OXFORD

INTERNATIONAL
AQA EXAMINATIONS

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

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I declare this is my own work.

INTERNATIONAL A-LEVEL
CHEMISTRY (9620)

Unit 3: Inorganic 2 and Physical 2

Monday 12 June 2023 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	

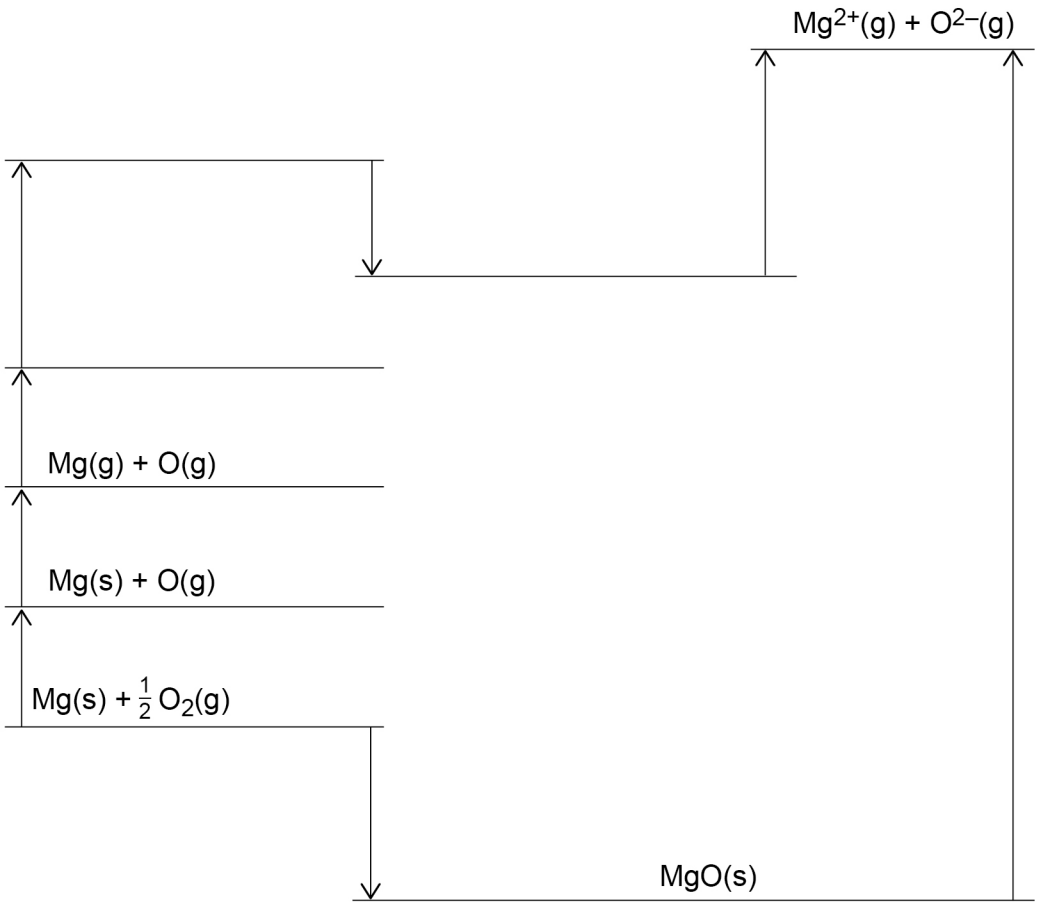
Do not write outside the box

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

0 1 This question is about enthalpy changes.

Figure 1 shows an incomplete Born–Haber cycle for magnesium oxide.

Figure 1



0 1 . 1 Write the formulas, including state symbols, of the appropriate species on each of the three blank horizontal lines in **Figure 1**.

[3 marks]

Do not write outside the box

0 1 . 2 **Table 1** shows some enthalpy data.

Table 1

Enthalpy change	**ΔH / kJ mol^{-1}**
Atomisation of magnesium	+150
Atomisation of oxygen	+248
First electron affinity of oxygen	–142
Second electron affinity of oxygen	+844
Enthalpy of formation of magnesium oxide	–602
First ionisation energy of magnesium	+736
Second ionisation energy of magnesium	+1450

Use **Figure 1** and **Table 1** to calculate the enthalpy of lattice dissociation, in kJ mol^{-1}, for magnesium oxide.

[2 marks]

Enthalpy of lattice dissociation _____ kJ mol^{-1}

0 1 . 3 The enthalpy of lattice dissociation of barium oxide is less endothermic than the enthalpy of lattice dissociation of magnesium oxide.

Explain why.

[2 marks]

_____

_____

_____

_____

0 1 . 4 Suggest why the second electron affinity of oxygen is endothermic.

[1 mark]

_____

_____

8

Do not write outside the box

0 2 Lead(II) nitrate decomposes when heated.

$$2\,Pb(NO_3)_2(s) \rightarrow 2\,PbO(s) + 4\,NO_2(g) + O_2(g)$$

Table 2 shows how the free-energy change (ΔG) for this reaction varies with temperature (T).

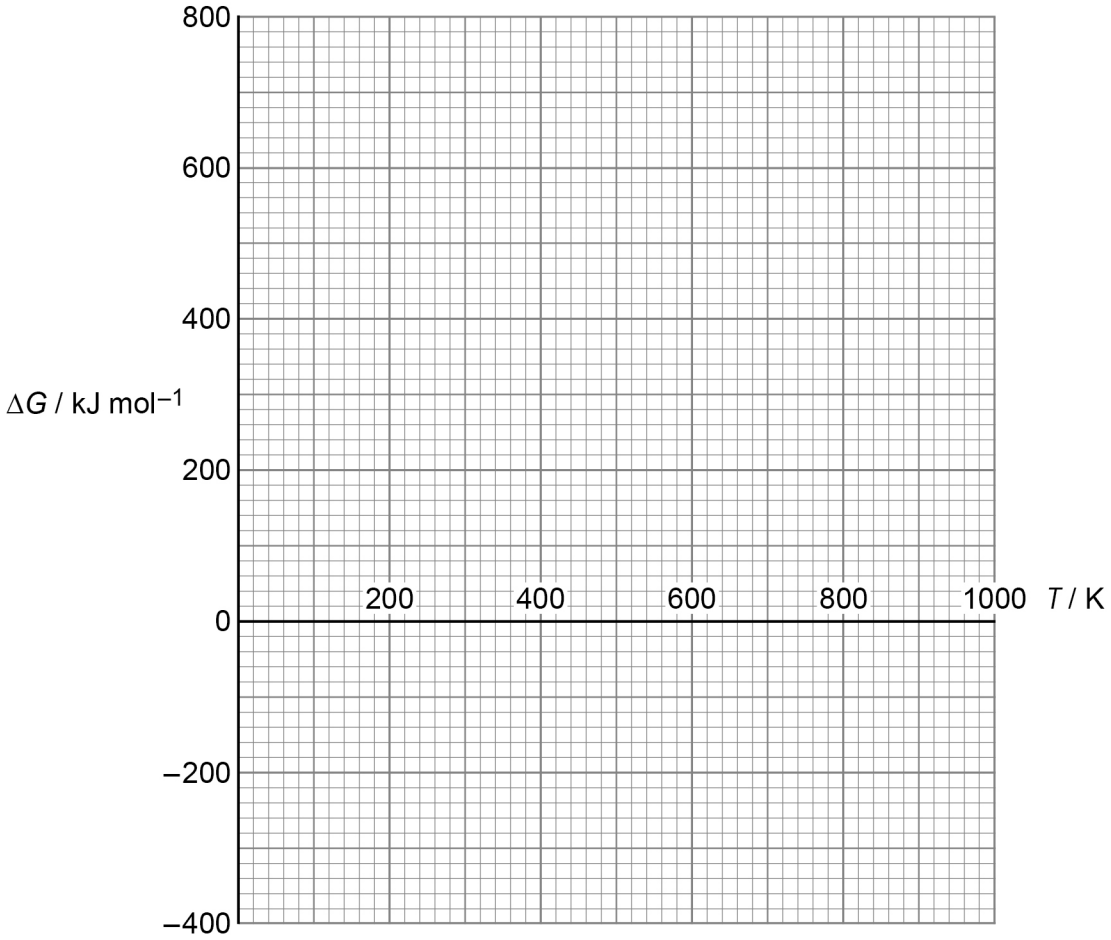
Table 2

***T* / K**	200	400	600	800	1000
ΔG / kJ mol^{-1}	440	280	120	–40	–200

0 2 . 1 Use the data from **Table 2** to draw a graph on **Figure 2**.

[2 marks]

Figure 2



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0 2 . 2 Use your graph in **Figure 2** and the equation $\Delta G = \Delta H - T\Delta S$ to deduce the enthalpy change, in kJ mol^{-1}, for the reaction.

[1 mark]

Enthalpy change _____ kJ mol^{-1}

0 2 . 3 Use your graph in **Figure 2** to calculate the entropy change, in J K^{-1} mol^{-1}, for the reaction.

[3 marks]

Entropy change _____ J K^{-1} mol^{-1}

0 2 . 4 Deduce the temperature, in K, at which the decomposition becomes feasible.

(If you were unable to answer Question **02.2** or Question **02.3** you should use the values $\Delta H = +105$ kJ mol^{-1} and $\Delta S = +140$ J K^{-1} mol^{-1}
These are **not** the correct values.)

[1 mark]

Temperature _____ K

7

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0 3 Propanoic acid (CH_3CH_2COOH) is a weak acid.

When propanoic acid is added to water, an equilibrium is established.

$$CH_3CH_2COOH + H_2O \rightleftharpoons CH_3CH_2COO^- + H_3O^+$$

The acid dissociation constant (K_a) can be given by the expression

$$K_a = \frac{[CH_3CH_2COO^-][H_3O^+]}{[CH_3CH_2COOH]}$$

0 3 . 1 Explain why the expression for K_a does not include the concentration of water.

[1 mark]

_____

_____

_____

0 3 . 2 Calculate the pH of a 0.150 mol dm^{-3} solution of propanoic acid at 25 °C
Give your answer to 2 decimal places.

For propanoic acid, $K_a = 1.34 \times 10^{-5}$ mol dm^{-3} at 25 °C

[2 marks]

pH _____

Do not write outside the box

0 3 . 3 A student prepares an acidic buffer solution using propanoic acid and sodium propanoate.

The student dissolves some solid sodium propanoate in 100 cm^3 of 0.150 mol dm^{-3} propanoic acid.

Calculate the mass, in g, of sodium propanoate needed to prepare a buffer solution with pH = 5.06 at 25 °C

For propanoic acid, $K_a = 1.34 \times 10^{-5}$ mol dm^{-3} at 25 °C

[5 marks]

Mass _____g

Do not write outside the box

0 3 . 4 **Figure 3** shows the pH curve for a titration involving a solution of propanoic acid.

Figure 3

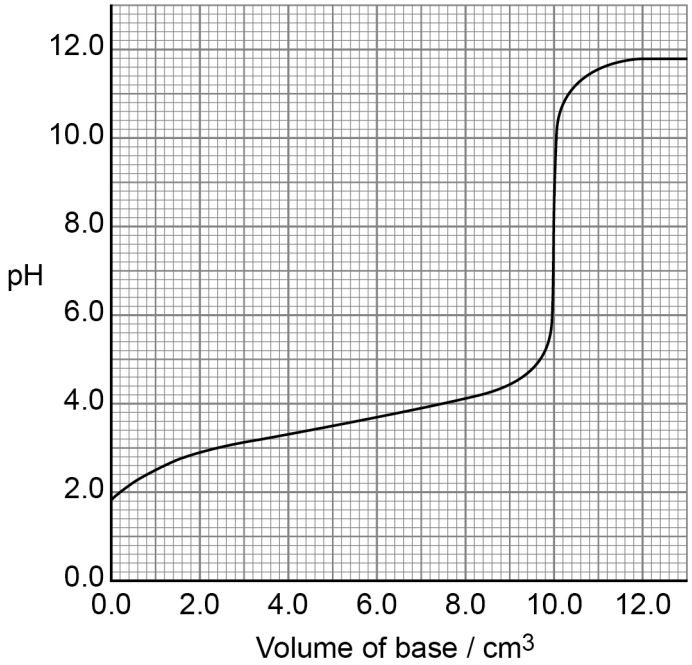

Table 3 shows the pH ranges for some indicators.

Table 3

Indicator	**pH range**
Methyl orange	3.1–4.4
Phenol red	6.8–8.4
Indigo carmine	11.4–13.0

Which indicator should be used in this titration?

Tick (✓) **one** box.

[1 mark]

Methyl orange ☐

Phenol red ☐

Indigo carmine ☐

9

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0 4 The lithium cell is a rechargeable electrochemical cell commonly used in mobile phones.

The cell has an EMF of +3.60 V

The reaction that occurs at the positive electrode when the cell is used as a source of electrical energy is

$$Li^+ + CoO_2 + e^- \rightarrow Li^+[CoO_2]^- \qquad E^\ominus = +0.60\,V$$

0 4 . 1 Give the oxidation state of cobalt in $LiCoO_2$

[1 mark]

_____

0 4 . 2 Write an equation for the reaction at the negative electrode when the cell is being electrically **recharged**.

Calculate the electrode potential for this electrode.

[2 marks]

Equation

_____

Electrode potential _____ V

0 4 . 3 Some lithium cells use graphite as one of the electrodes.

Give **two** reasons why a graphite electrode can be used in a lithium cell.

[2 marks]

Reason 1 _____

_____

Reason 2 _____

_____

5

Turn over ►

Do not write outside the box

0 5 This question is about Period 3 elements and their compounds.

0 5 . 1 Magnesium reacts rapidly with H_2O

State a condition needed for the reaction.

Describe **two** observations you would make during the reaction.

Write an equation for the reaction.

[4 marks]

Condition _____

Observation 1 _____

_____

Observation 2 _____

_____

Equation

_____

0 5 . 2 Describe **two** observations you would make when phosphorus(V) oxide reacts with H_2O

Write an equation for the reaction.

[3 marks]

Observation 1 _____

_____

Observation 2 _____

_____

Equation

_____

0 5 . 3 Write an equation for the reaction between aluminium and chlorine.

[1 mark]

_____

Do not write outside the box

0 5 . 4 Explain, in terms of structure and bonding, why the melting point of sodium chloride is higher than the melting point of silicon(IV) chloride.

[4 marks]

0 5 . 5 Some sodium chloride is added to a test tube of water.

What is the approximate pH of the solution formed?

Tick (✓) **one** box.

[1 mark]

14 ☐

7 ☐

1 ☐

0 5 . 6 Some silicon(IV) chloride is added to a test tube of water.

What is the approximate pH of the solution formed?

Tick (✓) **one** box.

[1 mark]

14 ☐

7 ☐

1 ☐

14

Do not write outside the box

0 6 This question is about copper compounds.

0 6 . 1 Complete the electron configuration of a copper(I) ion.

Suggest why copper(I) chloride is **not** coloured.

[3 marks]

Electron configuration $1s^2$ _____

Why copper(I) chloride is **not** coloured _____

_____

_____

_____

_____

0 6 . 2 Aqueous copper(II) sulfate is blue.
The energy of a transition in the spectrum of copper(II) sulfate is 3.354×10^{-19} J

Calculate the frequency of the light absorbed in this transition.

State the units for your answer.

The Planck constant, $h = 6.626 \times 10^{-34}$ J s

[3 marks]

Frequency _____

Units _____

6

Do not write outside the box

0 7 Chromium forms octahedral complexes.

0 7 . 1 State what is meant by a complex.

[1 mark]

0 7 . 2 The $[Cr(H_2O)_4Cl_2]^+$ complex exists as two stereoisomers.

Draw the structure of each stereoisomer.

[2 marks]

Stereoisomer 1 Stereoisomer 2

0 7 . 3 The $[Cr(H_2O)_6]^{3+}$ complex undergoes a ligand substitution reaction.

Write an equation for the complete substitution of $[Cr(H_2O)_6]^{3+}$ by $H_2NCH_2CH_2NH_2$ to form an octahedral complex.

Explain why this reaction has a positive entropy change.

[3 marks]

Equation

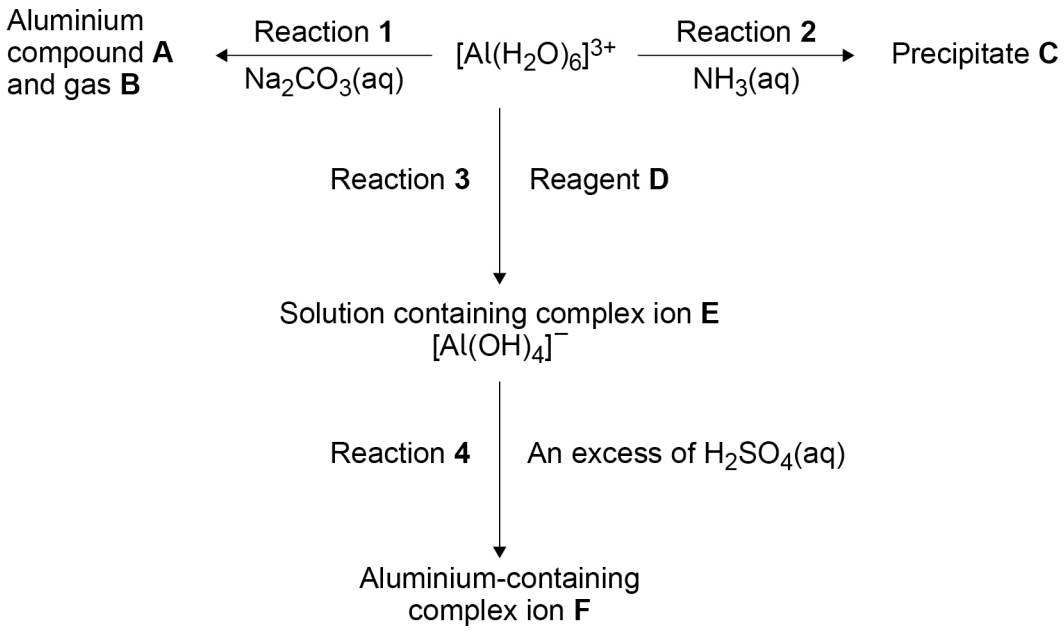
Explanation

6

Do not write outside the box

0 8 **Figure 4** shows some reactions of aqueous aluminium ions.

Figure 4



0 8 . 1 Identify compound **A** and gas **B**.

[1 mark]

Compound **A** _____

Gas **B** _____

0 8 . 2 State the type of reaction that forms precipitate **C**.

[1 mark]

_____

0 8 . 3 Identify reagent **D**.

State a necessary condition to form complex ion **E**.

Write an ionic equation for reaction **3**.

[3 marks]

Reagent **D** _____

Condition _____

Equation

_____

Do not write outside the box

0 8 . 4 Give the formula of complex ion **F**.

Write an ionic equation for reaction **4**.

[2 marks]

Formula _____

Equation

_____

7

Turn over for the next question

Do not write outside the box

0 9 A student does an experiment to determine the concentration of a solution of potassium manganate(VII)

The student reacts the potassium manganate(VII) solution with a standard solution of sodium ethanedioate ($Na_2C_2O_4$)

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

Method

- Dissolve 1.68 g of sodium ethanedioate in water and make the solution up to 250 cm^3 in a volumetric flask.
- Transfer 25.0 cm^3 of this solution to a conical flask and add 25 cm^3 of dilute sulfuric acid.
- Warm the conical flask in a water bath to about 60 °C
- Add potassium manganate(VII) solution from a burette until there is a permanent colour change.

Table 4 shows the student's initial and final burette readings for three titrations.

Table 4

	1	**2**	**3**
Final reading / cm^3	26.25	25.15	34.55
Initial reading / cm^3	0.00	0.30	9.60

0 9 . 1 Calculate the mean titre.

Use the mean titre to calculate the concentration, in mol dm^{-3}, of the potassium manganate(VII) solution.

M_r ($Na_2C_2O_4$) = 134.0

[5 marks]

Mean titre _____ cm^3

Concentration _____ mol dm^{-3}

Do not write outside the box

0 9 . 2 Suggest why the solution in the conical flask is warmed before starting the titration.

[1 mark]

_____

_____

0 9 . 3 Before the first titration, a small air bubble was seen in the space below the tap of the burette.
After the first titration, there was no air bubble in this space.

State the effect of the air bubble on the titre value.

[1 mark]

_____

0 9 . 4 The first titration usually gives an approximate end point.

State why obtaining an approximate end point before starting accurate titrations is good practical technique.

[1 mark]

_____

_____

0 9 . 5 State and explain the colour change in the conical flask at the end point.

[2 marks]

Colour change _____

Explanation _____

_____

_____

0 9 . 6 A second student does the experiment but adds hydrochloric acid instead of sulfuric acid to the conical flask in the titration.
The chloride ions in hydrochloric acid are oxidised by the manganate(VII) ions.

State the effect, if any, of using hydrochloric acid on the titre values.

Explain why using hydrochloric acid would be more hazardous than using sulfuric acid.

[2 marks]

Effect on titre values _____

_____

Explanation _____

_____

12

Turn over ►

Do not write outside the box

1 0 This question is about the reaction of sulfur dioxide with oxygen to form sulfur trioxide.

The catalyst for this reaction is vanadium(V) oxide.

1 0 . 1 Name the type of catalysis shown in this reaction.

Write **two** equations to show how vanadium(V) oxide acts as a catalyst for this reaction.

[3 marks]

Type of catalysis _____

Equation 1

_____

Equation 2

_____

1 0 . 2 State the feature of transition metal compounds that allows vanadium(V) oxide to act as a catalyst for this reaction.

[1 mark]

_____

1 0 . 3 Describe how impurities in the reactants can decrease the effectiveness of the catalyst.

[1 mark]

_____

_____

1 0 . 4 Give one reason, other than cost, why a support medium is often used for the vanadium(V) oxide catalyst in this reaction.

[1 mark]

_____

_____

6

END OF QUESTIONS

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