Q1. Hydrogen peroxide is used as an oxidising agent in the preparation of transition metal complexes.

(a) Consider the following reaction scheme. All the complexes are in aqueous solution.

$$[Co(H_2O)_6]^{2+} \xrightarrow{\text{Reaction 1}} \text{cobalt(II) complex} \xrightarrow[H_2O_2]{\text{Reaction 2}} [Co(NH_3)_6]^{3+}$$

(i) Identify a reagent for Reaction **1** and describe the colour change that occurs.

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(3)

(ii) State the colour of the final solution formed in Reaction **2**.

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(1)

(b) Consider the following reaction scheme. All the complexes are in aqueous solution.

$$[Cr(H_2O)_6]^{3+} \xrightarrow[\text{Excess NaOH(aq)}]{\text{Reaction 3}} \text{chromium(III) complex} \xrightarrow[H_2O_2]{\text{Reaction 4}} CrO_4^{2-}$$

(i) For Reaction **3**, state the colour of the initial and of the final solution and write an equation for the reaction.

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(4)

(ii) Write a half-equation for the reduction of hydrogen peroxide to hydroxide ions.

Deduce an overall equation for Reaction **4** and state the colour of the final

solution.

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(4)

(c) The concentration of a hydrogen peroxide solution can be determined by titration with acidified potassium manganate(VII) solution. In this reaction the hydrogen peroxide is oxidised to oxygen gas.

A 5.00 cm^3 sample of the hydrogen peroxide solution was added to a volumetric flask and made up to 250 cm^3 of aqueous solution. A 25.0 cm^3 sample of this diluted solution was acidified and reacted completely with 24.35 cm^3 of 0.0187 mol dm^{-3} potassium manganate(VII) solution.

Write an equation for the reaction between acidified potassium manganate(VII) solution and hydrogen peroxide.
Use this equation and the results given to calculate a value for the concentration, in mol dm^{-3}, of the original hydrogen peroxide solution.
(If you have been unable to write an equation for this reaction you may assume that 3 mol of $KMnO_4$ react with 7mol of H_2O_2. This is **not** the correct reacting ratio.)

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(5)
(Total 17 marks)

Q2. Calcium fluoride occurs naturally as the mineral fluorite, a very hard crystalline solid that is almost insoluble in water and is used as a gemstone.

Tables 1 and **2** contain thermodynamic data.

Table 1

Process	$\Delta H^{\ominus}$ / kJ mol^{-1}
$Ca(s) \rightarrow Ca(g)$	+193
$Ca(g) \rightarrow Ca^{+}(g) + e^{-}$	+590
$Ca^{+}(g) \rightarrow Ca^{2+}(g) + e^{-}$	+1150
$F_2(g) \rightarrow 2F(g)$	+158
$F(g) + e^{-} \rightarrow F^{-}(g)$	–348

Table 2

Name of enthalpy change	$\Delta H^{\ominus}$ / kJ mol^{-1}
Enthalpy of lattice dissociation for calcium fluoride	+2602
Enthalpy of lattice dissociation for calcium chloride	+2237
Enthalpy of hydration for F^- ions	–506
Enthalpy of hydration for Cl^- ions	–364
Enthalpy of hydration for Ca^{2+} ions	–1650

(a) Write an equation, including state symbols, for the process that occurs when the calcium fluoride lattice dissociates and for which the enthalpy change is equal to the lattice enthalpy.

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(1)

(b) (i) Define the term *standard enthalpy of formation*.

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(3)

(ii) Write an equation, including state symbols, for the process that has an enthalpy change equal to the standard enthalpy of formation of calcium fluoride.

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(1)

(iii) Use data from the **Tables 1** and **2** to calculate the standard enthalpy of formation for calcium fluoride.

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(3)

(c) Explain why the enthalpy of lattice dissociation for calcium fluoride is greater than that for calcium chloride.

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(2)

(d) Calcium chloride dissolves in water. After a certain amount has dissolved, a saturated solution is formed and the following equilibrium is established.

$$CaCl_2(s) \rightleftharpoons Ca^{2+}(aq) + 2Cl^-(aq)$$

(i) Using data from **Table 2**, calculate the enthalpy change for this reaction.

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(2)

(ii) Predict whether raising the temperature will increase, decrease or have no effect on the amount of solid calcium chloride that can dissolve in a fixed mass of water.
Explain your prediction.
(If you have been unable to obtain an answer to part (d) (i), you may assume that the enthalpy change = –60 kJ mol^{-1}. This is **not** the correct answer.)

Effect on amount of solid that can dissolve .....

Explanation .....

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(3)

(e) Calcium fluoride crystals absorb ultra-violet light. Some of the energy gained is given out as visible light. The name of this process, fluorescence, comes from the name of the mineral, fluorite.

Use your knowledge of the equation $\Delta E = h\nu$ to suggest what happens to the electrons in fluorite when ultra-violet light is absorbed and when visible light is given out.

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(2)

(Total 17 marks)

Q3. Transition elements form complex ions with a range of colours and shapes.

(a) By considering its electron arrangement, state how an element can be classified as a transition element.

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(1)

(b) Explain the meaning of the term *complex ion*.

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(2)

(c) In terms of electrons, explain why an aqueous solution of cobalt(II) sulfate has a red colour.

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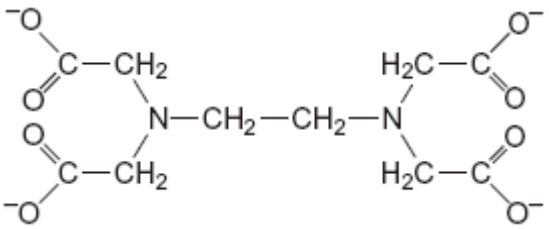
(3)

(d) The ligand $EDTA^{4-}$ is shown below.



(i) Draw circles around the atoms of **two** different elements that link to a transition metal ion by a co-ordinate bond when $EDTA^{4-}$ behaves as a ligand.

(2)

(ii) Write an equation for the reaction between $EDTA^{4-}$ and a $[Co(H_2O)_6]^{2+}$ ion. Use the abbreviation $EDTA^{4-}$ in your equation.

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(1)

(iii) Explain why the complex ion, formed as a product of the reaction in part (d) (ii), is more stable than the $[Co(H_2O)_6]^{2+}$ ion.

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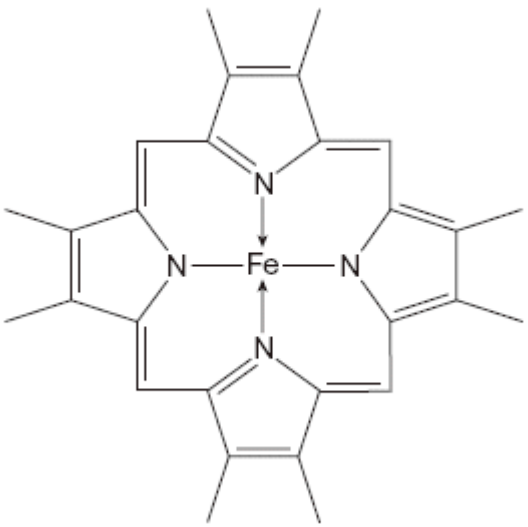
(2)

(e) The diagram below shows part of the structure of haemoglobin.



Haemoglobin contains an iron(II) ion bonded to five nitrogen atoms and one other ligand. The fifth nitrogen atom and the additional ligand are not shown in this

diagram.

(i) In this diagram, bonds between nitrogen and iron are shown as N→Fe and as N—Fe.

State the meaning of each of these symbols.

Meaning of → ….....

Meaning of — .....

(2)

(ii) State the function of haemoglobin in the blood.

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(1)

(iii) With reference to haemoglobin, explain why carbon monoxide is toxic.

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(2)

(Total 16 marks)