

Please write clearly in block capitals.

Centre number

--	--	--	--	--

Candidate number

--	--	--	--

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

INTERNATIONAL A-LEVEL CHEMISTRY (9620)

Unit 3: Inorganic 2 and Physical 2

Thursday 11 January 2024 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	
TOTAL	



There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



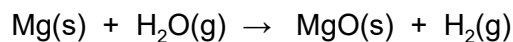
Answer **all** questions in the spaces provided.

0 1

This question is about Period 3 elements and their compounds.

0 1 . 1

Magnesium reacts rapidly with steam in a redox reaction.



Give **two** observations in this reaction.

Explain, by reference to oxidation states, why this is a redox reaction.

[4 marks]

Observation 1 _____

Observation 2 _____

Explanation _____

0 1 . 2

Phosphorus reacts with chlorine to form PCl_5

In the solid state, PCl_5 exists as two ions PCl_4^+ and PCl_6^-

Name the shape of the PCl_4^+ ion.

Give the bond angle in the PCl_4^+ ion.

Draw the structure of PCl_6^- showing clearly the 3D shape of the ion.

[3 marks]

Shape of PCl_4^+ _____

Bond angle in PCl_4^+ _____

Structure of PCl_6^-

Turn over ►



0 1 . 3 Write an equation for the reaction of PCl_5 with water.

[1 mark]

0 1 . 4 A Period 3 element reacts with oxygen to form an acidic oxide.
The oxide contains 53% of oxygen by mass.

Identify the Period 3 element.

Tick (✓) **one** box.

[1 mark]

Silicon

☐

Sulfur

☐

Phosphorus

☐

0 1 . 5 Aluminium oxide is amphoteric.
This means that aluminium oxide reacts with acids and with alkalis.

Write **two** ionic equations to show how aluminium oxide is amphoteric.

[2 marks]

Equation 1

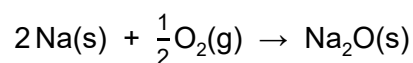
Equation 2



0 2

This question is about thermodynamics.

Sodium reacts with oxygen to form sodium oxide.



0 2 . 1

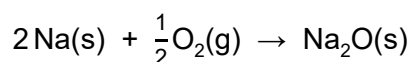
Give **two** observations in this reaction.

[2 marks]

Observation 1 _____

Observation 2 _____

0 2 . 2



The entropy change (ΔS) for this reaction is $-131.7 \text{ J K}^{-1} \text{ mol}^{-1}$

Table 1 shows some standard entropy values.

Table 1

	$S^\ominus / \text{J K}^{-1} \text{ mol}^{-1}$
Na(s)	51.0
Na ₂ O(s)	72.8

Use the data to calculate a value for the standard entropy for O₂(g)

Comment on the difference in the standard entropy values for O₂ and for Na

[4 marks]

Entropy for O₂(g) _____ J K⁻¹ mol⁻¹

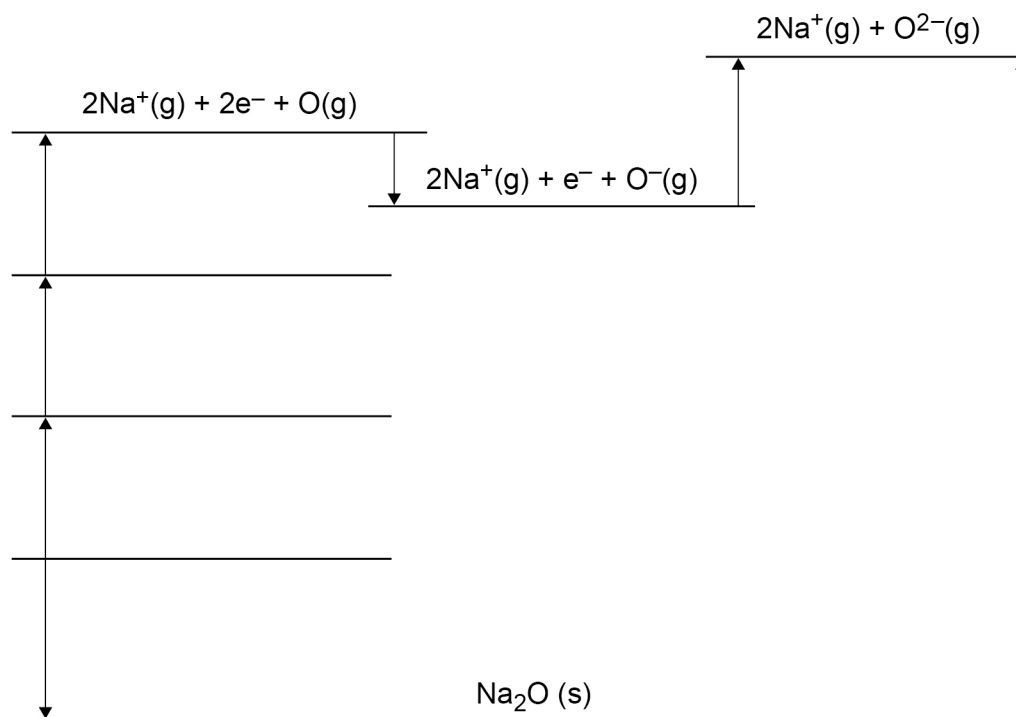
Comment _____

Turn over ►



0 2 . 3 **Figure 1** shows an incomplete Born–Haber cycle for the formation of sodium oxide.

Figure 1



Complete **Figure 1** by writing the formulas, including state symbols, of the appropriate species on each of the three horizontal blank lines.

[3 marks]



0 2 . 4 Table 2 shows some enthalpy change data.

Table 2

	Enthalpy change / kJ mol^{-1}
Enthalpy of formation of $\text{Na}_2\text{O(s)}$	−416
Enthalpy of atomisation of sodium	+109
Enthalpy of atomisation of oxygen	+248
First ionisation energy for Na(g)	+494
First electron affinity of oxygen	−142
Second electron affinity of oxygen	+844

Use **Figure 1** and the data in **Table 2** to calculate a value, in kJ mol^{-1} , for the enthalpy of lattice dissociation of $\text{Na}_2\text{O(s)}$

[2 marks]

Enthalpy of lattice dissociation of $\text{Na}_2\text{O(s)}$ _____ kJ mol^{-1}

Question 2 continues on the next page

Turn over ►



0 2 . 5 Table 3 shows some more enthalpy change data.

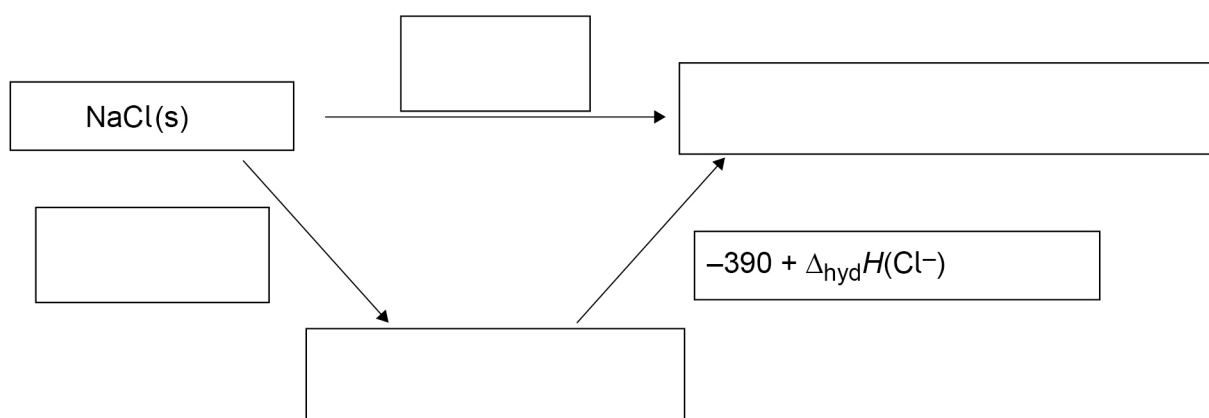
Table 3

	Enthalpy change / kJ mol^{-1}
Enthalpy of lattice dissociation of NaCl(s)	+787
Enthalpy of hydration of $\text{Na}^+(\text{g})$	-390
Enthalpy of hydration of $\text{Cl}^-(\text{g})$	to be calculated
Enthalpy of solution of NaCl(s)	+4

Complete the Hess' Cycle by adding the appropriate species and values.

Use the data in **Table 3** to calculate a value, in kJ mol^{-1} , for the enthalpy of hydration of $\text{Cl}^-(\text{g})$

[2 marks]



Enthalpy of hydration of $\text{Cl}^-(\text{g})$ _____ kJ mol^{-1}

0 2 . 6 Suggest why there is no data book value for the enthalpy of solution of $\text{Na}_2\text{O(s)}$

[1 mark]



Turn over for the next question

*Do not write
outside the
box*

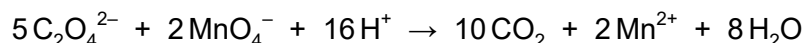
**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**

Turn over ►



0 3

This question is about the reaction of ethanedioate ions ($\text{C}_2\text{O}_4^{2-}$) with manganate(VII) ions (MnO_4^-)



The reaction between $\text{C}_2\text{O}_4^{2-}$ and MnO_4^- is slow at the start because the activation energy is high. The reaction then speeds up when some Mn^{2+} ions are formed.

0 3 . 1

Explain why the reaction has a high activation energy.

[1 mark]

0 3 . 2

Write **two** equations to show how Mn^{2+} ions act as a catalyst for this reaction.

[2 marks]

Equation 1

Equation 2

A student completes an experiment to determine whether a solid is lithium ethanedioate, sodium ethanedioate, or potassium ethanedioate.

Method

1. Dissolve 1.775 g of the solid metal ethanedioate in about 100 cm^3 water.
2. Make the solution up to 250 cm^3 with dilute sulfuric acid in a volumetric flask and mix well.
3. Use a pipette to transfer a 25.0 cm^3 portion of the solution into a conical flask.
4. Warm the flask to about 50°C in a water bath.
5. Add $0.0200\text{ mol dm}^{-3}$ potassium manganate(VII) from a burette until there is a permanent colour change.
6. Repeat until two titres are obtained that are within 0.10 cm^3 of each other.

Table 4, on page 11, shows data from the experiment.



Table 4

	Rough	1	2	3
Final burette reading / cm ³	22.40	22.80	44.55	24.65
Initial burette reading / cm ³	0.00	1.50	22.80	3.25
Titre volume / cm ³	22.40	21.30	21.75	21.40

0 3 . 3 Use appropriate results to determine the mean titre for this experiment.

Use the mean titre to calculate the M_r of the solid metal ethanedioate.

Identify the metal ion in the solid.

[6 marks]

Mean titre _____ cm³

M_r of solid metal ethanedioate _____

Metal ion _____

Turn over ►



0 3 . 4 Describe the colour change at the end point of this titration.

Give a reason for this colour change.

[2 marks]

Colour change _____

Reason _____

11

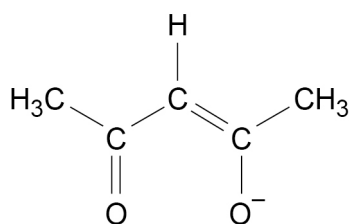
0 4 This question is about bidentate ligands and multidentate ligands.

0 4 . 1 **Figure 2** shows the structure of the **acac** ion ($\text{C}_5\text{H}_7\text{O}_2^-$)
The **acac** ion can act as a bidentate ligand.

Draw **two** lone pairs on the structure to show how the **acac** ion can act as a bidentate ligand.

[1 mark]

Figure 2



acac ion

0 4 . 2 The complex $\text{Co}(\text{C}_5\text{H}_7\text{O}_2)_3$ contains three **acac** ions.

Give the oxidation state of cobalt in this complex.

State the type of isomerism shown by the complex.

[2 marks]

Oxidation state of cobalt _____

Type of isomerism _____



The EDTA^{4-} ion has six lone pairs of electrons that are donated when it forms a complex.

Explain, in terms of thermodynamics, why the complex formed is more stable than $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$

Equation

Explanation

9

0 5

This question is about the reactions of three aqueous solutions (**P**, **Q** and **R**).
The aqueous solutions each contain a different transition metal ion: Fe^{3+} , Fe^{2+} or Cu^{2+}

A student adds three different reagents to the three solutions.

Table 5 shows some observations from the experiments.

Table 5

	Test 1 Add $\text{NH}_3(\text{aq})$ drop by drop until in excess	Test 2 Add $\text{Na}_2\text{CO}_3(\text{aq})$	Test 3 Add concentrated $\text{HCl}(\text{aq})$
P	Blue precipitate formed Blue precipitate reacts to give deep blue solution with excess	Blue–green precipitate formed	Solution turns from blue to yellow–green
Q	Green precipitate formed No further change with excess	Green precipitate formed	
R	Brown precipitate formed No further change with excess	Brown precipitate formed Effervescence	

0 5

1

Write an equation for the reaction in **Test 1** for the formation of the deep blue solution.

[1 mark]



0 5 . 2

The wavelength of the light absorbed by the deep blue solution formed in **Test 1** is 650 nm

Calculate the energy gap (ΔE), in J, between the ground state and the excited state of the d electrons.

You should assume that all the light absorbed is because of the movement of electrons between d orbitals.

The Planck constant, $h = 6.63 \times 10^{-34} \text{ J s}$

The speed of light, $c = 3.00 \times 10^8 \text{ m s}^{-1}$

[2 marks]

ΔE _____ J

0 5 . 3

State the type of reaction that occurs when solution **P** reacts with concentrated HCl

Write an equation for this reaction.

[2 marks]

Type of reaction _____

Equation

0 5 . 4

Identify a reagent, or combination of reagents, used in a test-tube reaction to show that solution **P** also contains sulfate(VI) ions.

Describe the expected observation(s).

[2 marks]

Reagent(s) _____

Observation(s) _____

Turn over ►



Table 5 is repeated here.

Table 5

	Test 1 Add $\text{NH}_3(\text{aq})$ drop by drop until in excess	Test 2 Add $\text{Na}_2\text{CO}_3(\text{aq})$	Test 3 Add concentrated $\text{HCl}(\text{aq})$
P	Blue precipitate formed Blue precipitate reacts to give deep blue solution with excess	Blue–green precipitate formed	Solution turns from blue to yellow–green
Q	Green precipitate formed No further change with excess	Green precipitate formed	
R	Brown precipitate formed No further change with excess	Brown precipitate formed Effervescence	

0 5 . 5

Solution **Q** forms a green precipitate when it reacts in **Test 1**, and a green precipitate when it reacts in **Test 2**.

Give the formula for each green precipitate.

[2 marks]

Formula of green precipitate formed in **Test 1** _____

Formula of green precipitate formed in **Test 2** _____

0 5 . 6

Write an equation for the reaction that occurs when solution **R** reacts in **Test 2**.

[1 mark]



Turn over for the next question

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**

Turn over ►

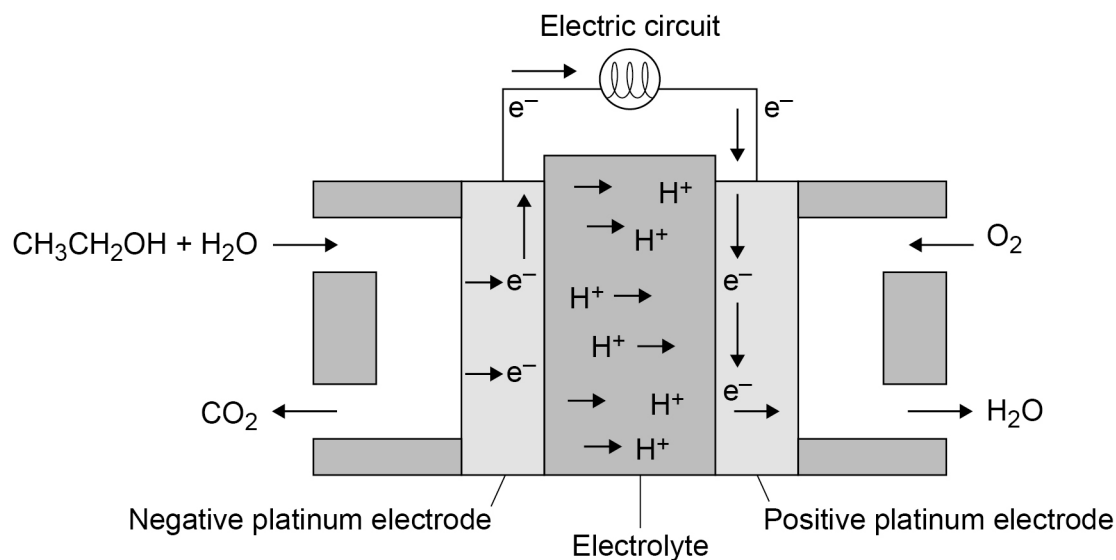


0 6

This question is about fuel cells.

Figure 3 shows an ethanol fuel cell.

Figure 3



When the cell is in use:

- At the positive electrode, oxygen reacts with hydrogen ions to form water.
- At the negative electrode, ethanol reacts with water to form carbon dioxide and hydrogen ions.

0 6 . 1

Deduce the half-equation for the reaction at the positive electrode.

Deduce the half-equation for the reaction at the negative electrode.

Write the equation for the overall reaction that occurs in the ethanol fuel cell.

[3 marks]

Positive electrode

Negative electrode

Overall cell reaction



0 6 . 2 The EMF of the ethanol fuel cell is 1.14 V

The electrode potential for the positive electrode is 1.23 V

Calculate the electrode potential for the negative electrode.

[1 mark]

Electrode potential _____ V

0 6 . 3 State what must be done to maintain a constant EMF during the use of this fuel cell.

[1 mark]

Ethanol fuel cells are being developed as a possible alternative to the alkaline hydrogen–oxygen fuel cell to power vehicles.

In the alkaline hydrogen–oxygen fuel cell, the reactions that occur at each platinum electrode are

Positive platinum electrode $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$

Negative platinum electrode $2\text{H}_2 + 4\text{OH}^- \rightarrow 4\text{H}_2\text{O} + 4\text{e}^-$

0 6 . 4 Give the conventional cell representation for the alkaline hydrogen–oxygen fuel cell.

[2 marks]

0 6 . 5 State **one** disadvantage of the alkaline hydrogen–oxygen fuel cell compared with the ethanol fuel cell.

[1 mark]



07

This question is about acids and bases.

07.1

Define pH

[1 mark]**07.2**

Some concentrated hydrochloric acid contains 38.0 g of HCl in 100 g of acid.
The concentrated acid solution has a density of 1.19 g cm^{-3}

Calculate the concentration, in mol dm^{-3} , of the solution.
Give your answer to three significant figures.

[2 marks]Concentration _____ mol dm^{-3} **07.3**

A teacher needs to make 4.00 dm^3 of a dilute solution of hydrochloric acid with a pH of 0.80 using the concentrated solution.

Use your answer to Question **07.2** to calculate the volume, in cm^3 , of concentrated HCl that is needed to prepare this dilute aqueous solution.

(If you were unable to answer Question **07.2**, you should assume that the concentration of the concentrated HCl is 7.25 mol dm^{-3}
This is **not** the correct answer.)

[3 marks]Volume _____ cm^3 

07.4

1.50 g of barium hydroxide ($M_r = 171.3$) is dissolved in water to give 100 cm³ of aqueous barium hydroxide.

Calculate the pH of this solution at 298 K
Give your answer to two decimal places.

At 298 K the ionic product of water, $K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$

[4 marks]

pH _____

07.5

1.50 g of calcium hydroxide is added to water to give 100 cm³ of aqueous calcium hydroxide.

Explain why the pH of this solution is lower than the pH of the barium hydroxide solution prepared in Question **07.4**.

[1 mark]

Question 7 continues on the next page

Turn over ►

A weak acid, HA, has an acid dissociation constant (K_a) of $1.86 \times 10^{-5} \text{ mol dm}^{-3}$ at 298 K

0 7 . 6

Calculate the pK_a for this weak acid at 298 K

Give your answer to two decimal places.

[1 mark]

pK_a _____

0 7 . 7

10.0 cm³ of 0.350 mol dm⁻³ aqueous sodium hydroxide are added to 25.0 cm³ of a 0.250 mol dm⁻³ aqueous solution of HA

Calculate the pH of the solution formed.
Give your answer to two decimal places.

[5 marks]

pH _____

17

END OF QUESTIONS



There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



[illegible]

*Do not write
outside the
box*

[illegible]

*Do not write
outside the
box*

[illegible]

*Do not write
outside the
box*

[illegible]

There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**

Copyright information

For confidentiality purposes, all acknowledgements of third-party copyright material are published in a separate booklet. This booklet is published after each live examination series and is available for free download from www.oxfordaqa.com

Permission to reproduce all copyright material has been applied for. In some cases, efforts to contact copyright-holders may have been unsuccessful and OxfordAQA will be happy to rectify any omissions of acknowledgements. If you have any queries please contact the Copyright Team.

Copyright © 2024 OxfordAQA International Examinations and its licensors. All rights reserved.

