Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____
I declare this is my own work.

A-level
CHEMISTRY

Paper 1 Inorganic and Physical Chemistry

Time allowed: 2 hours

Materials
For this paper you must have:
- the Periodic Table/Data Booklet, provided as an insert (enclosed)
- 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 105.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
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 equilibria.

0 1 . 1 Give **two** features of a reaction in dynamic equilibrium.

[2 marks]

Feature 1 _____

_____

Feature 2 _____

_____

0 1 . 2 A gas-phase reaction is at equilibrium.
When the pressure is increased the yield of product decreases.

State what can be deduced about the chemical equation for this equilibrium.

[1 mark]

_____

_____

Question 1 continues on the next page

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0 1 . 3 Carbon monoxide and hydrogen react to form methanol.

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

0.430 mol of carbon monoxide is mixed with 0.860 mol of hydrogen.
At equilibrium, the total pressure in the flask is 250 kPa and the mixture contains 0.110 mol of methanol.

Calculate the amount, in moles, of carbon monoxide present at equilibrium.

Calculate the partial pressure, in kPa, of carbon monoxide in this equilibrium mixture.

[3 marks]

Amount of carbon monoxide _____ mol

Partial pressure _____ kPa

0 1 . 4 Give an expression for the equilibrium constant (K_p) for this reaction.

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

[1 mark]

K_p

Do not write outside the box

0 1 . 5 A different mixture of carbon monoxide and hydrogen is left to reach equilibrium at a temperature *T*.

Some data for this equilibrium are shown in **Table 1**.

Table 1

Partial pressure of CO	125 kPa
Partial pressure of CH_3OH	5.45 kPa
K_p	1.15×10^{-6} kPa^{-2}

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

Calculate the partial pressure, in kPa, of hydrogen in this equilibrium mixture.

[3 marks]

Partial pressure _____ kPa

0 1 . 6 Use the K_p value from **Table 1** to calculate a value for K_p for the following reaction at temperature *T*.

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

Give the units for K_p

[2 marks]

K_p _____

Units _____

12

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0 2 Rhenium has an atomic number of 75

0 2 . 1 Define the term relative atomic mass.

[2 marks]

_____

_____

_____

0 2 . 2 The relative atomic mass of a sample of rhenium is 186.3

Table 2 shows information about the two isotopes of rhenium in this sample.

Table 2

Relative isotopic mass	Relative abundance
185	10
To be calculated	17

Calculate the relative isotopic mass of the other rhenium isotope.
Show your working.

[2 marks]

Relative isotopic mass _____

0 2 . 3 State why the isotopes of rhenium have the same chemical properties.

[1 mark]

_____

_____

Do not write outside the box

A sample of rhenium is ionised by electron impact in a time of flight (TOF) mass spectrometer.

0 2 . 4 A $^{185}Re^{+}$ ion with a kinetic energy of 1.153×10^{-13} J travels through a 1.450 m flight tube.

The kinetic energy of the ion is given by the equation $KE = \frac{1}{2}mv^2$

where
m = mass / kg
v = speed / m s^{-1}
KE = kinetic energy / J

Calculate the time, in seconds, for the ion to reach the detector.

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

[5 marks]

Time _____ s

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0 2 . 5 State how the relative abundance of $^{185}Re^{+}$ is determined in a TOF mass spectrometer.

[2 marks]

12

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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0 3 This question is about hydrogen peroxide, H_2O_2

The half-equation for the oxidation of hydrogen peroxide is

$$H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-$$

Hair bleach solution contains hydrogen peroxide.

A sample of hair bleach solution is diluted with water.
The concentration of hydrogen peroxide in the diluted solution is 5.00% of that in the original solution.
A 25.0 cm^3 sample of the diluted hair bleach solution is acidified with dilute sulfuric acid.
This acidified sample is titrated with 0.0200 mol dm^{-3} potassium manganate(VII) solution.
The reaction is complete when 35.85 cm^3 of the potassium manganate(VII) solution are added.

0 3 . 1 Give an ionic equation for the reaction between potassium manganate(VII) and acidified hydrogen peroxide.

Calculate the concentration, in mol dm^{-3}, of hydrogen peroxide in the original hair bleach solution.

(If you were unable to write an equation for the reaction you may assume that the mole ratio of potassium manganate(VII) to hydrogen peroxide is 3:4
This is **not** the correct mole ratio.)

[5 marks]

Concentration _____ mol dm^{-3}

Do not write outside the box

0 3 . 2 State why an indicator is **not** added in this titration.

[1 mark]

_____

_____

0 3 . 3 Give the oxidation state of oxygen in hydrogen peroxide.

[1 mark]

_____

0 3 . 4 Hydrogen peroxide decomposes to form water and oxygen.

Give an equation for this reaction.

Calculate the amount, in moles, of hydrogen peroxide that would be needed to produce 185 cm^3 of oxygen gas at 100 kPa and 298 K

The gas constant, R = 8.31 J K^{-1} mol^{-1}

[5 marks]

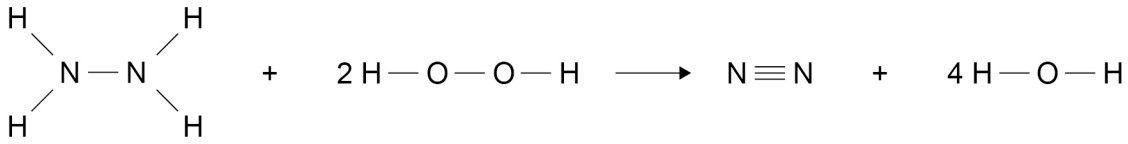
Equation

_____

Amount _____ mol

Do not write outside the box

0 3 . 5 Hydrazine (N_2H_4) is used as a rocket fuel that is oxidised by hydrogen peroxide. The equation for this reaction in the gas phase is



The enthalpy change for this reaction, $\Delta H = -789$ kJ mol^{-1}

Table 3 shows some mean bond enthalpy values.

Table 3

	N–H	**N–N**	**N≡N**	**O–H**
Mean bond enthalpy / kJ mol^{-1}	388	163	944	463

Define the term mean bond enthalpy.

Use the equation and the data in **Table 3** to calculate a value for the O–O bond enthalpy in hydrogen peroxide.

[5 marks]

Definition _____

_____

Bond enthalpy _____ kJ mol^{-1}

17

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0 4 This question is about acids and bases.

0 4 . 1 Calculate the pH of a 0.150 mol dm^{-3} solution of ethanoic acid at 25 °C
Give your answer to 2 decimal places.

For ethanoic acid, K_a = 1.74 x 10^{-5} mol dm^{-3} at 25 °C

[3 marks]

pH _____

0 4 . 2 Strontium is an element in Group 2.

Calculate the pH of a 0.0100 mol dm^{-3} solution of strontium hydroxide at 10 °C
You may assume that strontium hydroxide is completely dissociated in this solution.

At 10 °C the ionic product of water, K_w = 2.93 x 10^{-15} mol^2 dm^{-6}

[3 marks]

pH _____

Do not write outside the box

0 4 . 3 The pH of a barium hydroxide solution is lower at 50 °C than at 10 °C

At 50 °C a 25 cm^3 sample of this barium hydroxide solution was neutralised by 22.45 cm^3 of hydrochloric acid added from a burette.

Deduce the volume of this hydrochloric acid that should be added from a burette to neutralise another 25 cm^3 sample of this barium hydroxide solution at 10 °C

[2 marks]

Circle (⬭) the correct answer.

> 22.45 cm^3 = 22.45 cm^3 < 22.45 cm^3

Explain your answer _____

_____

_____

_____

0 4 . 4 State how a buffer solution can be made from solutions of potassium hydroxide and ethanoic acid.

Give an equation for the reaction between potassium hydroxide and ethanoic acid.

State how this buffer solution resists changes in pH when a small amount of acid is added.

[3 marks]

How buffer solution is made _____

_____

_____

_____

Equation

_____

How buffer solution resists pH change _____

_____

_____

_____

Do not write outside the box

0 4 . 5 A buffer solution is made by adding 2.00 g of sodium hydroxide to 500 cm^3 of 1.00 mol dm^{-3} ethanoic acid solution.

Calculate the pH of this buffer solution at 25 °C

Give your answer to 2 decimal places.

For ethanoic acid, K_a = 1.74 x 10^{-5} mol dm^{-3} at 25 °C

[5 marks]

pH _____

16

Do not write outside the box

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

0 5 . 1 Which is **not** a correct statement about magnesium hydroxide?

[1 mark]

Tick (✓) **one** box.

It is used to neutralise stomach acid ☐

It forms a solution with pH = 14 at 25 °C ☐

It has the empirical formula H_2MgO_2 ☐

0 5 . 2 Give an equation for the reaction of aluminium oxide with sulfuric acid.

[1 mark]

_____

0 5 . 3 Identify a reagent or test that could be used to distinguish between aqueous solutions of sulfur dioxide and sulfur trioxide with the same concentrations.

State the observation in each case.

[3 marks]

Reagent or test _____

Observation with sulfur dioxide solution _____

_____

Observation with sulfur trioxide solution _____

_____

Question 5 continues on the next page

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0 5 . 4 The mass spectrum of the element phosphorus has a peak at $\frac{m}{z}$ = 124

Give the formula of the species responsible for this peak.

[2 marks]

_____

0 5 . 5 Give an equation for the reaction of phosphorus(V) oxide with sodium hydroxide solution.

[1 mark]

_____

0 5 . 6 Draw the displayed formula of the molecule formed when phosphorus(V) oxide reacts with water.

[1 mark]

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Question 5 continues on the next page

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0 5 . 7 **Table 4** shows the melting points of three substances.

Table 4

Substance	Melting point / K
sodium chloride	1074
chlorine	172
hydrogen chloride	158

Explain why the melting points of these substances are different.

You should refer to the structure of and bonding in each substance.

[6 marks]

Do not write outside the box

15

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0 6 This question is about some elements in Group 7 and their compounds.

0 6 . 1 Chlorine is added to some drinking water supplies to decrease the risk of people suffering from diseases such as cholera.

State why the amount of chlorine added must be controlled.

[1 mark]

_____

_____

0 6 . 2 Give an equation for the reaction of chlorine with water to form a solution containing **two** acids.

Explain, with reference to electrons, why this is a redox reaction.

[2 marks]

Equation

_____

Explanation _____

_____

_____

_____

0 6 . 3 A student bubbles chlorine gas through a solution of sodium iodide.

State the observation the student would make.

Give an ionic equation for the reaction.

[2 marks]

Observation _____

Ionic equation

_____

Do not write outside the box

0 6 . 4 The student adds a few drops of concentrated sulfuric acid to a small amount of solid sodium iodide.

Two gaseous sulfur-containing products are formed.

Give an equation for the formation of each of these sulfur-containing products.

State the role of sulfuric acid in the formation of these products.

[3 marks]

Equation 1

_____

Equation 2

_____

Role _____

0 6 . 5 The student adds a few drops of acidified silver nitrate solution to a solution of an unknown **impure** sodium halide.
The student observes bubbles of gas and a colourless solution.
The student bubbles the gas through calcium hydroxide solution and a white precipitate forms.

Deduce the identity of the sodium halide.

Suggest the identity of the gas.

Give an ionic equation for the formation of this gas from the impurity.

[3 marks]

Identity of sodium halide _____

Identity of gas _____

Ionic equation

_____

Question 6 continues on the next page

Do not write outside the box

0 6 . 6 The ClF_2^+ ion contains two different Group 7 elements.

Use your understanding of the electron pair repulsion theory to draw the shape of this ion.

Include any lone pairs of electrons that influence the shape.

Explain why the ion has the shape you have drawn.

Suggest a value for the bond angle in the ion.

[3 marks]

Shape

Explanation _____

_____

_____

Bond angle _____

0 6 . 7 Magnesium is used in the extraction of titanium from titanium(IV) chloride.

Give an equation for this reaction.

[1 mark]

_____

15

Do not write outside the box

0 7 Copper(II) complexes are coloured.
The colour is caused by the d electrons of copper moving from their ground state to an excited state.

0 7 . 1 Explain why aqueous solutions containing $[CuCl_4]^{2-}$ ions are yellow.

[2 marks]

_____

_____

_____

_____

_____

0 7 . 2 When a d electron moves from the ground state to the excited state in a copper complex, the energy change is 3.98×10^{-19} J

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

Calculate the frequency, in s^{-1}, of the light absorbed.

[2 marks]

Frequency _____ s^{-1}

0 7 . 3 State **three** ways in which a transition metal complex can be changed to alter its colour.

[3 marks]

1 _____

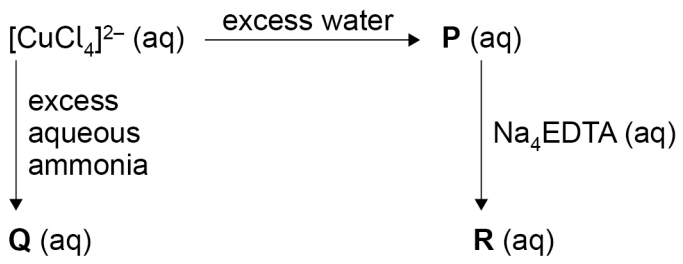
2 _____

3 _____

Question 7 continues on the next page

Do not write outside the box

Consider the following reaction scheme in which **P**, **Q** and **R** are different complex ions of copper.



0 7 . 4 Name the shape of the $[CuCl_4]^{2-}$ ion.

[1 mark]

_____

0 7 . 5 Give an ionic equation for the conversion of $[CuCl_4]^{2-}$ to complex ion **P**.

[1 mark]

_____

0 7 . 6 State the colour of the solution containing the complex ion **Q**.

Give an ionic equation for the conversion of $[CuCl_4]^{2-}$ to **Q**.

[2 marks]

Colour _____

Equation

_____

0 7 . 7 Identify complex ion **R**.

[1 mark]

_____

12

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0 8 This question is about cells.

0 8 . 1 The half-equations for two electrodes that combine to make a non-rechargeable cell are

$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$ $E^\ominus = -0.76$ V

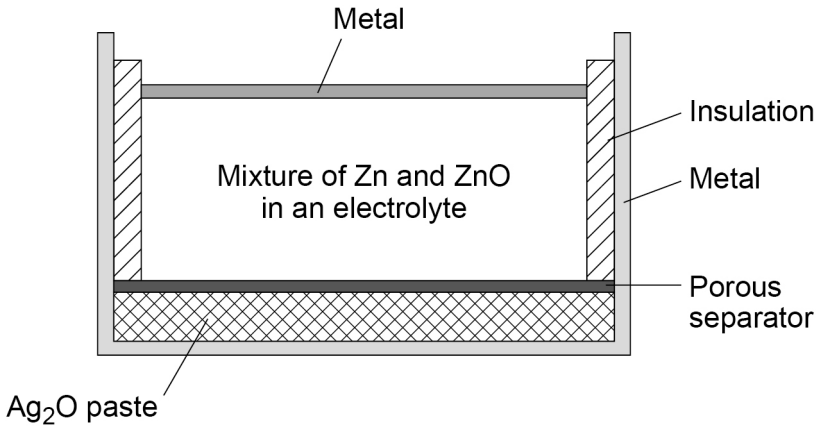
$2\,MnO_2(s) + 2\,NH_4^+(aq) + 2e^- \rightarrow Mn_2O_3(s) + 2\,NH_3(aq) + H_2O(l)$ $E^\ominus = +0.52$ V

Identify the oxidising agent in this cell.

[1 mark]

Figure 1 shows a cross-section through a rechargeable silver–zinc cell.

Figure 1



0 8 . 2 Suggest the function of the porous separator in **Figure 1**.

[1 mark]

---

0 8 . 3 The standard electrode potentials for two half-equations for the silver–zinc cell are

$Ag_2O(s) + H_2O(l) + 2e^- \rightarrow 2\,Ag(s) + 2\,OH^-(aq)$ $E^\ominus = +0.34$ V

$ZnO(s) + H_2O(l) + 2e^- \rightarrow Zn(s) + 2\,OH^-(aq)$ $E^\ominus = -1.26$ V

Give an equation for the overall reaction that occurs when the cell is recharging.

[1 mark]

Do not write outside the box

The EMF of an alkaline hydrogen–oxygen fuel cell is +1.23 V
The standard electrode potential for one of the electrodes in the alkaline hydrogen–oxygen fuel cell is

$$2\,H_2O(l) + 2e^- \rightarrow 2\,OH^-(aq) + H_2(g) \qquad E^{\ominus} = -0.83\ V$$

0 8 . 4 Give the half-equation for the other electrode and calculate its standard electrode potential.

[2 marks]

Equation

_____

$E^{\ominus}$ _____

0 8 . 5 Suggest why the EMF values of the acidic and alkaline hydrogen–oxygen fuel cells are the same.

[1 mark]

_____

_____

6

END OF QUESTIONS

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