1 Copper and zinc are both in the d-block of the Periodic Table. Copper forms compounds that contain Cu^+ and Cu^{2+} ions but zinc only forms compounds that contain Zn^{2+} ions.

(a) Complete the electronic configurations of the Cu^{2+} ions and Zn^{2+} ions and hence explain why copper is classified as a transition metal but zinc is not.

(2)

Cu^{2+} [Ar] .....

Zn^{2+} [Ar] .....

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(b) Some photochromic glasses contain silver(I) and copper(I) chlorides.

Explain, with the aid of an equation, why these photochromic glasses go darker in sunlight.

(2)

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(c) Copper forms a complex ion with the formula $[CuCl_4]^{2-}$. This has the same shape as $[Pt(NH_3)_2Cl_2]$.

Draw the shape of the $[CuCl_4]^{2-}$ ion and state the type of bonding between the ligands and the metal ion.

(2)

Shape

Bonding.....

(d) The $[CuCl_2]^-$ ion is formed by boiling a solution of copper(II) chloride with copper turnings and concentrated hydrochloric acid.

(i) Write an equation for this reaction. State symbols are not required.

(1)

(ii) State the meaning of the term **disproportionation** and explain whether or not this reaction to form the $[CuCl_2]^-$ ion is a disproportionation reaction.

(2)

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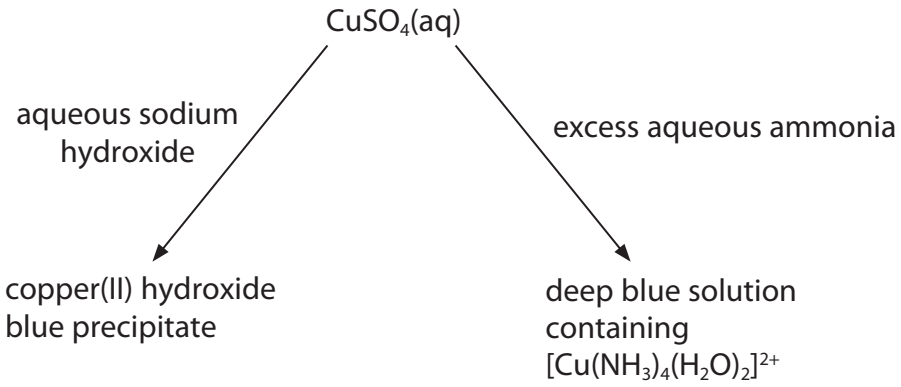
(iii) Explain why the $[CuCl_2]^-$ ions are colourless.

(2)

(e) Copper(II) sulfate solution reacts with aqueous sodium hydroxide and with aqueous ammonia.



(i) Write the **ionic** equation for the reaction of copper(II) sulfate solution with aqueous sodium hydroxide. Include state symbols.

(1)

(ii) State the type of reaction occurring overall when excess aqueous ammonia is added to copper(II) sulfate solution.

(1)

(f) 1,2-diaminoethane is a bidentate ligand. It reacts with copper(II) ions in aqueous solution.

$$[Cu(H_2O)_6]^{2+} + 3H_2NCH_2CH_2NH_2 \rightleftharpoons [Cu(H_2NCH_2CH_2NH_2)_3]^{2+} + 6H_2O$$

(i) State what is meant by the term **bidentate**.

(1)

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(ii) Explain, in terms of entropy, why the reaction takes place.

(2)

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(Total for Question = 16 marks)

2 (a) The table below shows the first and second ionization energies of nickel, copper and zinc.

Element	1st ionization energy / kJ mol^{-1}	2nd ionization energy / kJ mol^{-1}
Ni	737	1753
Cu	746	1958
Zn	906	1733

(i) Complete the electronic configurations for an atom of nickel and an atom of copper.

(2)

Ni: $1s^2\ 2s^2\ 2p^6$ .....

Cu: $1s^2\ 2s^2\ 2p^6$ .....

*(ii) The values for the first ionization energies of copper and nickel are similar, but the values of the second ionization energies are significantly different.

Explain how these data give evidence for the electronic configuration of a copper atom.

(2)

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(iii) Suggest why you might expect the **third** ionization energies of the three elements to increase from nickel to zinc.

(1)

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(b) (i) $Cu^+(aq)$ ions are not stable in solution and undergo a disproportionation reaction.

Suggest an equation for this reaction, including state symbols.

(1)

(ii) Suggest in what way the **appearance** of CuI is similar to that of ZnI_2.

Give a reason for this similarity.

(2)

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(c) Explain why zinc is **not** classified as a transition element.

(1)

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(Total for Question = 9 marks)

3 Chromium is a typical transition metal: it forms complexes, coloured compounds and exists in a range of stable oxidation states. Chromium and some of its compounds also show catalytic properties.

(a) Define the term **transition metal**.

(1)

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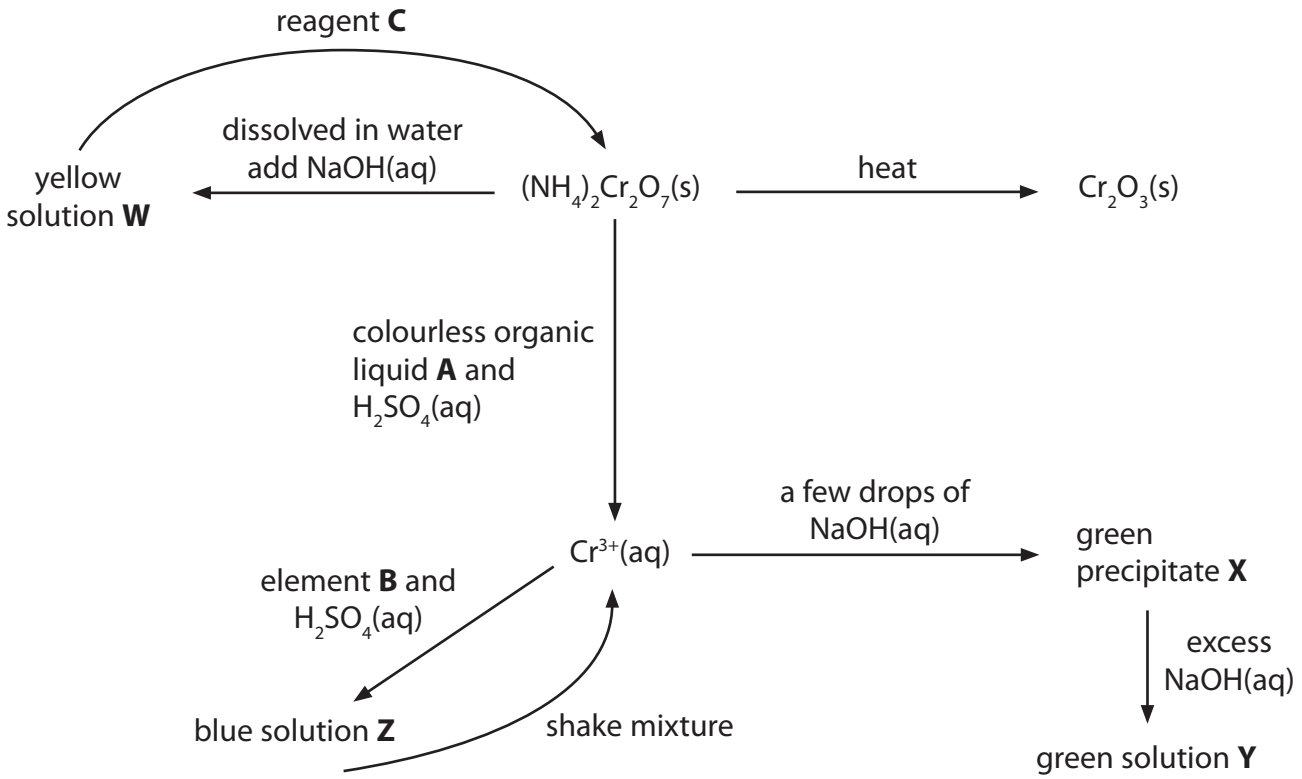
(b) The diagram below summarises some reactions of chromium compounds.



(i) Identify, by name (including the oxidation state where appropriate) or formula, the species containing **chromium** in the sequence.

(4)

W .....

X .....

Y .....

Z .....

(ii) Identify, by name or formula, suitable reagents for the sequence.

(3)

A .....

B .....

C .....

(iii) Write the ionic equation for the reaction between $(NH_4)_2Cr_2O_7$ and NaOH to form the yellow solution. State symbols are not required.

(1)

(iv) When $(NH_4)_2Cr_2O_7$ is heated, steam and nitrogen are formed as well as Cr_2O_3. Write the equation for this reaction. State symbols are not required.

Explain why this is a redox reaction, stating any changes in oxidation numbers that occur.

(3)

Equation

Explanation .....

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(v) Explain how shaking solution **Z** re-forms $Cr^{3+}(aq)$.

(1)

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(c) If excess aqueous ammonia is added to $Cr^{3+}(aq)$, the ammonia acts as a ligand and the resulting green solution contains a chromium species which is different from the one found in **Y**.

(i) Explain the term 'ligand'.

(2)

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(ii) Write an equation for the reaction that occurs, showing **all** the ligands involved for both the chromium species in the reaction. State symbols are not required.

(2)

(Total for Question = 17 marks)

4 This question is about the transition metal iron and some of its compounds.

(a) Give the electronic configuration of the Fe^{3+} ion and use this to define what is meant by a transition element.

(2)

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*(b) Iron will act as a surface catalyst in some gaseous reactions. Outline the processes that take place during such catalysis and suggest two reasons to explain why the catalyst speeds up the reaction.

(4)

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(c) One of the components of rust, found on objects made from iron, is iron(III) hydroxide, $Fe(OH)_3$. Use items 17, 19 and 44 from the Standard Electrode Potential table in your data booklet to show how it is able to form in two steps, writing an equation for each step.

(4)

(d) Haemoglobin is a complex containing iron(II) ions.

Describe how nitrogen atoms in the haemoglobin bond to the iron(II) ions.

(2)

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(Total for Question 12 marks)

5 More than half of the elements in the Periodic Table are transition elements. Vanadium, element 23, is a typical transition element.

(a) (i) Give TWO properties shown by vanadium **compounds** that are characteristic of transition metal chemistry, other than variable oxidation state.

(2)

(ii) Vanadium(III) ions in aqueous solution exist as $[V(H_2O)_6]^{3+}$.

Draw this ion so as to clearly show its shape. Name the type of bond between the ligand and the vanadium ion and state the feature of the ligand that enables this bond to be formed.

(3)

(b) Vanadium ions exist in oxidation states from (V) to (II).

(i) Use your data booklet (page 15) to find the standard electrode (reduction) potential for the reduction of vanadium(IV), VO^{2+}, to vanadium(III), V^{3+}.

(1)

*(ii) Explain the term **disproportionation.**

(2)

(iii) Use your answer to (b)(i), and the data below, to calculate $E^{\ominus}_{cell}$ for the formation of vanadium(V) and vanadium(III) from vanadium(IV) in acidic solution. State if the reaction is feasible under standard conditions and justify your answer.

$VO_2^+(aq) + 2H^+(aq) + e^- \rightleftharpoons VO^{2+}(aq) + H_2O(l) \quad E^{\ominus} = +1.00\ V$

(2)

(Total for Question = 10 marks)