The value of pK_a for the $[Fe(H_2O)_6]^{3+}$ ion is 2.22

[6 marks]

Expression for K_a

Calculation

pH _____

1 0 . 2 Solutions containing $Fe^{3+}(aq)$, $Fe^{2+}(aq)$ or $Al^{3+}(aq)$ ions are acidic.

State why solutions of $Fe^{2+}(aq)$ are **less** acidic than $Fe^{3+}(aq)$

Suggest why solutions of $Al^{3+}(aq)$ are **more** acidic than $Fe^{3+}(aq)$

[2 marks]

$Fe^{2+}(aq)$ is less acidic than $Fe^{3+}(aq)$ _____

_____

_____

$Al^{3+}(aq)$ is more acidic than $Fe^{3+}(aq)$ _____

_____

_____

8

END OF QUESTIONS

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Question number	Additional page, if required. Write the question numbers in the left-hand margin.

Do not write outside the box

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