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

Tuesday 19 January 2021 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 Period 3 elements and their compounds.

0 1 . 1 State **two** observations that you would make when magnesium is burned in oxygen.

Write an equation for the reaction.

[3 marks]

Observation 1 _____

Observation 2 _____

Equation

_____

0 1 . 2 A strip of magnesium is added to some cold water. At first, there is no visible change but magnesium does react very slowly with cold water.

Write an equation for the reaction.

Explain how an indicator can be used to show that a reaction is occurring.

[3 marks]

Equation

_____

Explanation

_____

_____

0 1 . 3 Write an equation for the reaction of aluminium oxide with aqueous potassium hydroxide.

[1 mark]

_____

Do not write outside the box

0 1 . 4 Draw the structure of the acid formed when phosphorus(V) oxide reacts with water.

[1 mark]

0 1 . 5 A 0.589 g sample of solid sodium oxide is reacted with water to form 50.0 cm^3 of sodium hydroxide solution.

$$Na_2O(s) + H_2O(l) \rightarrow 2\ NaOH(aq)$$

Calculate the pH, at 25 °C, of this solution.
Give your answer to 2 decimal places.

At 25 °C, the ionic product of water, $K_w = 1.00 \times 10^{-14}\ mol^2\ dm^{-6}$

[5 marks]

pH_____

13

Do not write outside the box

0 2 This question is about copper complexes.

0 2 . 1 Copper forms a complex ion $[Cu(H_2O)_6]^{2+}$

State what is meant by the term complex ion.

[1 mark]

_____

_____

0 2 . 2 A solution containing a copper(II) complex absorbs light with a wavelength of 593 nm

Calculate the energy difference (ΔE), in J, between the ground state and the excited state of d-electrons in this complex.

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

Planck's constant, $h = 6.626 \times 10^{-34}$ J s
Speed of light, $c = 2.998 \times 10^{8}$ m s^{-1}

[3 marks]

ΔE _____ J

Do not write outside the box

0 2 . 3 When an excess of aqueous ammonia is added to a solution containing aqueous copper(II) ions, a different copper complex is formed.

Name this type of reaction.

Write an equation for this reaction.

[2 marks]

Type of reaction _____

Equation

_____

0 2 . 4 Copper forms a complex with the formula $[Cu(NH_2CH_2CH_2NH_2)_2(H_2O)_2]^{2+}$

Draw the structure of the *trans* isomer of this complex.

[2 marks]

8

Turn over for the next question

Do not write outside the box

0 3 This question is about some reactions of iron salts.

A student investigates the reactions of an aqueous solution of an iron(II) salt.
Table 1 shows the observations from some test-tube reactions.

Table 1

		Observations
Test 1	Add acidified $BaCl_2$(aq)	White precipitate formed
Test 2	Add NaOH(aq) until in excess	Green precipitate formed that turns brown on standing in air
Test 3	Add Na_2CO_3(aq)	Green precipitate formed

0 3 . 1 Use the observation in **Test 1** to identify the anion in the iron(II) salt.

[1 mark]

_____

0 3 . 2 Give the formula of the green precipitate formed in **Test 2**.

State the type of reaction that occurs when the green precipitate turns brown in **Test 2**.

[2 marks]

Formula _____

Type of reaction _____

0 3 . 3 Write an ionic equation for the reaction occurring in **Test 3**.

[1 mark]

_____

Do not write outside the box

0 3 . 4 The student repeats **Test 2** and **Test 3** using aqueous iron(III) chloride.

Complete **Table 2** to describe what is observed in **Test 2** and **Test 3** with iron(III) chloride.

[3 marks]

Table 2

		Observations with iron(III) chloride
Test 2	Add NaOH(aq) until in excess	
Test 3	Add Na_2CO_3(aq)	

0 3 . 5 In a separate test-tube reaction, the student adds an excess of concentrated hydrochloric acid to the iron(III) chloride solution.

What is the shape of the complex ion formed in this reaction?

Tick (✓) **one** box

[1 mark]

Octahedral ☐

Square Planar ☐

Tetrahedral ☐

Question 3 continues on the next page

Do not write outside the box

0 3 . 6 The reaction between I^- ions and $S_2O_8^{2-}$ ions is slow but is much faster when iron(II) ions are added as a catalyst.

Explain why the reaction between I^- ions and $S_2O_8^{2-}$ ions is slow.

Explain how iron(II) ions catalyse the reaction.
Use suitable equations in your answer.

[5 marks]

Why reaction is slow _____

_____

_____

_____

_____

How iron(II) ions catalyse reaction

_____

_____

_____

13

Do not write outside the box

0 4 Water dissociates as shown

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The ionic product of water (K_w) is given by the expression

$$K_w = [H^+]\,[OH^-]$$

0 4 . 1 State why the concentration of water is **not** shown in the expression for K_w

[1 mark]

_____

_____

0 4 . 2 The dissociation of water is an endothermic process.

Explain why the value for K_w increases as the temperature increases.

[2 marks]

_____

_____

_____

_____

0 4 . 3 At 45 °C, $K_w = 4.02 \times 10^{-14}\ mol^2\ dm^{-6}$

Calculate the pH of water at 45 °C

Give your answer to 2 decimal places.

[2 marks]

pH_____

5

Turn over ►

Do not write outside the box

0 5 This question is about weak acids.

0 5 . 1 A 0.150 mol dm^{-3} aqueous solution of propanoic acid (CH_3CH_2COOH) has a pH of 2.85 at 25 °C

Calculate a value, in mol dm^{-3}, for the acid dissociation constant (K_a) of propanoic acid at 25 °C

[3 marks]

K_a _____ mol dm^{-3}

0 5 . 2 A buffer solution is prepared by mixing
25.0 cm^3 of 0.120 mol dm^{-3} aqueous sodium butanoate with
35.0 cm^3 of 0.150 mol dm^{-3} aqueous butanoic acid at 25 °C

Calculate the pH of the buffer solution formed.
Give your answer to 2 decimal places.

For butanoic acid, the acid dissociation constant, $K_a = 1.51 \times 10^{-5}$ mol dm^{-3} at 25 °C

[5 marks]

pH _____

Do not write outside the box

0 5 . 3 Explain why the pH of the buffer solution formed in Question **05.2** remains approximately constant when a small amount of sodium hydroxide solution is added.

[2 marks]

_____

_____

_____

_____

10

Turn over for the next question

Do not write outside the box

0 6 This question is about two chlorides of potassium, KCl_2 and KCl

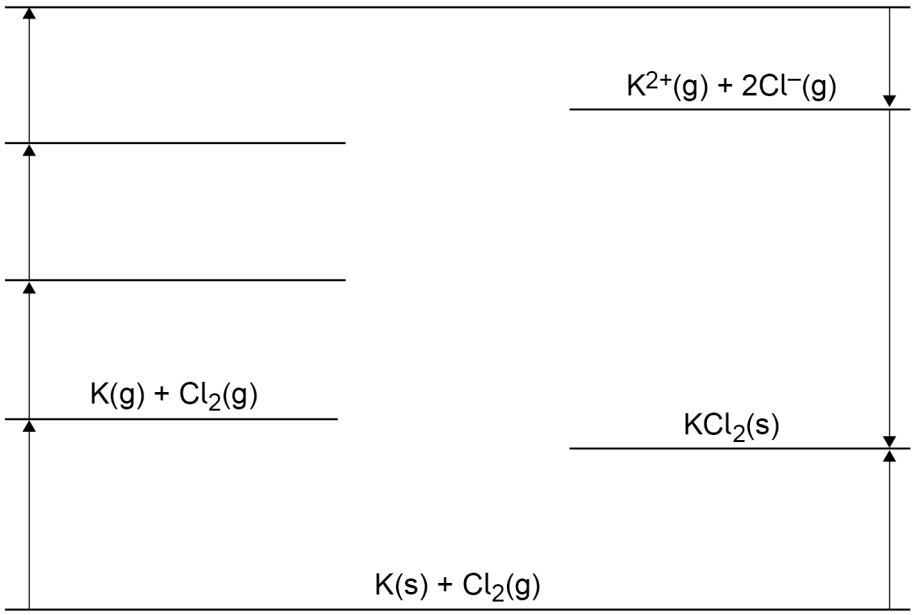
KCl_2 is a theoretical compound that has never been isolated.

KCl_2 contains the K^{2+} ion.

Born-Haber cycles can be used to determine the enthalpy of formation of a theoretical compound.

Figure 1 shows an incomplete Born-Haber cycle for the formation of KCl_2 including the formation of the K^{2+} ion. (The diagram is not drawn to scale.)

Figure 1



0 6 . 1 Complete the Born-Haber cycle for the formation of KCl_2

Write the correct species, including state symbols, on the three blank lines.

[3 marks]

Do not write outside the box

0 6 . 2 Use the values in **Table 3** to calculate a value for the enthalpy of formation of KCl_2

[2 marks]

Table 3

	$\Delta H^{\ominus}$ / kJ mol^{-1}
$K(s) \rightarrow K(g)$	+90
$K(g) \rightarrow K^{+}(g) + e^{-}$	+418
$K^{+}(g) \rightarrow K^{2+}(g) + e^{-}$	+3070
$Cl_2(g) \rightarrow 2Cl(g)$	+242
$Cl(g) + e^{-} \rightarrow Cl^{-}(g)$	–364
$K^{2+}(g) + 2Cl^{-}(g) \rightarrow KCl_2(s)$	–2350

Enthalpy of formation_____ kJ mol^{-1}

Question 6 continues on the next page

Do not write outside the box

0 6 . 3 The other chloride, KCl, is very soluble in water.

Use the values in **Table 4** to calculate a value for the enthalpy of solution of KCl

[2 marks]

Table 4

	$\Delta H^{\ominus}$ / kJ mol^{-1}
$K^+(g) + Cl^-(g) \rightarrow KCl(s)$	–701
$K^+(g) \rightarrow K^+(aq)$	–322
$Cl^-(g) \rightarrow Cl^-(aq)$	–364

Enthalpy of solution_____ kJ mol^{-1}

0 6 . 4 How does the value of the hydration enthalpy of K^{2+} compare with the value of the hydration enthalpy of K^+ ?

Tick (✓) **one** box.

[1 mark]

More exothermic than K^+ ☐

The same as K^+ ☐

Less exothermic than K^+ ☐

8

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0 7 Chromium(III) oxide can be reduced to chromium using carbon monoxide.

$$Cr_2O_3(s) + 3CO(g) \rightarrow 2Cr(s) + 3CO_2(g)$$

0 7 . 1 **Table 5** shows some thermodynamic data.

Use the values in **Table 5** to calculate the free energy change ($\Delta G^{\ominus}$) for this reaction at 25 °C
Show your working.

[6 marks]

Table 5

	$Cr_2O_3(s)$	$CO(g)$	$Cr(s)$	$CO_2(g)$
$\Delta_f H^{\ominus}$ / kJ mol^{-1}	–1128	–111	0	–394
$S^{\ominus}$ / J K^{-1} mol^{-1}	81.2	198	23.8	214

$\Delta G^{\ominus}$ _____ kJ mol^{-1}

0 7 . 2 Explain the significance of your answer to Question **07.1**
(If you were unable to answer Question **07.1**, you should use the value for $\Delta G^{\ominus}$ of +150 kJ mol^{-1} This is **not** the correct answer.)

[1 mark]

_____

_____

7

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0 8 This question is about a metal ethanedioate salt, $\mathbf{M}_2C_2O_4$, where **M** is an unknown metal.

$\mathbf{M}_2C_2O_4$ is analysed by titration with a standard solution of potassium manganate(VII) in acidic conditions. The metal ion does not react with manganate(VII) ions.

2.07 g of $\mathbf{M}_2C_2O_4$ are dissolved in distilled water. The solution is made up to 250 cm^3

25.0 cm^3 samples of this solution are titrated with acidified potassium manganate(VII) solution.

26.50 cm^3 of 0.0188 mol dm^{-3} acidified potassium manganate(VII) solution are required for a complete reaction.

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

Calculate the relative atomic mass of the unknown metal, **M**.

Identify **M**.

[6 marks]

Relative atomic mass _____

Metal **M** _____

6

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Turn over for the next question

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0 9 **Table 6** shows some electrode potential data.

Table 6

Electrode half-equation	$E^{\ominus}$/V
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	0.77
$Br_2(g) + 2e^- \rightarrow 2Br^-(aq)$	1.07
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	1.33
$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$	1.36
$F_2(g) + 2e^- \rightarrow 2F^-(aq)$	2.87

0 9 . 1 A platinum electrode is needed when measuring the standard electrode potential for the half-equation

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$

Give **two** reasons why platinum is used.

[2 marks]

1 _____

_____

2 _____

_____

0 9 . 2 Identify the strongest reducing agent in **Table 6**.

[1 mark]

_____

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0 9 . 3 An electrochemical cell uses two platinum electrodes.

One platinum electrode is placed in an aqueous solution containing Fe^{3+} and Fe^{2+} ions and the other in an aqueous solution containing $Cr_2O_7^{2-}$, H^+ and Cr^{3+} ions.

Give the conventional representation of this cell.

Use data from **Table 6** to calculate the cell EMF.

[3 marks]

Conventional representation

Calculation

EMF_____ V

6

Turn over for the next question

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1 0 Methanol has been proposed as the fuel in a fuel cell instead of hydrogen.

1 0 . 1 The overall cell reaction in the methanol fuel cell is shown.

$$CH_3OH(l) + 1\frac{1}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

In this fuel cell, in acidic conditions:
- the methanol is oxidised to form carbon dioxide
- the oxygen is reduced to form water.

Deduce the oxidation half-equation and the reduction half-equation for this cell when operating in acidic conditions.

[2 marks]

Oxidation half-equation

_____

Reduction half-equation

_____

1 0 . 2 Suggest **one** advantage of using methanol and **one** advantage of using hydrogen in a fuel cell.

[2 marks]

Advantage of methanol _____

_____

Advantage of hydrogen _____

_____

4

END OF QUESTIONS

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