



Oxford Cambridge and RSA

# A Level Chemistry A

## H432/01 Periodic table, elements and physical chemistry

**Tuesday 13 June 2017 – Afternoon**

**Time allowed: 2 hours 15 minutes**



**You must have:**

- the Data Sheet for Chemistry A (sent with general stationery)

**You may use:**

- a scientific or graphical 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 barcodes.

### 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.

## 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 atom is **not** an isotope of iodine?

|   | Number of neutrons | Mass number |
|---|--------------------|-------------|
| A | 72                 | 125         |
| B | 74                 | 127         |
| C | 75                 | 128         |
| D | 77                 | 129         |

Your answer

[1]

2 What is the bonding between the ligands and the metal ion in  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ ?

- A Metallic
- B Ionic
- C Hydrogen
- D Dative covalent

Your answer

[1]

3 What is the oxidation number of Mn in  $\text{K}_2\text{MnO}_4$ ?

- A +4
- B +5
- C +6
- D +7

Your answer

[1]

4 Which calcium compound contains the **greatest** percentage by mass of calcium?

- A calcium carbonate
- B calcium nitrate
- C calcium hydroxide
- D calcium sulfate

Your answer

[1]

5 0.0200 mol of calcium oxide is reacted completely with 2.00 mol dm<sup>-3</sup> HCl.

What is the volume, in cm<sup>3</sup>, of 2.00 mol dm<sup>-3</sup> HCl required for this reaction?

- A 15
- B 20
- C 30
- D 60

Your answer

[1]

6 How many electrons are removed from  $2.02 \times 10^{-2}$  g of Ne(g) atoms to form Ne<sup>+</sup>(g) ions?

- A  $3.36 \times 10^{-26}$
- B  $1.66 \times 10^{-27}$
- C  $6.02 \times 10^{20}$
- D  $1.22 \times 10^{22}$

Your answer

[1]

7 Silicon can be made by heating silicon tetrachloride,  $\text{SiCl}_4$ , with zinc.



8.50 g of  $\text{SiCl}_4$  is reacted with an excess of zinc. The percentage yield of silicon is 90%.

What is the mass of silicon made?

- A 1.26 g
- B 1.31 g
- C 1.40 g
- D 1.55 g

Your answer

[1]

8 Four pairs of solutions are mixed.

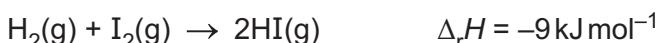
Which pair of solutions forms a white precipitate?

- A  $\text{NH}_4\text{Cl}(\text{aq})$  and  $\text{NaOH}(\text{aq})$
- B  $\text{KBr}(\text{aq})$  and  $\text{AgNO}_3(\text{aq})$
- C  $\text{FeCl}_3(\text{aq})$  and  $\text{NH}_3(\text{aq})$
- D  $\text{Cr}_2(\text{SO}_4)_3(\text{aq})$  and  $\text{BaCl}_2(\text{aq})$

Your answer

[1]

9 Enthalpy values are provided below.



| Bond | Bond enthalpy /kJ mol <sup>-1</sup> |
|------|-------------------------------------|
| H–H  | +436                                |
| I–I  | +151                                |

What is the bond enthalpy, in  $\text{kJ mol}^{-1}$ , of the H–I bond?

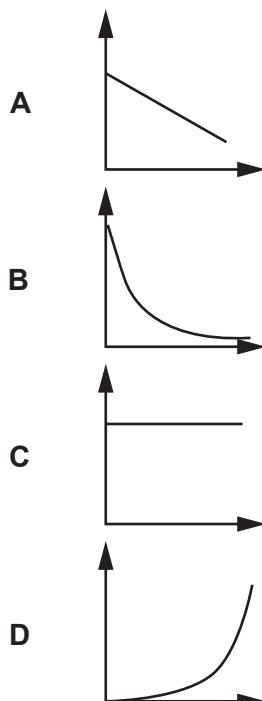
- A -596
- B -298
- C +298
- D +596

Your answer

[1]

10 A reaction is zero order with respect to a reactant A.

Which concentration–time graph for reactant A is the correct shape?



Your answer

[1]

11 Aqueous  $\text{Cr}^{3+}$  ions are reacted with an excess of aqueous sodium hydroxide.

Which product is formed?

- A  $\text{Cr}(\text{OH})_6^{3-}$
- B  $\text{Cr}(\text{OH})_3$
- C  $[\text{Cr}(\text{OH})_4(\text{H}_2\text{O})_2]^-$
- D  $[\text{Cr}(\text{OH})_4]^{3-}$

Your answer

[1]

12 **HA** and **HB** are two strong monobasic acids.

25.0 cm<sup>3</sup> of 6.0 mol dm<sup>-3</sup> **HA** is mixed with 45.0 cm<sup>3</sup> of 3.0 mol dm<sup>-3</sup> **HB**.

What is the H<sup>+</sup>(aq) concentration, in mol dm<sup>-3</sup>, in the resulting solution?

- A 1.9
- B 2.1
- C 4.1
- D 4.5

Your answer

[1]

13 A mixture of N<sub>2</sub> and O<sub>2</sub> gases has a total pressure of 1.42 atm.

The mole fraction of N<sub>2</sub> is 0.700.

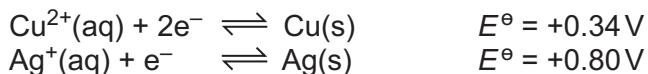
What is the partial pressure, in atm, of O<sub>2</sub> in the mixture?

- A 0.211
- B 0.426
- C 0.493
- D 0.994

Your answer

[1]

14 A cell is constructed from the two redox systems below.



Which statement(s) is/are correct for the cell?

- 1 The cell potential is 1.14 V.
- 2 The reaction at the copper electrode is  $\text{Cu}(\text{s}) \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$ .
- 3 The silver electrode increases in mass.

**A** 1, 2 and 3

**B** Only 1 and 2

**C** Only 2 and 3

**D** Only 1

Your answer

[1]

15 Which electron configuration(s) is/are correct?

- 1 Cr atom:  $1\text{s}^2 2\text{s}^2 2\text{p}^6 3\text{s}^2 3\text{p}^6 3\text{d}^5 4\text{s}^1$
- 2 Cu atom:  $1\text{s}^2 2\text{s}^2 2\text{p}^6 3\text{s}^2 3\text{p}^6 3\text{d}^{10} 4\text{s}^1$
- 3  $\text{Fe}^{2+}$  ion:  $1\text{s}^2 2\text{s}^2 2\text{p}^6 3\text{s}^2 3\text{p}^6 3\text{d}^5 4\text{s}^1$

**A** 1, 2 and 3

**B** Only 1 and 2

**C** Only 2 and 3

**D** Only 1

Your answer

[1]

## SECTION B

Answer **all** the questions.

**16** This question is about ions and compounds containing hydrogen.

(a) Lithium aluminium hydride,  $\text{LiAlH}_4$ , contains the  $\text{AlH}_4^-$  ion.

Draw a 'dot-and-cross' diagram to show the bonding in an  $\text{AlH}_4^-$  ion.

Show outer electrons only.

[1]

(b) Nitrogen forms  $\text{NH}_4^+$  and  $\text{NH}_2^-$  ions.

Predict the name of the shape of, and H–N–H bond angle in,  $\text{NH}_4^+$  and  $\text{NH}_2^-$ .

| Ion             | Name of shape | H–N–H bond angle |
|-----------------|---------------|------------------|
| $\text{NH}_4^+$ | .....         | .....            |
| $\text{NH}_2^-$ | .....         | .....            |

[2]

(c) Nitrogen, phosphorus and arsenic are in Group 15 (5) of the periodic table.

The boiling points of their hydrides are shown below.

| Element | Hydride        | Boiling point/°C |
|---------|----------------|------------------|
| N       | $\text{NH}_3$  | -33              |
| P       | $\text{PH}_3$  | -88              |
| As      | $\text{AsH}_3$ | -55              |

(i) Explain why the boiling point of  $\text{PH}_3$  is lower than the boiling point of  $\text{NH}_3$ .

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....

[2]

(ii) Explain why the boiling point of  $\text{PH}_3$  is lower than the boiling point of  $\text{AsH}_3$ .

.....  
.....  
.....  
.....  
.....  
.....  
.....  
.....

[2]

10

17 This question is about Group 2 and Group 17 (7).

(a) Barium chloride can be prepared from barium hydroxide in a neutralisation reaction.

Write the equation for this reaction. State symbols are **not** required.

..... [1]

(b) The reactivity of the Group 2 elements Mg–Ba increases down the group.

Explain why.

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

(c) On gently heating, the compound  $\text{KC}l\text{O}_3$  reacts as shown in the equation.



This reaction is an example of disproportionation.

(i) State what is meant by *disproportionation* and use oxidation numbers to show that disproportionation has taken place.

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

(ii) What is the systematic name for  $\text{KC}l\text{O}_4$ ?

..... [1]

(d) Two changes are described below.

For each change,

- write an equation, including state symbols,
- state and explain how the entropy changes.

(i) The reaction of aqueous barium nitrate with aqueous sodium sulfate.

Full equation with state symbols

.....

Explanation of entropy change .....

.....

..... [2]

(ii) The change that accompanies the standard enthalpy change of atomisation of iodine.

Equation with state symbols

.....

Explanation of entropy change .....

.....

..... [2]

12

18 This question is about free energy changes,  $\Delta G$ , enthalpy changes,  $\Delta H$ , and temperature,  $T$ .

(a) The Gibbs' equation is shown below.

$$\Delta G = \Delta H - T\Delta S$$

A chemist investigates a reaction to determine how  $\Delta G$  varies with  $T$ .

The results are shown in Fig. 18.1.

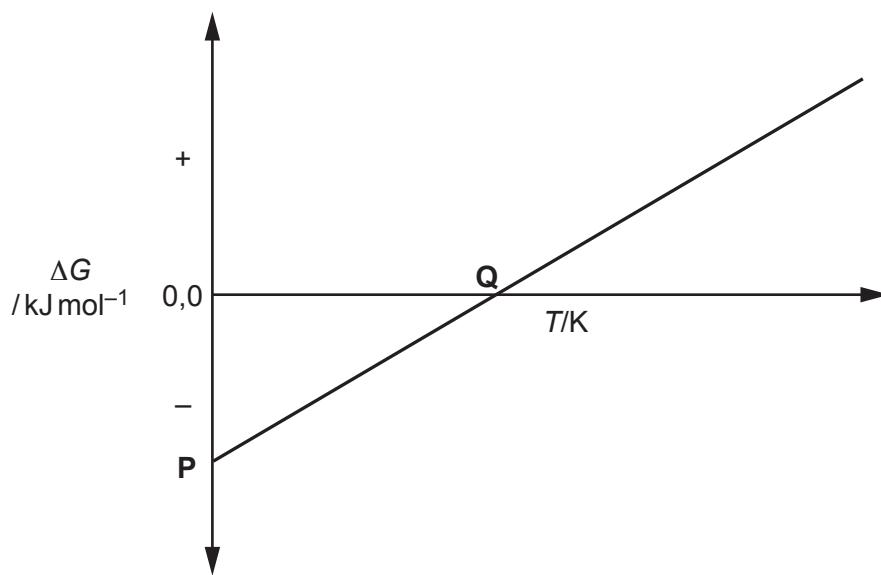
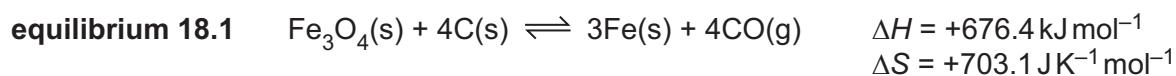


Fig. 18.1

What is significant about the gradient of the line and the values **P** and **Q** shown in **Fig. 18.1**? Explain your reasoning.

. [4]

(b) Iron can be extracted from its ore  $\text{Fe}_3\text{O}_4$  using carbon.  
 Several equilibria are involved including **equilibrium 18.1**, shown below.



(i) Why is **equilibrium 18.1** a *heterogeneous* equilibrium?

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

(ii) Write the expression for  $K_p$  for **equilibrium 18.1**.

[1]

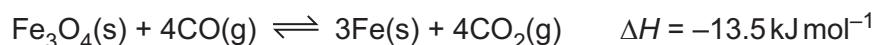
(iii) The forward reaction in **equilibrium 18.1** is only feasible at high temperatures.

- Show that the forward reaction is **not** feasible at 25 °C.
- Calculate the minimum temperature, in K, for the forward reaction to be feasible.

minimum temperature = ..... K [3]

## 14

(iv) Another equilibrium involved in the extraction of iron from  $\text{Fe}_3\text{O}_4$  is shown below.



Enthalpy changes of formation,  $\Delta_f H$ , for  $\text{Fe}_3\text{O}_4(\text{s})$  and  $\text{CO}_2(\text{g})$  are shown in the table.

| Compound                          | $\Delta_f H / \text{kJ mol}^{-1}$ |
|-----------------------------------|-----------------------------------|
| $\text{Fe}_3\text{O}_4(\text{s})$ | -1118.5                           |
| $\text{CO}_2(\text{g})$           | -393.5                            |

Calculate the enthalpy change of formation,  $\Delta_f H$ , for  $\text{CO}(\text{g})$ .

$$\Delta_f H, \text{ for CO(g)} = \dots \text{ kJ mol}^{-1} \quad [3]$$

15

**BLANK PAGE**

**PLEASE DO NOT WRITE ON THIS PAGE**

## 16

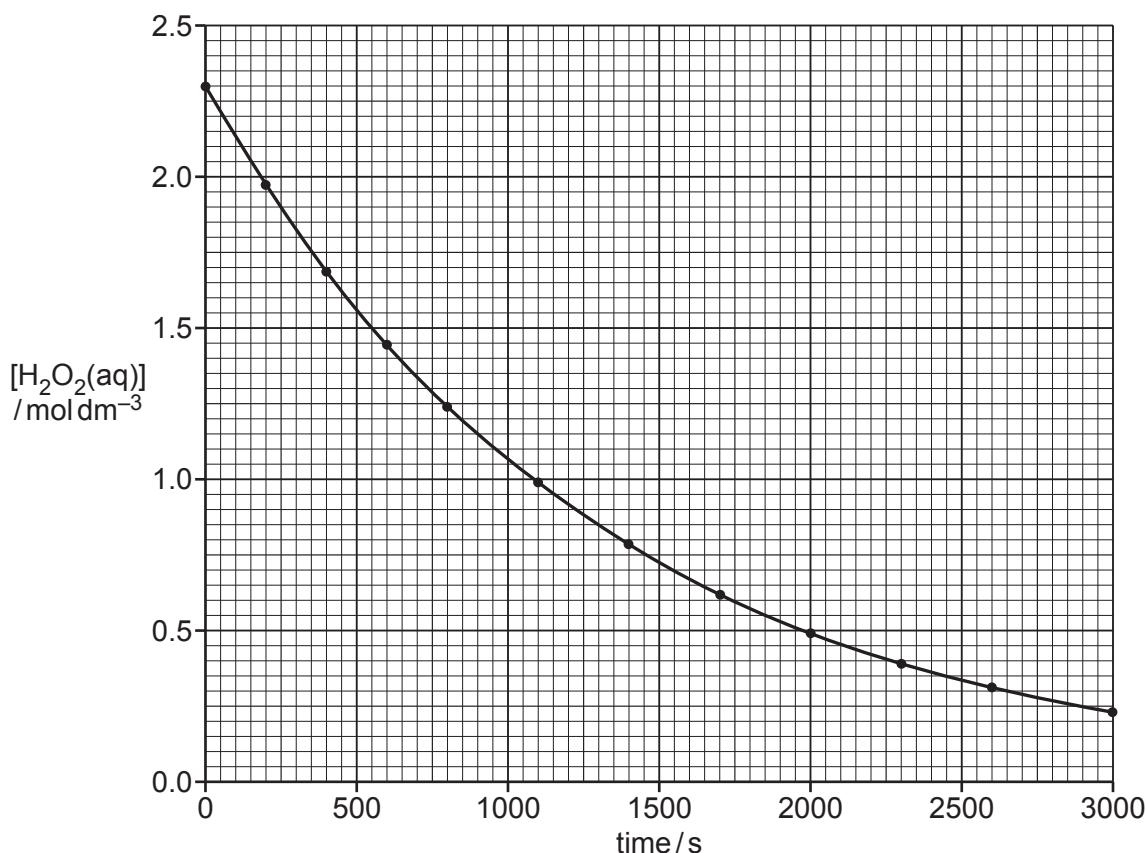
19 Aqueous solutions of hydrogen peroxide,  $\text{H}_2\text{O}_2\text{(aq)}$ , decompose as in the equation below.



A student investigates the decomposition of  $\text{H}_2\text{O}_2\text{(aq)}$  by measuring the volume of oxygen gas produced over time. All gas volumes are measured at room temperature and pressure.

The student uses  $25.0\text{ cm}^3$  of  $2.30\text{ mol dm}^{-3}$   $\text{H}_2\text{O}_2$ .

From the results, the student determines the concentration of  $\text{H}_2\text{O}_2\text{(aq)}$  at each time. The student then plots a concentration–time graph.



(a) Determine the total volume of oxygen, measured at room temperature and pressure, that the student should be prepared to collect in this investigation.

Suggest apparatus that would allow this gas volume to be collected, indicating clearly the scale of working.

.....

.....

.....

.....

.....

.....

.....

[3]

(b) Suggest a different experimental method that would allow the rate of this reaction to be followed over time.

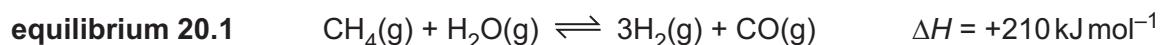
[1]

(c)\* Determine the initial rate of reaction, the order with respect to  $\text{H}_2\text{O}_2$ , and the rate constant.

Your answer must show full working on the graph and on the lines below.

**20** This question is about equilibrium reactions.

(a) Hydrogen gas is manufactured by the chemical industry using the reaction of methane and steam. This is a reversible reaction, shown in **equilibrium 20.1** below.



Explain, in terms of le Chatelier's principle, the conditions of pressure and temperature for a maximum yield of hydrogen from **equilibrium 20.1**, and explain why the operational conditions used by the chemical industry may be different.

. [4]

(b) A chemist investigates the equilibrium reaction between sulfur dioxide, oxygen, and sulfur trioxide, shown below.



- The chemist mixes together  $\text{SO}_2$  and  $\text{O}_2$  with a catalyst.
- The chemist compresses the gas mixture to a volume of  $400\text{ cm}^3$ .
- The mixture is heated to a constant temperature and is allowed to reach equilibrium without changing the total gas volume.

The equilibrium mixture contains  $0.0540\text{ mol SO}_2$  and  $0.0270\text{ mol O}_2$ .

At the temperature used, the numerical value for  $K_c$  is  $3.045 \times 10^4\text{ dm}^3\text{ mol}^{-1}$ .

(i) Write the expression for  $K_c$  and the units of  $K_c$  for this equilibrium.

[2]

(ii) Determine the amount, in mol, of  $\text{SO}_3$  in the equilibrium mixture at this temperature.

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

Show all your working.

equilibrium amount of  $\text{SO}_3$  = ..... mol [4]

## 20

21 This question is about the properties and reactions of ethanoic acid,  $\text{CH}_3\text{COOH}$ . Ethanoic acid is a weak acid with an acid dissociation constant,  $K_a$ , of  $1.75 \times 10^{-5} \text{ mol dm}^{-3}$  at  $25^\circ\text{C}$ .

(a) A student uses a pH meter to measure the pH of a solution of  $\text{CH}_3\text{COOH}$  at  $25^\circ\text{C}$ . The measured pH is 2.440.

Calculate the concentration of ethanoic acid in the solution.

Give your answer to **three** significant figures.

$$\text{concentration} = \dots \text{ mol dm}^{-3} \quad [3]$$

(b) Ethanoic acid is added to another weak acid, fluoroethanoic acid,  $\text{FCH}_2\text{COOH}$  ( $K_a = 2.19 \times 10^{-3} \text{ mol dm}^{-3}$ ). An equilibrium is set up containing two acid-base pairs.

Complete the equilibrium and label the conjugate acid-base pairs as **A1**, **B1** and **A2**, **B2**.



.....   .....   .....   .....

[2]

21

(c) The student plans to prepare a buffer solution that has a pH of 4.50. The buffer solution will contain ethanoic acid,  $\text{CH}_3\text{COOH}$ , and sodium ethanoate,  $\text{CH}_3\text{COONa}$ .

The student plans to add 9.08 g  $\text{CH}_3\text{COONa}$  to  $250\text{ cm}^3$  of  $0.800\text{ mol dm}^{-3}$   $\text{CH}_3\text{COOH}$ . The student assumes that the volume of the solution does not change.

(i) Show by calculation whether, or not, the student's experimental method would produce the required pH.

Show **all** your working.

[5]

(ii) When the student prepares the buffer solution, the volume of solution increases slightly.

Suggest whether the pH of the buffer solution would be the same, greater than, or less than your calculated value in (c)(i).

Explain your reasoning.

.....  
.....  
.....  
.....

[2]

## 22

22 This question is about redox, electrode potentials and feasibility.

**Table 22.1** shows standard electrode potentials for four redox systems. You need to use this information to answer the questions below.

| Redox system | Equation   | $E^\ominus/V$ |
|--------------|--|---------------|
| 1            | $Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$                                | -0.76         |
| 2            | $SO_4^{2-}(aq) + 2H^+(aq) + 2e^- \rightleftharpoons SO_3^{2-}(aq) + H_2O(l)$ | +0.17         |
| 3            | $Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$                           | +0.77         |
| 4            | $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$    | +1.51         |

**Table 22.1**

(a) A standard cell is set up in the laboratory based on redox systems **1** and **3** and the standard cell potential is measured.

(i) Draw a labelled diagram to show how this cell could be set up to measure its standard cell potential.

Include details of the apparatus, solutions and the standard conditions required to measure this standard cell potential.

Standard conditions .....

.....

[4]

(ii) Predict the standard cell potential of this cell.

standard cell potential = ..... V [1]

23

(b) In **Table 22.1**, what is the strongest reducing agent and the strongest oxidising agent?

Strongest reducing agent .....

Strongest oxidising agent .....

[2]

(c) Electrode potentials can be used to predict the feasibility of reactions.

Construct an overall equation for the predicted reaction between the species in redox systems **2** and **4**.

..... [2]

**24**

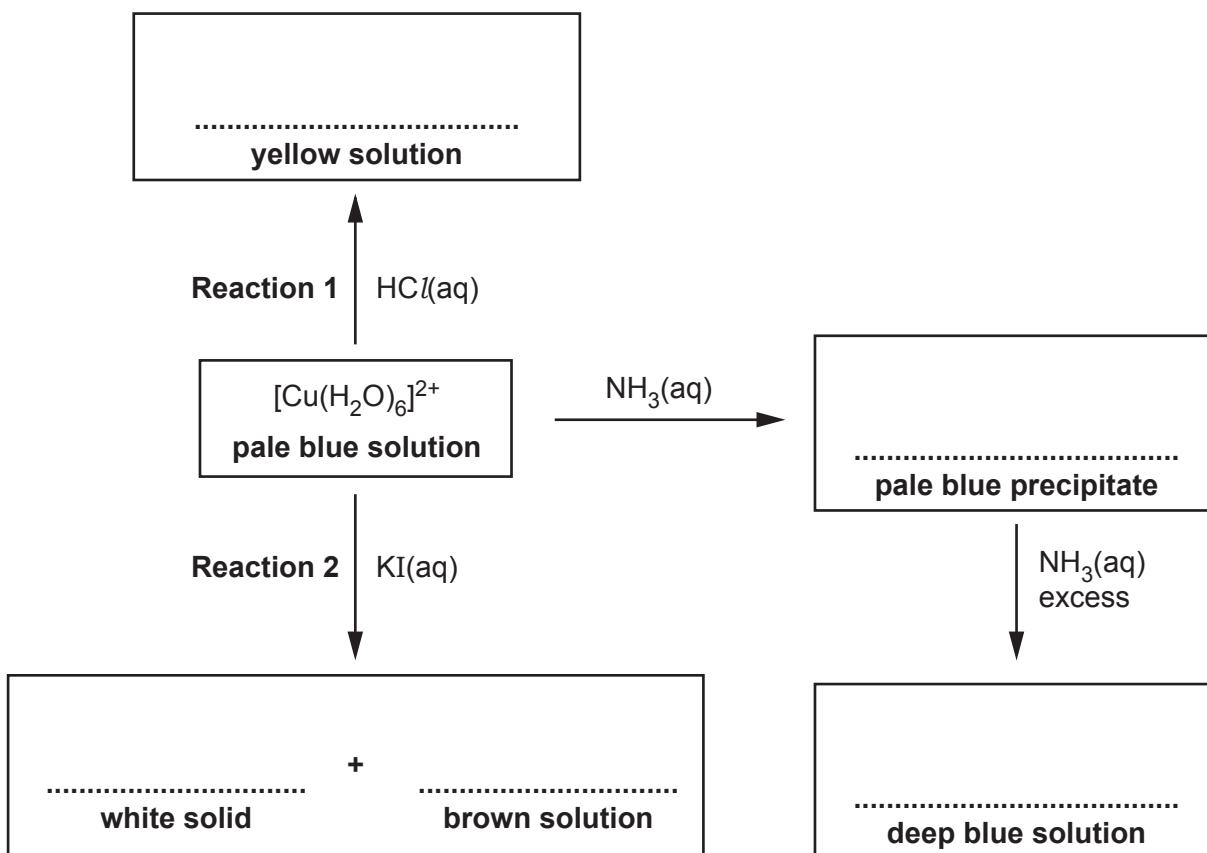
**BLANK PAGE**

**PLEASE DO NOT WRITE ON THIS PAGE**

23 This question is about reactions of ions and compounds of transition elements.

(a) The flowchart shows reactions of the complex ion  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ .

(i) In the boxes, write down the formulae of the species responsible for the observations.



[5]

(ii) Name the type of reaction for **Reaction 1** and **Reaction 2**.

**Reaction 1** .....

**Reaction 2** .....

[2]

(b)\* A hydrated nickel(II) complex, **A**, is heated in a crucible to remove the water of crystallisation. The anhydrous complex **B** is formed. The results are shown below.

Mass of crucible + hydrated complex **A** = 59.554 g  
Mass of crucible + anhydrous complex **B** = 58.690 g  
Mass of crucible = 51.257 g

The anhydrous complex **B** is analysed and found to have a molar mass of  $309.7\text{ g mol}^{-1}$  and to contain the following percentage composition by mass:

Ni, 18.95%; C, 23.25%; N, 27.12%; H, 7.75%; Cl, 22.93%.

The anhydrous complex **B** contains a cation **C** comprising Ni, C, N and H only.

Cation **C** is six-coordinate, contains three molecules of the bidentate ligand **D**, and exists as optical isomers.

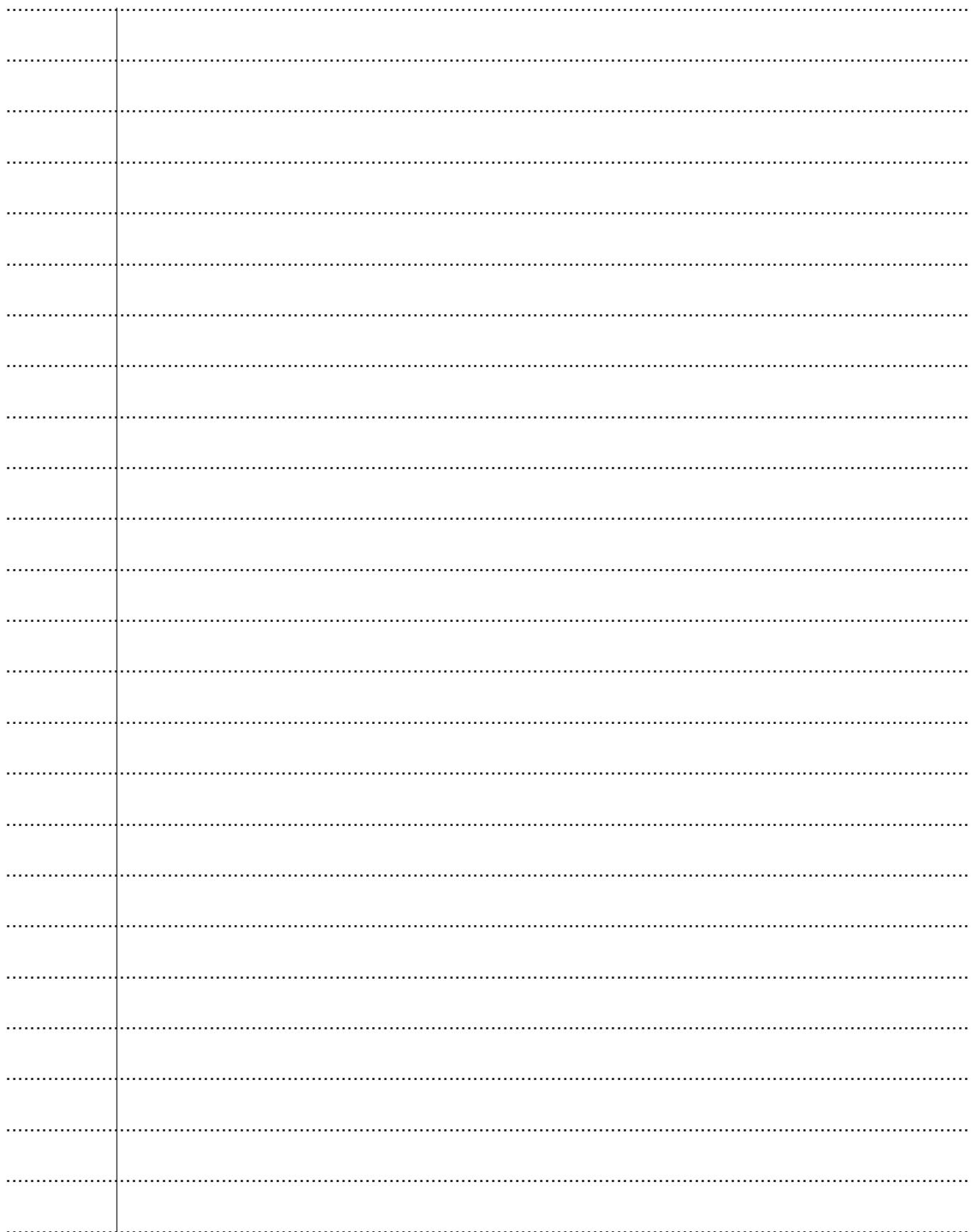
Determine the formula of **A**, **B**, **C** and **D** and show the 3D structures for the optical isomers of **C**.

Show **all** your working.

END OF QUESTION PAPER

**ADDITIONAL ANSWER SPACE**

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





Oxford Cambridge and RSA

### Copyright Information

OCR is committed to seeking permission to reproduce all third-party content that it uses in its assessment materials. OCR has attempted to identify and contact all copyright holders whose work is used in this paper. To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced in the OCR Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download from our public website ([www.ocr.org.uk](http://www.ocr.org.uk)) after the live examination series.

If OCR has unwittingly failed to correctly acknowledge or clear any third-party content in this assessment material, OCR will be happy to correct its mistake at the earliest possible opportunity.

For queries or further information please contact the Copyright Team, First Floor, 9 Hills Road, Cambridge CB2 1GF.

For queries or further information, please contact the Copyright Team, The University, Hills Road, Cambridge CB2 2SE.

OCR is part of the Cambridge Assessment Group; Cambridge Assessment is the brand name of University of Cambridge Local Examinations Syndicate (UCLES), which is itself a department of the University of Cambridge.