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.

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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 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 $[Fe(H_2O)_6]^{2+}$?

A Metallic

B Ionic

C Hydrogen

D Dative covalent

Your answer ☐ **[1]**

3 What is the oxidation number of Mn in K_2MnO_4?

A +4

B +5

C +6

D +7

Your answer ☐ **[1]**

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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^{-3} HCl.

What is the volume, in cm^3, of 2.00 mol dm^{-3} HCl required for this reaction?

A 15

B 20

C 30

D 60

Your answer ☐ **[1]**

6 How many electrons are removed from 2.02×10^{-2} g of Ne(g) atoms to form Ne^+(g) ions?

A 3.36×10^{-26}

B 1.66×10^{-27}

C 6.02×10^{20}

D 1.22×10^{22}

Your answer ☐ **[1]**

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7 Silicon can be made by heating silicon tetrachloride, $SiCl_4$, with zinc.

$$SiCl_4 + 2Zn \rightarrow Si + 2ZnCl_2$$

8.50 g of $SiCl_4$ 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 NH_4Cl(aq) and NaOH(aq)

B KBr(aq) and $AgNO_3$(aq)

C $FeCl_3$(aq) and NH_3(aq)

D $Cr_2(SO_4)_3$(aq) and $BaCl_2$(aq)

Your answer ☐ **[1]**

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9 Enthalpy values are provided below.

$H_2(g) + I_2(g) \rightarrow 2HI(g)$ $\Delta_r H = -9\,kJ\,mol^{-1}$

Bond	Bond enthalpy / kJ mol^{-1}
H–H	+436
I–I	+151

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

A –596

B –298

C +298

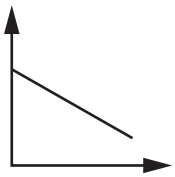
D +596

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?

A



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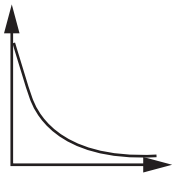

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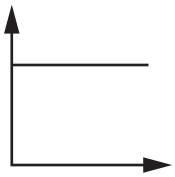

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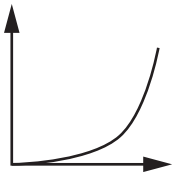

Your answer ☐ **[1]**

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

Which product is formed?

A $Cr(OH)_6^{3-}$

B $Cr(OH)_3$

C $[Cr(OH)_4(H_2O)_2]^-$

D $[Cr(OH)_4]^{3-}$

Your answer ☐ **[1]**

12 **HA** and **HB** are two strong monobasic acids.
25.0 cm^3 of 6.0 mol dm^{-3} **HA** is mixed with 45.0 cm^3 of 3.0 mol dm^{-3} **HB**.

What is the $H^+(aq)$ concentration, in mol dm^{-3}, in the resulting solution?

A 1.9

B 2.1

C 4.1

D 4.5

Your answer ☐ **[1]**

13 A mixture of N_2 and O_2 gases has a total pressure of 1.42 atm.
The mole fraction of N_2 is 0.700.

What is the partial pressure, in atm, of O_2 in the mixture?

A 0.211

B 0.426

C 0.493

D 0.994

Your answer ☐ **[1]**

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

$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$ $E^{\ominus} = +0.34\,V$
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$ $E^{\ominus} = +0.80\,V$

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 $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$.

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: $1s^22s^22p^63s^23p^63d^54s^1$

2 Cu atom: $1s^22s^22p^63s^23p^63d^{10}4s^1$

3 Fe^{2+} ion: $1s^22s^22p^63s^23p^63d^54s^1$

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 ions and compounds containing hydrogen.

(a) Lithium aluminium hydride, $LiAlH_4$, contains the AlH_4^- ion.

Draw a '*dot-and-cross*' diagram to show the bonding in an AlH_4^- ion.

Show outer electrons only.

[1]

(b) Nitrogen forms NH_4^+ and NH_2^- ions.

Predict the name of the shape of, and H–N–H bond angle in, NH_4^+ and NH_2^-.

Ion	Name of shape	H–N–H bond angle
NH_4^+	.....	.....
NH_2^-	.....	.....

[2]

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(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	NH_3	–33
P	PH_3	–88
As	AsH_3	–55

(i) Explain why the boiling point of PH_3 is lower than the boiling point of NH_3.

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

(ii) Explain why the boiling point of PH_3 is lower than the boiling point of AsH_3.

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

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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.

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

(c) On gently heating, the compound $KClO_3$ reacts as shown in the equation.

$$4KClO_3(s) \rightarrow KCl(s) + 3KClO_4(s)$$

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.

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

(ii) What is the systematic name for $KClO_4$?

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

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(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

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Explanation of entropy change .....

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

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

Equation with state symbols

.....

Explanation of entropy change .....

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

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18 This question is about free energy changes, ΔG, enthalpy changes, ΔH, 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 ΔG varies with T.
The results are shown in **Fig. 18.1**.

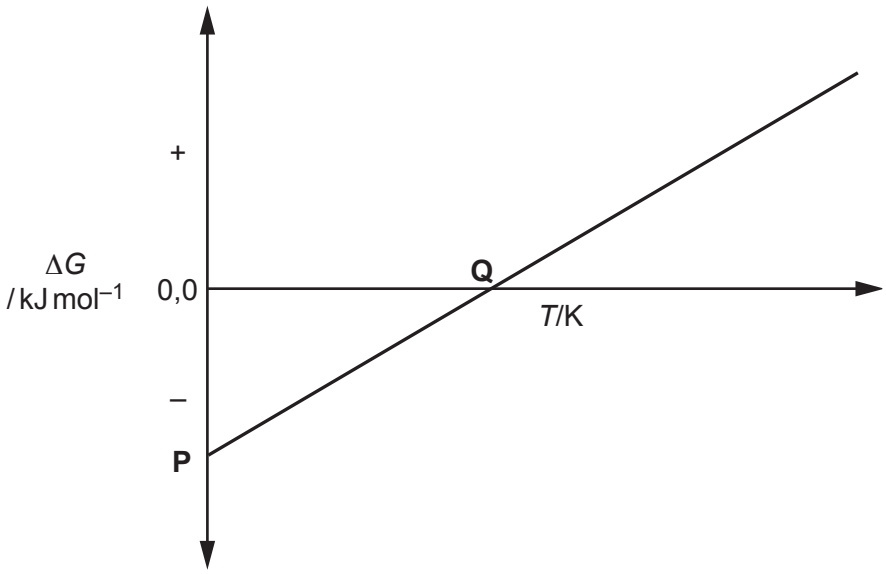

Fig. 18.1

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

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

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(b) Iron can be extracted from its ore Fe_3O_4 using carbon.
Several equilibria are involved including **equilibrium 18.1**, shown below.

equilibrium 18.1 $Fe_3O_4(s) + 4C(s) \rightleftharpoons 3Fe(s) + 4CO(g)$ $\Delta H = +676.4\,kJ\,mol^{-1}$
$\Delta S = +703.1\,J\,K^{-1}\,mol^{-1}$

(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]**

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(iv) Another equilibrium involved in the extraction of iron from Fe_3O_4 is shown below.

$$Fe_3O_4(s) + 4CO(g) \rightleftharpoons 3Fe(s) + 4CO_2(g) \qquad \Delta H = -13.5\,kJ\,mol^{-1}$$

Enthalpy changes of formation, $\Delta_f H$, for $Fe_3O_4(s)$ and $CO_2(g)$ are shown in the table.

Compound	$\Delta_f H$ **/ kJ mol^{-1}**
$Fe_3O_4(s)$	–1118.5
$CO_2(g)$	–393.5

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

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

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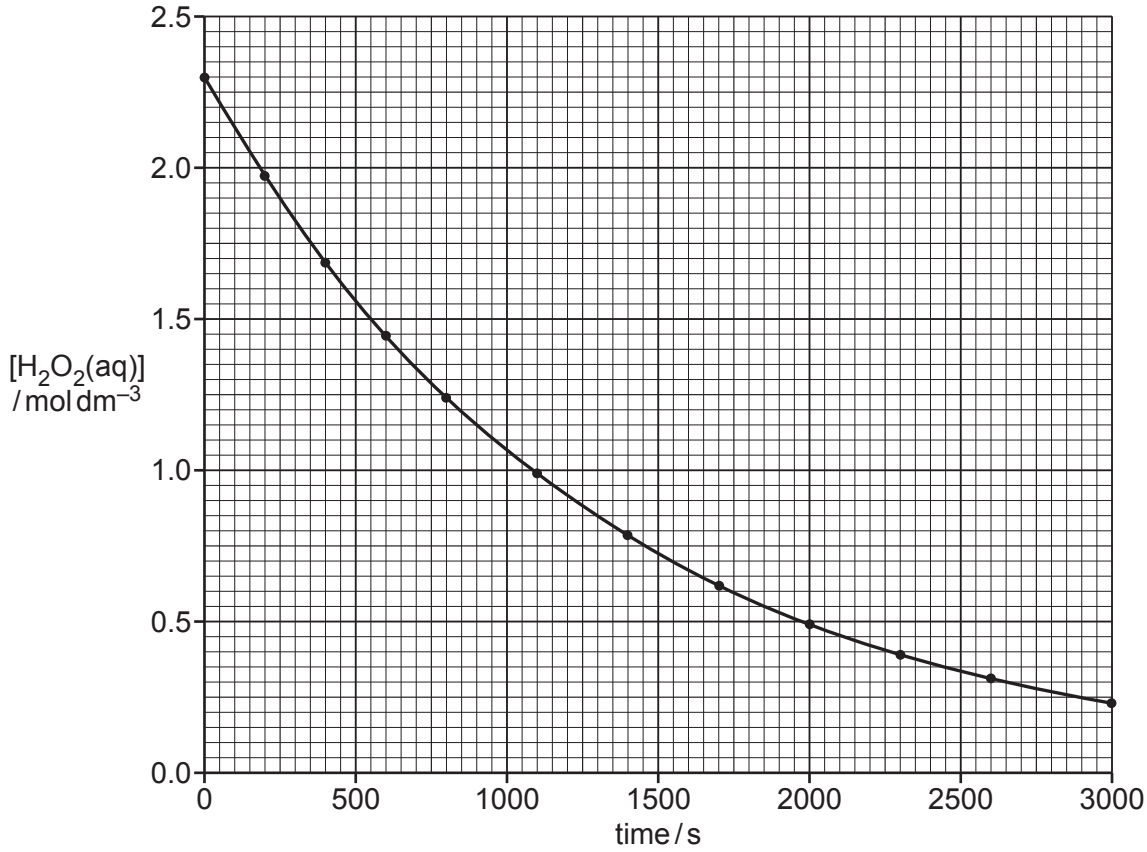
19 Aqueous solutions of hydrogen peroxide, $H_2O_2(aq)$, decompose as in the equation below.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

A student investigates the decomposition of $H_2O_2(aq)$ 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 cm^3 of 2.30 mol dm^{-3} H_2O_2.

From the results, the student determines the concentration of $H_2O_2(aq)$ 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.

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

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

(c)* Determine the initial rate of reaction, the order with respect to H_2O_2, and the rate constant.

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

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

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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.

equilibrium 20.1 $CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$ $\Delta H = +210\,kJ\,mol^{-1}$

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.

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

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

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

- The chemist mixes together SO_2 and O_2 with a catalyst.
- The chemist compresses the gas mixture to a volume of 400 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 mol SO_2 and 0.0270 mol O_2.

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

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

[2]

(ii) Determine the amount, in mol, of 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 SO_3 = ... mol **[4]**

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21 This question is about the properties and reactions of ethanoic acid, CH_3COOH.
Ethanoic acid is a weak acid with an acid dissociation constant, K_a, of 1.75×10^{-5} mol dm^{-3} at 25 °C.

(a) A student uses a pH meter to measure the pH of a solution of CH_3COOH at 25 °C.
The measured pH is 2.440.

Calculate the concentration of ethanoic acid in the solution.

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

concentration = ... mol dm^{-3} **[3]**

(b) Ethanoic acid is added to another weak acid, fluoroethanoic acid, FCH_2COOH ($K_a = 2.19 \times 10^{-3}$ 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**.

$CH_3COOH + FCH_2COOH \rightleftharpoons$ ..... + ...

....

[2]

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(c) The student plans to prepare a buffer solution that has a pH of 4.50. The buffer solution will contain ethanoic acid, CH_3COOH, and sodium ethanoate, CH_3COONa.

The student plans to add 9.08 g CH_3COONa to 250 cm^3 of 0.800 mol dm^{-3} CH_3COOH. 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.

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

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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]**

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(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]**

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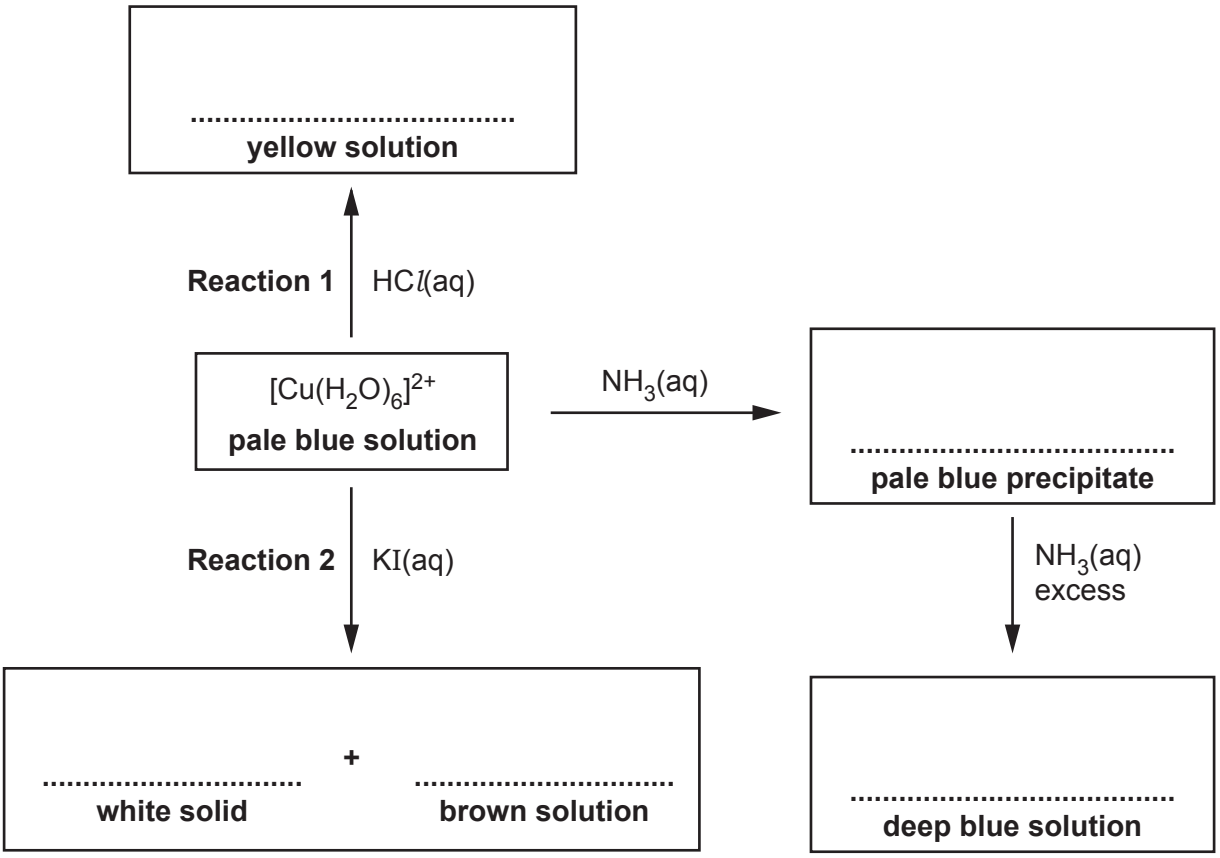
23 This question is about reactions of ions and compounds of transition elements.

(a) The flowchart shows reactions of the complex ion $[Cu(H_2O)_6]^{2+}$.

(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]

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(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 g mol^{-1} and to contain the following percentage composition by mass:

Ni, 18.95%; C, 23.25%; N, 27.12%; H, 7.75%; C*l*, 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.

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

END OF QUESTION PAPER

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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).

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