OXFORD AQA

INTERNATIONAL QUALIFICATIONS

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	
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6	
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TOTAL	

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ANSWER IN THE SPACES PROVIDED

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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.

$$Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$$

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^-

Do not write outside the box

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

11

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0 2 This question is about thermodynamics.

Sodium reacts with oxygen to form sodium oxide.

$$2\,Na(s) + \frac{1}{2}O_2(g) \rightarrow Na_2O(s)$$

0 2 . 1 Give **two** observations in this reaction.

[2 marks]

Observation 1 _____

Observation 2 _____

0 2 . 2

$$2\,Na(s) + \frac{1}{2}O_2(g) \rightarrow Na_2O(s)$$

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

Table 1 shows some standard entropy values.

Table 1

	$S^{\ominus}$ / J K^{-1} mol^{-1}
Na(s)	51.0
$Na_2O(s)$	72.8

Use the data to calculate a value for the standard entropy for $O_2(g)$

Comment on the difference in the standard entropy values for O_2 and for Na

[4 marks]

Entropy for $O_2(g)$ _____ J K^{-1} mol^{-1}

Comment _____

_____

_____

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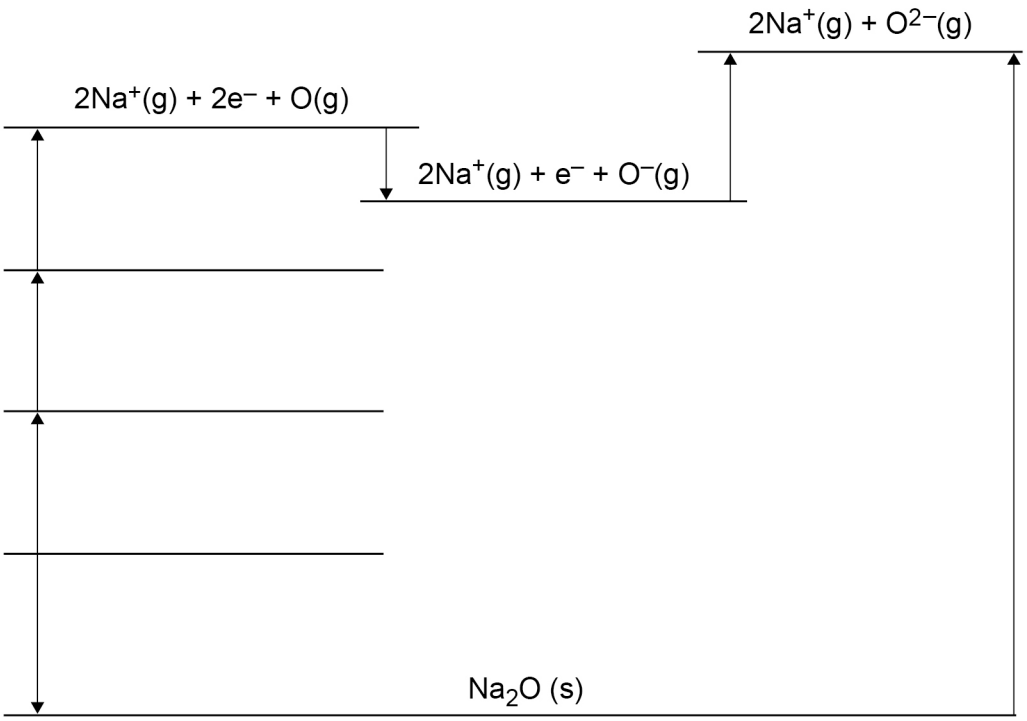
0 2 . 3 **Figure 1** shows an incomplete Born–Haber cycle for the formation of sodium oxide.

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]

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

Table 2

	Enthalpy change / kJ mol^{-1}
Enthalpy of formation of $Na_2O(s)$	–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 $Na_2O(s)$

[2 marks]

Enthalpy of lattice dissociation of $Na_2O(s)$ _____ kJ mol^{-1}

Question 2 continues on the next page

Turn over ►

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

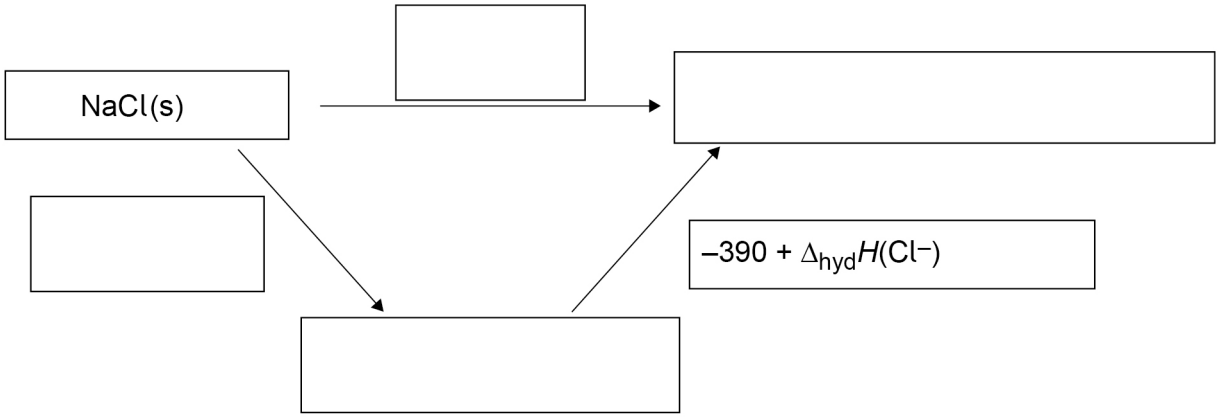
Table 3

	Enthalpy change / kJ mol^{-1}
Enthalpy of lattice dissociation of NaCl(s)	+787
Enthalpy of hydration of $Na^+(g)$	–390
Enthalpy of hydration of $Cl^-(g)$	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 $Cl^-(g)$

[2 marks]



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

0 2 . 6 Suggest why there is no data book value for the enthalpy of solution of $Na_2O(s)$

[1 mark]

_____

_____

14

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0 3 This question is about the reaction of ethanedioate ions ($C_2O_4^{2-}$) with manganate(VII) ions (MnO_4^-)

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

The reaction between $C_2O_4^{2-}$ 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 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.

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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 _____ cm^3

M_r of solid metal ethanedioate _____

Metal ion _____

Turn over ►

Do not write outside the box

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

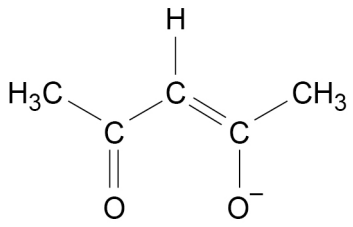
0 4 This question is about bidentate ligands and multidentate ligands.

0 4 . 1 **Figure 2** shows the structure of the **acac** ion ($C_5H_7O_2^-$)
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 $Co(C_5H_7O_2)_3$ 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 _____

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0 4 . 3 $EDTA^{4-}$ is a multidentate ligand.

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

Write an equation for the reaction that occurs when an excess of $EDTA^{4-}$ ions is added to a solution containing $[Fe(H_2O)_6]^{2+}$

Explain, in terms of thermodynamics, why the complex formed is more stable than $[Fe(H_2O)_6]^{2+}$

[6 marks]

Equation

Explanation

9

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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 $NH_3(aq)$ drop by drop until in excess	**Test 2** Add $Na_2CO_3(aq)$	**Test 3** Add concentrated HCl(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]

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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, $h = 6.63 \times 10^{-34}$ J s
The speed of light, $c = 3.00 \times 10^{8}$ 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 ►

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Table 5 is repeated here.

Table 5

	Test 1 Add $NH_3(aq)$ drop by drop until in excess	**Test 2** Add $Na_2CO_3(aq)$	**Test 3** Add concentrated HCl(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]

_____

10

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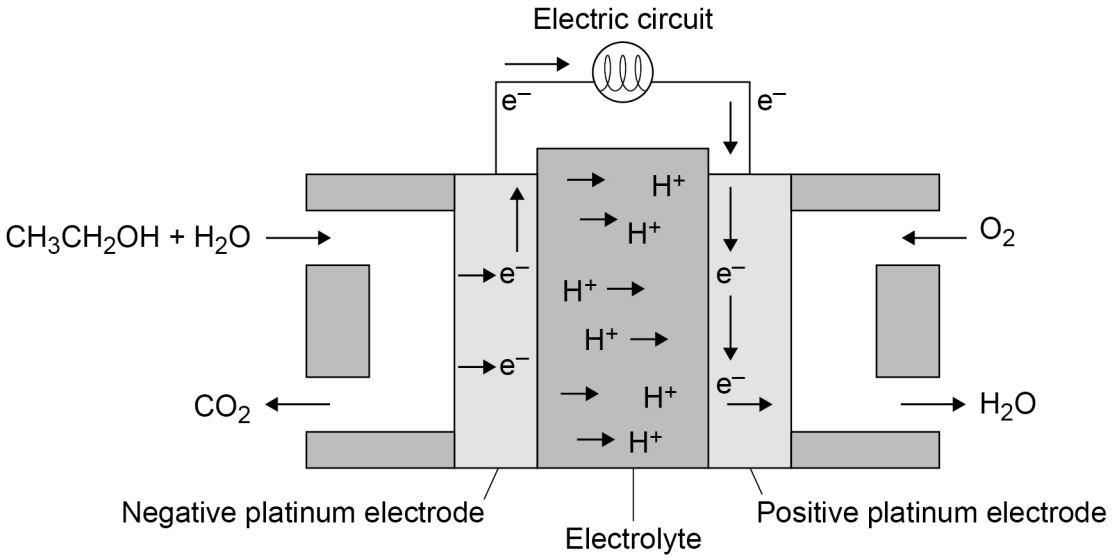
0 6 This question is about fuel cells.

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

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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 $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

Negative platinum electrode $2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$

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]

8

Turn over ►

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0 7 This question is about acids and bases.

0 7 . 1 Define pH

[1 mark]

_____

0 7 . 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}

0 7 . 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

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0 7 . 4 1.50 g of barium hydroxide (M_r = 171.3) is dissolved in water to give 100 cm^3 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, $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}

[4 marks]

pH _____

0 7 . 5 1.50 g of calcium hydroxide is added to water to give 100 cm^3 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

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A weak acid, HA, has an acid dissociation constant (K_a) of 1.86×10^{-5} 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 cm^3 of 0.350 mol dm^{-3} aqueous sodium hydroxide are added to 25.0 cm^3 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 _____

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END OF QUESTIONS

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