OXFORD

INTERNATIONAL AQA EXAMINATIONS

Please write clearly in block capitals.

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

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Candidate signature _____

INTERNATIONAL A-LEVEL

CHEMISTRY (9620)

Unit 3: Inorganic 2 and Physical 2

Friday 18 January 2019 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	
TOTAL	

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

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0 1 This question is about compounds of the elements in Period 3.

0 1 . 1 Phosphorus burns in air to form phosphorus(V) oxide.

Write an equation for this reaction.

[1 mark]

0 1 . 2 Sulfur forms two oxides, SO_2 and SO_3
Both oxides react with water to form acidic solutions.

State the formula of each acid formed and the approximate pH of a 0.1 mol dm^{-3} solution of each acid.

[2 marks]

Formula of acid formed by SO_2 _____

pH _____

Formula of acid formed by SO_3 _____

pH _____

0 1 . 3 Aluminium oxide can act as an acid and can act as a base.

Write an equation to show aluminium oxide acting as an acid.

[1 mark]

Do not write outside the box

0 1 . 4 Silicon reacts with oxygen to form SiO_2 and with chlorine to form $SiCl_4$

Table 1 shows the melting points of SiO_2 and $SiCl_4$

Table 1

Compound	Melting point / °C
SiO_2	1710
$SiCl_4$	–69

Explain, in terms of structure and bonding, why SiO_2 has a very high melting point but $SiCl_4$ has a very low melting point.

[4 marks]

SiO_2

$SiCl_4$

8

Turn over for the next question

Do not write outside the box

0 2 This question is about Fe^{2+} and Fe^{3+} ions.

0 2 . 1 The reaction between I^- ions and $S_2O_8^{2-}$ ions has a high activation energy and is slow unless a catalyst is used.

$$2I^-(aq) + S_2O_8^{2-}(aq) \rightarrow I_2(aq) + 2SO_4^{2-}(aq)$$

Fe^{2+} ions catalyse the reaction between I^- ions and $S_2O_8^{2-}$ ions.

Write **two** equations to show how Fe^{2+} ions catalyse this reaction.

[2 marks]

Equation 1

Equation 2

0 2 . 2 Describe how Fe(II) enables oxygen to be transported in the blood.

[2 marks]

0 2 . 3 State why carbon monoxide is toxic.

[1 mark]

Do not write outside the box

0 2 . 4 Iron also forms the Fe^{3+} ion.
A student adds sodium carbonate solution to a solution containing $[Fe(H_2O)_6]^{3+}$
Effervescence is observed.

State **one** other observation the student would make.
Write an equation for the reaction between $[Fe(H_2O)_6]^{3+}$ and carbonate ions.

[2 marks]

Observation _____

Equation

_____

0 2 . 5 Explain why $[Fe(H_2O)_6]^{3+}$ ions are more acidic than $[Fe(H_2O)_6]^{2+}$ ions.

[2 marks]

_____

_____

_____

_____

_____

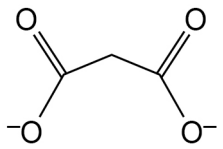
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9

Turn over for the next question

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0 3 A propanedioate ion can act as a bidentate ligand.
The skeletal formula of a propanedioate ion is shown.

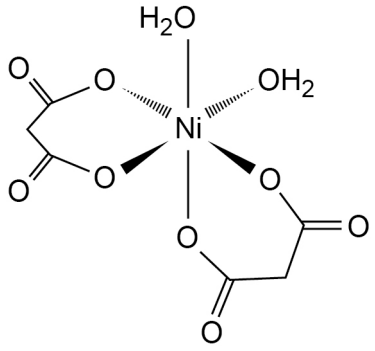


0 3 . 1 Give the meaning of the term bidentate ligand.

[1 mark]

0 3 . 2 Ni^{2+} ions form a complex ion **Z** that contains two propanedioate ligands and two water ligands.

Z exists as three stereoisomers. One of these stereoisomers is shown. The charge has not been shown.

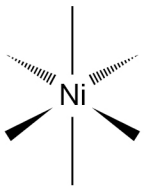


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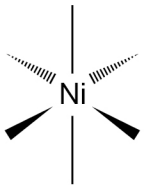
Complete the diagrams of the other two stereoisomers of **Z**.
You do **not** need to include any charges on your diagrams.

For each stereoisomer, place one or more ticks in the boxes to identify the type or types of isomer shown.

[4 marks]



cis	
trans	
optical	



cis	
trans	
optical	

5

Turn over for the next question

Do not write outside the box

0 4 A student investigates the solubility of hydrated iron(II) ethanedioate ($FeC_2O_4.2H_2O$) in water.

The student uses the following method.

Step 1 Add hydrated iron(II) ethanedioate to approximately 500 cm^3 of water at 25 °C

Step 2 Stir until no more solid dissolves and a saturated solution is formed.

Step 3 Remove a 25.0 cm^3 portion of the saturated solution. Add 25.0 cm^3 of dilute sulfuric acid and heat to about 60 °C

Step 4 Titrate the hot solution with acidified potassium manganate(VII) solution.

0 4 . 1 The Fe^{2+} and $C_2O_4^{2-}$ ions react with MnO_4^- ions in acidic solution as shown.

$$5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$$

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

Complete the overall equation for the reaction between FeC_2O_4 and MnO_4^- ions in acidic solution.

[1 mark]

$5FeC_2O_4 + 3MnO_4^- +$ _____ $H^+ \rightarrow$ _____ $CO_2 +$ _____ $Mn^{2+} +$ _____ $H_2O +$ _____ Fe^{3+}

0 4 . 2 Suggest why the solution is heated in **Step 3**.

[1 mark]

_____

_____

0 4 . 3 During **Step 3** some evaporation of the solution occurs.

State and explain the effect, if any, this has on the volume of potassium manganate(VII) solution needed in **Step 4**.

[2 marks]

Effect on volume of potassium manganate(VII) _____

Explanation _____

_____

_____

_____

_____

Do not write outside the box

0 4 . 4 Explain why no indicator is needed for this titration.
State the colour at the end point.

[2 marks]

Explanation _____

_____

Colour at end point _____

0 4 . 5 In **Step 4**, the concentration of potassium manganate(VII) is 6.40×10^{-3} mol dm^{-3}
The mean titre is 12.45 cm^3

Calculate the solubility, in g dm^{-3}, of hydrated iron(II) ethanedioate at 25 °C

[5 marks]

Solubility _____ g dm^{-3}

Question 4 continues on the next page

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0 4 . 6 Iron(II) ethanedioate solution is yellow.
Outline a method, using a colorimeter, to determine the concentration of a solution of iron(II) ethanedioate.

[2 marks]

13

Turn over for the next question

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0 5 Methanol can be made by reacting carbon monoxide with hydrogen.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

0 5 . 1 Write an expression for K_p for the manufacture of methanol from carbon monoxide and hydrogen.

[1 mark]

K_p

0 5 . 2 What are the units of K_p for this equilibrium?

Tick (✓) **one** box.

[1 mark]

kPa^2 ☐

kPa^{-2} ☐

$mol^2\ dm^{-6}$ ☐

$mol^{-2}\ dm^6$ ☐

0 5 . 3 Explain why the value of K_p for this reaction decreases when the temperature is increased.

[2 marks]

Do not write outside the box

A mixture of 10.0 mol of each of CO, H_2 and CH_3OH is placed in a flask of volume 2.50 dm^3 and left to reach equilibrium at a given temperature.

At equilibrium, the flask contains 6.0 mol of CO

The total pressure in the flask is 5000 kPa

0 5 . 4 Calculate the amount, in mol, of H_2 and of CH_3OH in the flask at equilibrium.

[2 marks]

Amount of H_2 _____ mol

Amount of CH_3OH _____ mol

0 5 . 5 Calculate the value of K_p under these conditions. You do **not** need to give units for your answer in this part of the question.

(If you were unable to answer question **05.4** you should use 8.0 mol as the amount of H_2 and 8.0 mol as the amount of CH_3OH. These are **not** the correct values.)

[3 marks]

K_p _____

9

Turn over for the next question

Do not write outside the box

0 6 **Table 2** shows the standard electrode potentials ($E^{\ominus}$) for two half-cells.

Table 2

Half-equation	$E^{\ominus}$ / V
$Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$	–0.41
$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$	–0.28

0 6 . 1 A standard electrode potential is measured by comparison with a standard hydrogen electrode.

State the temperature and pressure used in a standard hydrogen electrode.

[1 mark]

Temperature _____

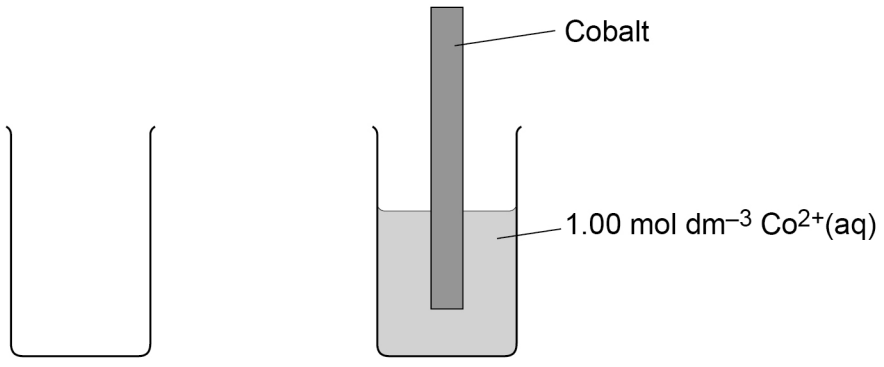
Pressure _____

An electrochemical cell is set up using the two half-cells from **Table 2**.
The EMF of the cell is measured.

0 6 . 2 Complete and label the diagram in **Figure 1** to show the electrochemical cell formed from these two half-cells.
Include in your diagram the piece of apparatus needed to measure the EMF of the cell.

[4 marks]

Figure 1



Do not write outside the box

0 6 . 3 Identify the negative electrode in the cell in question **06.2**.
Use the data in **Table 2** to give a reason for your answer.

[1 mark]

Negative electrode _____

Reason _____

_____

0 6 . 4 Deduce the EMF of the cell in question **06.2**.

[1 mark]

EMF _____ V

0 6 . 5 Write the conventional representation of the cell in question **06.2**.

[1 mark]

_____

Question 6 continues on the next page

Do not write outside the box

Table 3 shows the standard electrode potential values ($E^{\ominus}$) for some half-cells.

Table 3

Half-equation	$E^{\ominus}$ / V
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	–2.38
$Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq)$	–0.41
$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$	–0.28
$Ag^{+}(aq) + e^- \rightarrow Ag(s)$	+0.80
$Cr_2O_7^{2-}(aq) + 14H^{+}(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	+1.33
$HOI(aq) + H^{+}(aq) + e^- \rightarrow \frac{1}{2}I_2(aq) + H_2O(l)$	+1.45

0 6 . 6 $Cr^{3+}(aq)$ can act as an oxidising agent and as a reducing agent.

Use data from **Table 3** to write:

- **one** equation for a reaction where $Cr^{3+}(aq)$ acts as an oxidising agent
- **one** equation for a reaction where $Cr^{3+}(aq)$ acts as a reducing agent.

[2 marks]

$Cr^{3+}(aq)$ as an oxidising agent

$Cr^{3+}(aq)$ as a reducing agent

10

Turn over for the next question

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0 7 This question is about ionic solids dissolving in water.

Table 4 shows four enthalpy changes, **A**, **B**, **C** and **D**.

Table 4

	Enthalpy change	ΔH / **kJ mol^{-1}**
A	Enthalpy of hydration of chloride ions	–364
B	Enthalpy of hydration of magnesium ions	
C	Enthalpy of lattice dissociation of magnesium chloride	+2493
D	Enthalpy of solution of magnesium chloride	–155

0 7 . 1 Give the meaning of the term enthalpy of hydration.

[1 mark]

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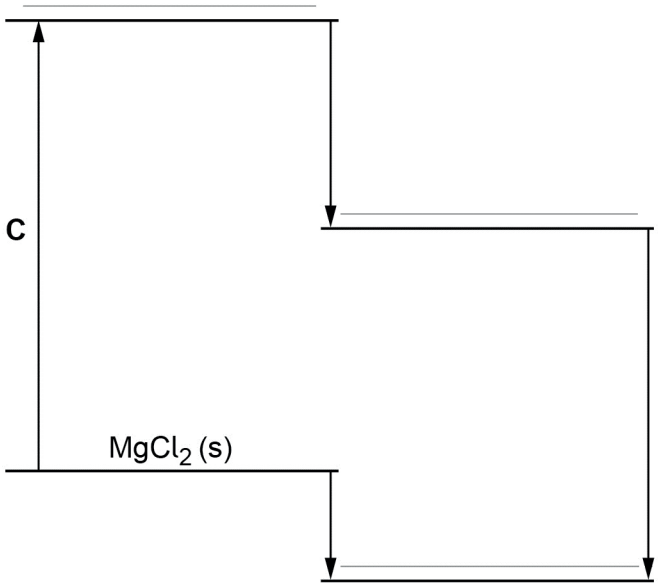
0 7 . 2 **Figure 2** shows an incomplete enthalpy cycle for the dissolving of magnesium chloride.

On **Figure 2**

- Write the missing species on each of the three blank lines.
- Label each arrow using the appropriate letters from **Table 4**.

[4 marks]

Figure 2



0 7 . 3 Use the data in **Table 4** to calculate the enthalpy of hydration of magnesium ions.

Show your working.

[2 marks]

Enthalpy of hydration of magnesium ions _____ kJ mol^{-1}

Turn over ►

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0 7 . 4 Heat-packs can be used to treat muscular injuries. Some heat-packs work by dissolving an ionic compound in water.

In one type of heat-pack, 10.0 g of magnesium chloride were dissolved in water at 20.0 °C to give 150 g of solution.

Calculate the maximum temperature, in °C, of the heat-pack.
Give your answer to **three** significant figures.

The enthalpy of solution of magnesium chloride = –155 kJ mol^{-1}
The specific heat capacity of the solution = 4.18 J K^{-1} g^{-1}

[4 marks]

Maximum temperature _____ °C

11

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0 8 Water is partially ionised.

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

At 50 °C, $K_w = 5.48 \times 10^{-14}$ mol^2 dm^{-6}

0 8 . 1 Calculate the pH of water at 50 °C

[2 marks]

pH _____

0 8 . 2 State why water at 50 °C is neutral.

[1 mark]

_____

_____

Question 8 continues on the next page

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A buffer solution contains 0.100 mol of propanoic acid and 0.200 mol of sodium propanoate in 200 cm^3 of solution at 25 °C

0 8 . 3 State what is meant by a buffer solution.

[1 mark]

0 8 . 4 Calculate the pH of the buffer solution at 25 °C
Give your answer to **two** decimal places.

For propanoic acid at 25 °C, the acid dissociation constant, $K_a = 1.35 \times 10^{-5}$ mol dm^{-3}

[2 marks]

pH _____

0 8 . 5 20 cm^3 of 1.00 mol dm^{-3} aqueous sodium hydroxide were added to the buffer solution.
Calculate the pH of the buffer solution after adding the sodium hydroxide.

Assume that the temperature of the solution stays at 25 °C
Give your answer to **two** decimal places.

[3 marks]

pH _____

9

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0 9 The equation for the reduction of iron(III) oxide by carbon monoxide is

$$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(l) + 3CO_2(g)$$

Table 5 gives some entropy values and enthalpies of formation.

Table 5

Substance	$Fe_2O_3(s)$	$CO(g)$	$Fe(l)$	$CO_2(g)$
Entropy / J K^{-1} mol^{-1}	90	198	35	214
Enthalpy of formation / kJ mol^{-1}	–822	–111	+12	–394

0 9 . 1 Calculate a value for the enthalpy change (ΔH) for this reaction.

[2 marks]

ΔH _____ kJ mol^{-1}

0 9 . 2 Calculate a value for the entropy change (ΔS) for this reaction.

[2 marks]

ΔS _____ J K^{-1} mol^{-1}

Question 9 continues on the next page

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0 9 . 3 Iron(III) oxide can also be reduced by carbon.

$$2Fe_2O_3(s) + 3C(s) \rightarrow 4Fe(l) + 3CO_2(g)$$

$$\Delta H = +510 \text{ kJ mol}^{-1}$$

$$\Delta S = +585 \text{ J K}^{-1} \text{ mol}^{-1}$$

Explain how the feasibility of this reaction changes as the temperature is increased. You do **not** need to do a calculation.

[2 marks]

6

END OF QUESTIONS

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