OCR
Oxford Cambridge and RSA

A Level Chemistry A

H432/01 Periodic table, elements and physical chemistry

Practice paper - Set 1

Time allowed: 2 hours 15 minutes

You must have:
- the Data Sheet for Chemistry A

You may use:
- a scientific calculator

First name									
Last name									
Centre number						**Candidate number**				

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the bar codes.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **28** pages.

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SECTION A

You should spend a maximum of 20 minutes on this section.

Write your answer to each question in the box provided.

Answer **all** the questions.

1 Which equation produces the enthalpy change of formation of copper(I) iodide?

A $Cu^+(g) + I^-(g) \rightarrow CuI\ (s)$

B $Cu(g) + I\ (g) \rightarrow CuI\ (s)$

C $Cu(s) + I_2(s) \rightarrow CuI_2(s)$

D $Cu(s) + \frac{1}{2}I_2(s) \rightarrow CuI(s)$

Your answer ☐

[1]

2 14.4 g of an element **X** react with oxygen to form 24.0 g of a compound $\mathbf{X}O_2$.

Which element is **X**?

A Fluorine

B Magnesium

C Titanium

D Molybdenum

Your answer ☐

[1]

3 Bromine is a toxic gas. The maximum safe concentration of bromine in air is 0.0040 mg dm^{-3}.

How many bromine molecules are present in each dm^3 of air at this concentration?

A 1.5×10^{16}

B 3.0×10^{16}

C 1.5×10^{19}

D 3.0×10^{19}

Your answer ☐

[1]

4 Which element contains atoms with the largest radius?

A Na

B K

C Mg

D Ca

Your answer ☐

[1]

5 The table shows standard enthalpy changes of formation, $\Delta_f H^{\ominus}$.

Compound	$NO_2(g)$	$H_2O(l)$	$HNO_3(l)$	NO(g)
$\Delta_f H^{\ominus}$ **/ kJ mol^{-1}**	+33.2	–285.8	–207.0	+91.3

Calculate the standard enthalpy change of the following reaction, in kJ mol^{-1}.

$$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(l) + NO(g)$$

A –136.9

B –136.5

C +136.5

D +136.9

Your answer ☐

[1]

6 For the reaction $2H_2(g) + 2NO(g) \rightarrow N_2(g) + 2H_2O(g)$, the rate equation is $rate = k[H_2][NO]^2$.

What is the effect on the rate of reaction when the concentration of H_2 is halved and the concentration of NO is doubled?

A The reaction rate is halved.

B The reaction rate is unchanged.

C The reaction rate is doubled.

D The reaction rate is quadrupled.

Your answer ☐

[1]

7 The reaction $2AB \rightarrow 2A + B_2$ is first order with respect to AB.
The half-life of the reaction is 2 minutes.

0.100 mol of AB is dissolved in a solvent to form 100 cm^3 of a reaction mixture.

What is the concentration of AB, in mol dm^{-3}, after 6 minutes?

A 0.0125

B 0.0250

C 0.125

D 0.250

Your answer ☐

[1]

8 The equilibrium system below is set up.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = +14 \text{ kJ mol}^{-1}$$

The equilibrium system is compressed at constant temperature.

What is the effect on the value of K_c and the amount, in moles, of CH_3OH?

	K_c	**Amount in moles of CH_3OH**
A	increases	increases
B	decreases	decreases
C	no change	no change
D	no change	increases

Your answer ☐

[1]

9 A buffer solution is based on methanoic acid, HCOOH (K_a = 1.70 × 10^{-4} mol dm^{-3}) and methanoate ions, $HCOO^-$.

In the buffer solution, the HCOOH concentration is half the $HCOO^-$ concentration.

What is the pH of the buffer solution?

A 2.47

B 3.07

C 3.47

D 4.07

Your answer ☐

[1]

10 Which statement is correct for a neutral solution at any temperature?

A K_w = 1.00 × 10^{-14} mol^2 dm^{-6}

B The solution contains only H_2O

C $[H^+] = [OH^-]$

D pH = 7

Your answer ☐

[1]

11 An unbalanced equation for a redox reaction is shown below.

$$Cu(s) + H^+(aq) + NO_3^-(aq) \rightarrow Cu^{2+}(aq) + NO_2(g) + H_2O(l)$$

What is the balancing number for H^+ when the equation is balanced using the smallest whole numbers?

A 2

B 4

C 6

D 8

Your answer ☐

[1]

12 Which property is **not** correct for calcium?

A It acts as an oxidising agent

B It forms a basic oxide

C It reacts with water to form hydrogen gas

D Its hydroxide is more alkaline than magnesium hydroxide

Your answer ☐

[1]

13 A standard cell is set up from $H^+(aq)|H_2(g)$ and $Ag^+(aq)|Ag(s)$ half cells .

The standard electrode potentials of the redox systems are shown below.

$H^+(aq) + e^- \rightleftharpoons \frac{1}{2}H_2(g)$ $\quad E^\ominus = +0.00$ V

$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$ $\quad E^\ominus = +0.80$ V

What is the reaction at the negative electrode of the cell?

A $H^+(aq) + e^- \rightarrow \frac{1}{2}H_2(g)$

B $\frac{1}{2}H_2(g) \rightarrow H^+(aq) + e^-$

C $Ag^+(aq) + e^- \rightarrow Ag(s)$

D $Ag(s) \rightarrow Ag^+(aq) + e^-$

Your answer ☐

[1]

14 **X** is a particle with 18 electrons and 20 neutrons.

Which of the following particles could be **X**?

1: ^{38}Ar

2: $^{40}Ca^{2+}$

3: $^{39}K^{+}$

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐

[1]

15 Zinc reacts with hydrochloric acid as shown below.

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

Which statement(s) is/are correct?

1: 3.27 g of Zn reacts with excess of HCl to form 0.050 mol of $ZnCl_2$.

2: 6.54 g Zn reacts exactly with 100 cm^3 of 1.00 mol dm^{-3} HCl.

3: 13.08 g Zn reacts with an excess of HCl to form 9.60 dm^3 of hydrogen, at room temperature and pressure.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐

[1]

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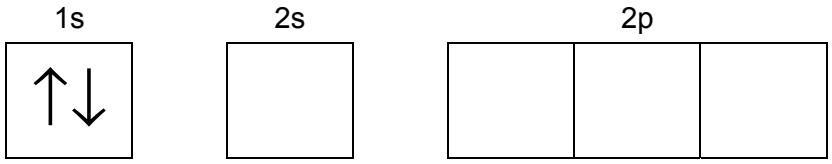
SECTION B

Answer **all** the questions.

16 This question is about electron structure and ions.

(a) Electrons occupy orbitals within an atom. The diagram below shows an incomplete 'electrons in boxes' representation for the filling of orbitals in an oxygen atom.

Complete the diagram.



[1]

(b) Successive ionisation energies provide evidence for electron structure.

Sodium has eleven successive ionisation energies, shown in **Table 16.1**.

Ionisation number	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th
Ionisation energy /kJ mol^{-1}	496	4562	6910	9543	13354	16613	20117	25496	28932	141362	159075

Table 16.1

(i) Write the equation for the **seventh** ionisation energy of sodium.

Include state symbols.

..... **[1]**

(ii) Why do successive ionisation energies increase with ionisation number?

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..... **[1]**

(iii) Explain how the successive ionisation energies in **Table 16.1** provide evidence for the electron shells in sodium atoms.

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..... **[2]**

(iv) The trend in first ionisation energies across periods gives further details of electron structure. The first ionisation energies of magnesium and aluminium are shown below.

Element	Mg	A*l*
First ionisation energy/kJ mol^{-1}	738	578

Explain how the first ionisation energies of magnesium and aluminium give further details of electron structure.

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..... **[2]**

(c) Two elements, **A** and **B**, react to form an ionic compound with the formula $\mathbf{A_2B_3}$.
In this compound, **A** and **B** both have the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6$.

Deduce possible identities of the ions in $\mathbf{A_2B_3}$.

A: .....

B: .....
[2]

(d) A salt of an organic acid has the following composition by mass:
C, 31.17%; H, 9.09%; N, 18.18%; O, 41.56%.

Calculate the empirical formula of the salt and deduce the formulae of the ions present.

Show your working.

empirical formula: .....

ions:.....
[3]

17 Enthalpy changes of solution can be determined both indirectly from other enthalpy changes, and directly from the results of experiments.

The table below shows the enthalpy changes that can be used to determine the enthalpy change of solution of calcium chloride, $CaCl_2$, indirectly.

Enthalpy change	Energy /kJ mol^{-1}
Hydration of calcium ions	–1616
Hydration of chloride ions	–359
Lattice enthalpy of calcium chloride	–2192

(a) The bonding in $CaCl_2$ can be represented by a '*dot-and-cross*' diagram.

Draw a '*dot-and-cross*' diagram for the bonding in $CaCl_2$.

Show outer electrons only.

[2]

(b) Explain what is meant by the term *enthalpy change of solution*.

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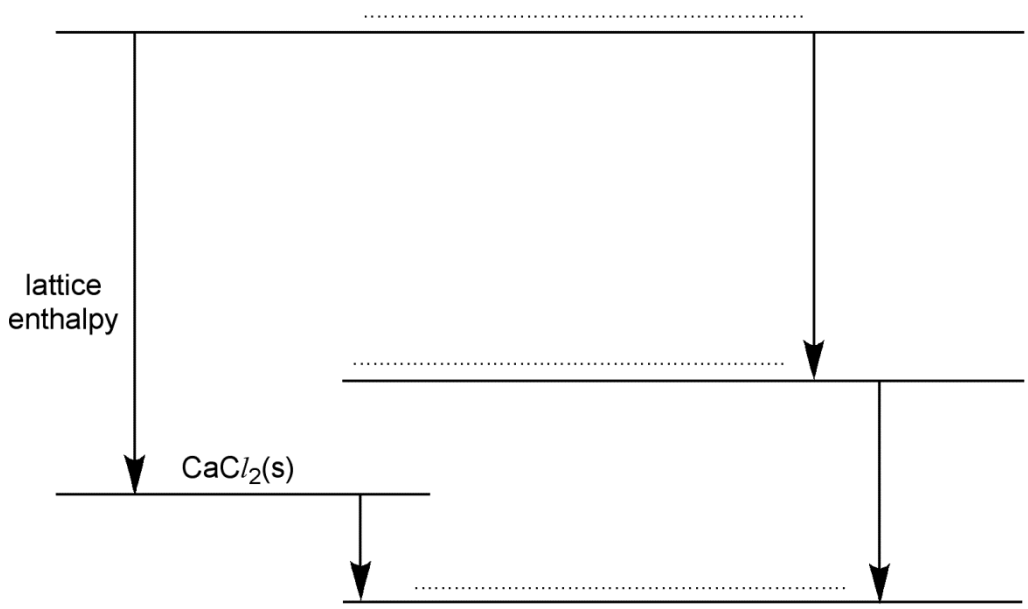
..... **[1]**

(c) The diagram below shows an incomplete energy cycle that can be used to determine the enthalpy change of solution, $\Delta_{sol}H$, of $CaCl_2$.

(i) On the **three** dotted lines, add the species present, including state symbols.



[3]

(ii) Calculate the enthalpy change of solution of $CaCl_2$.

$\Delta_{sol}H$ = ... kJ mol^{-1} **[2]**

(iii) The table shows enthalpy changes of hydration.

Ion	Enthalpy change of hydration / kJ mol^{-1}
aluminium ion	–4741
calcium ion	–1616
magnesium ion	–1963
sodium ion	–424

Explain the differences between these enthalpy changes of hydration.

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..... **[3]**

(d) **Student 1** carries out an experiment to determine the enthalpy change of solution, $\Delta_{sol}H$, of $CaCl_2$ directly.

The student follows the method outlined below.

- Weigh an empty polystyrene cup and weigh the bottle containing $CaCl_2$.
- Add about 50 cm^3 of water to the cup and measure the temperature of the water.
- Add the $CaCl_2$ to the cup, stir the mixture, and record the maximum temperature.
- Weigh the polystyrene cup + final solution, and weigh the empty bottle.

Results

Mass of bottle + $CaCl_2$	28.38 g
Mass of empty bottle	22.82 g
Mass of polystyrene cup + final solution	85.67 g
Mass of polystyrene cup	35.46 g
Initial temperature of water	22.0 ºC
Final temperature of solution	53.5 ºC

(i) Calculate $\Delta_{sol}H$, in kJ mol^{-1}, for calcium chloride.

Give your answer to an **appropriate** number of significant figures.

Assume that the density and specific heat capacity, *c*, of the solution have the same values as water.

$\Delta_{sol}H$ =..... kJ mol^{-1} **[4]**

(ii) **Student 2** carries out the same experiment but uses twice the mass of $CaCl_2$. All other quantities are very similar to **Student 1**'s experiment.

Predict any differences between the temperature change and the calculated value of $\Delta_{sol}H$ from the experiments of the two students. Explain your reasoning.

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..... **[2]**

18 Ammonia, NH_3, is manufactured by the chemical industry from nitrogen and hydrogen gases.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

- An iron catalyst is used which provides several benefits for sustainability.
- The chemical industry uses operational conditions that are different from the conditions predicted to give a maximum equilibrium yield.

(a)* Use your understanding of Chemistry to explain the above statements.

Your response should be well-developed, showing a line of reasoning which is clear and logically structured.

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.... **[6]**

(b) A research chemist investigates how the value of K_c changes with temperature.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92 \text{ kJ mol}^{-1}$$

- The chemist mixes 0.800 mol of $N_2(g)$ and 2.400 mol of $H_2(g)$ and leaves the mixture to reach equilibrium at 300 ºC.
- The total volume of the equilibrium mixture is 5.00 dm^3.
- At equilibrium, 0.360 mol of $NH_3(g)$ has formed.

Calculate the value of K_c under these conditions.

Show all your working.

K_c = ... units ..... **[6]**

(c) The chemist adds more nitrogen to the equilibrium mixture in **(b)**.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H = -92$ kJ mol^{-1}

The temperature is kept at 300 ºC and the volume at 5.00 dm^3.

The chemist predicts that the addition of nitrogen will increase the proportion of $H_2(g)$ that reacts.

(i) Explain whether the chemist's prediction is correct.

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..... **[3]**

(ii) Suggest why the chemist is more concerned with increasing the proportion of H_2 that reacts rather than the proportion of N_2 that reacts.

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..... **[1]**

19 This question is about reaction rates.

Ozone, O_3, reacts with nitrogen dioxide, NO_2, as shown below.

$$O_3(g) + 2NO_2(g) \rightarrow N_2O_5(g) + O_2(g)$$

A student carries out three experiments to investigate how different concentrations of $O_3(g)$ and $NO_2(g)$ affect the initial rate of this reaction.

The results of the three experiments are shown below

Experiment	$[O_3(g)]$ /mol dm^{-3}	$[NO_2(g)]$ /mol dm^{-3}	Initial rate, /mol dm^{-3} s^{-1}
1	1.00×10^{-3}	2.50×10^{-3}	3.20×10^{-8}
2	3.00×10^{-3}	2.50×10^{-3}	9.60×10^{-8}
3	3.00×10^{-3}	5.00×10^{-3}	1.92×10^{-7}

(a)* Determine the rate constant and a possible two-step mechanism for this reaction that is consistent with these results.

Your response should clearly show how your calculations and explanations are linked to the experimental results.

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..... **[6]**

(b) A student carries out an investigation to find the activation energy, E_a, of a reaction.

From the results, the student determines the rate constant, k, at different temperatures, T.

The student then calculates $1/T$ and ln k, as shown in **Table 19.1**.

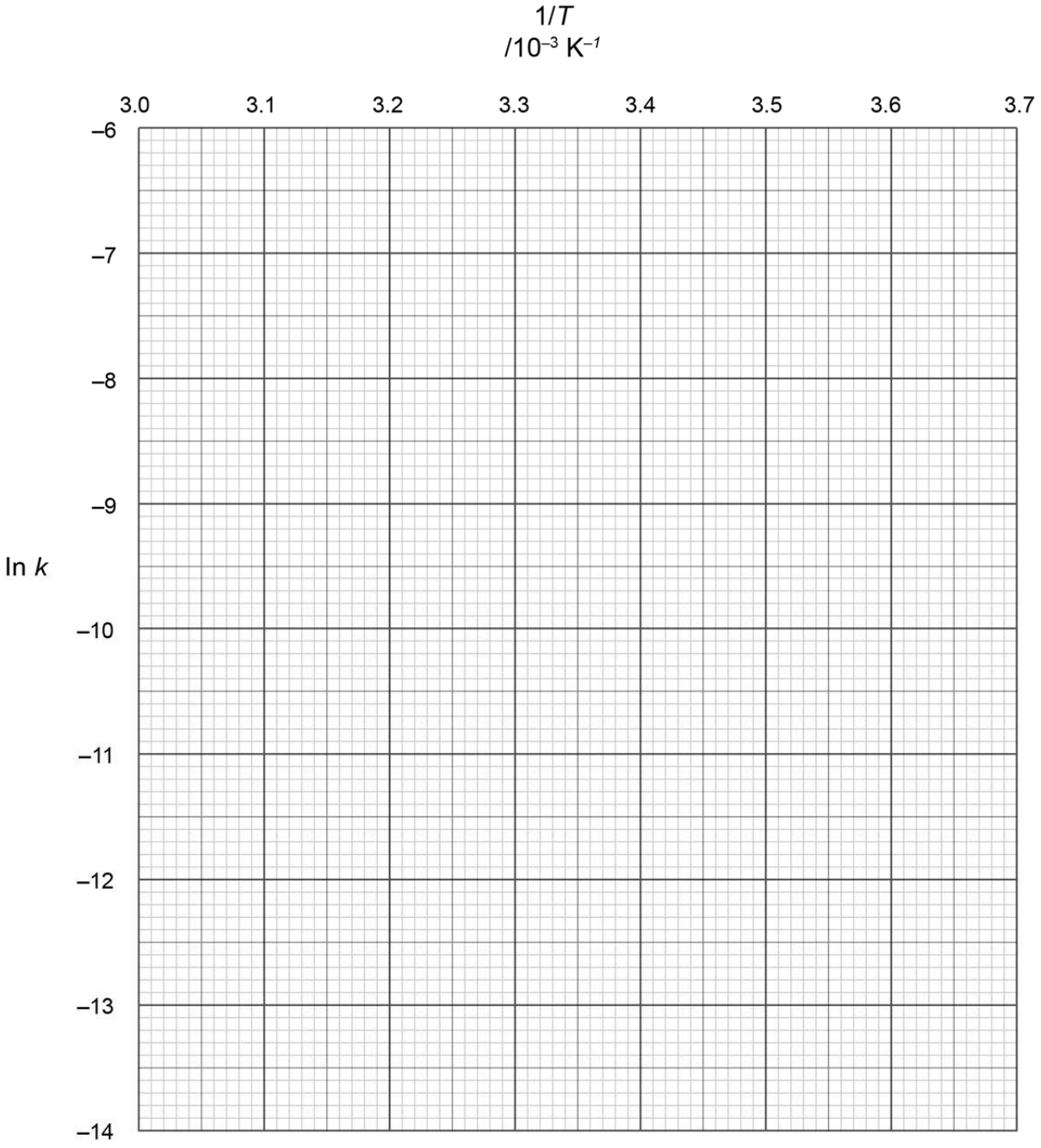
Temperature, T / K	**Rate constant, k / s^{-1}**	**$1/T$ / K^{-1}**	**ln k**
278	1.50×10^{-6}	3.60×10^{-3}	−13.41
290	1.51×10^{-5}		–11.10
298	4.11×10^{-5}	3.34×10^{-3}	−10.10
308	1.99×10^{-4}	3.23×10^{-3}	
323	1.40×10^{-3}	3.10×10^{-3}	−6.57

Table 19.1

Add the missing values to **Table 19.1** and plot a graph of ln k against $1/T$ on the graph paper opposite.

Using your graph, calculate the activation energy of the reaction.

Show your working.



activation energy, E_a = ... kJ mol^{-1} **[4]**

20 This question is about acids and bases.

(a) Nitric acid, HNO_3, and nitrous acid, HNO_2, are two Brønsted–Lowry acids containing nitrogen.

A student measures the pH of 0.0450 mol dm^{-3} solutions of HNO_3 and HNO_2 (pK_a = 3.35) and found that the acids had different pH values.

(i) Explain why the pH values are different.

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..... **[1]**

(ii) Calculate the pH value of 0.0450 mol dm^{-3} HNO_3 to **two** decimal places.

Show your working.

pH = ... **[1]**

(iii) Calculate the pH value of 0.0450 mol dm^{-3} HNO_2 to **two** decimal places.

Show your working.

pH = ... **[3]**

(b) Rubidium hydroxide, RbOH, is a strong alkali. A technician is asked to prepare a 250.0 cm^3 solution of RbOH with a pH of 12.500.

Calculate the mass of RbOH that the technician needs to use.

mass = ... g **[4]**

(c) Concentrated nitric acid, HNO_3, is an oxidising agent. For example, concentrated HNO_3 reacts with sulfur to form sulfuric acid, nitrogen dioxide and one other product.

- Using oxidation numbers, show the element that is oxidised and the element that is reduced in this reaction. Ensure that the oxidation numbers have signs.
- Construct the balanced equation for this reaction.

element oxidised ..... oxidation number change: from ..... to ….....

element reduced ..... oxidation number change: from ……..... to ……...

equation ..... **[4]**

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21 This question is about the chemistry of transition elements.

(a) Many chromium compounds contain chromium in the +3 oxidation state.

Complete the electron configurations of chromium as the element and in the +3 oxidation state.

Chromium as the element: $1s^2 2s^2 2p^6$ .....

Chromium in the +3 oxidation state: $1s^2 2s^2 2p^6$ .....

[2]

(b) Compound I is a complex with the empirical formula $CoN_4H_{12}Cl_3$.

The formula of compound I contains one chloride ion and a complex ion **J**, which has two stereoisomers.

Draw and label the three-dimensional structures of the two stereoisomers of complex ion **J**. Include the charge of the complex ion in your diagrams.

[3]

(c) **A** and **B** are compounds of two different transition elements.

Two students carry out test-tube tests on aqueous solutions of **A** and **B**.
They then analyse the results to identity **A** and **B**.

The observations of **Student 1's** tests are shown below.

Test		A(aq)	B(aq)
1	NH_3(aq) added dropwise Excess NH_3(aq) added	green precipitate **C** violet solution **D**	pale-brown precipitate **E** no further change
2	HNO_3(aq) followed by $Ba(NO_3)_2$(aq)	no change white precipitate **F**	no change no change
3	HNO_3(aq) followed by $AgNO_3$(aq)	no change no change	no change yellow precipitate, **G**

(i) Analyse the results and answer the following.

Identify **A** and **B** and write their formulae.

Construct ionic equations for the formation of the products **C**–**G** from the relevant ions present in **A(aq)** and **B(aq)**.

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..... **[7]**

(ii) What was the purpose of adding $HNO_3(aq)$ first in **Test 2** and **Test 3**?

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..... **[1]**

(iii) **Student 2** accidentally used $HCl(aq)$ instead of $HNO_3(aq)$ for both **Test 2** and **Test 3**.

What different observations would **Student 2** obtain?
Explain your reasoning.

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..... **[3]**

(iv) How could the procedure be modified to be more certain of the conclusions from **Test 3**?

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..... **[1]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).