Q1. Iron(II) ethanedioate is another insoluble solid used as a pigment in paints and glass. It occurs as a dihydrate ($FeC_2O_4.2H_2O$). One procedure used for the preparation of iron(II) ethanedioate is outlined below.

Procedure

A 6.95 g sample of hydrated iron(II) sulfate ($FeSO_4.7H_2O$) was added to 100 cm^3 of water in a beaker and stirred until all of the solid dissolved. A 150 cm^3 volume of 0.20 mol dm^{-3} sodium ethanedioate solution was added to the beaker. The mixture was stirred until precipitation was complete. After filtration, 3.31 g of the dihydrate ($FeC_2O_4.2H_2O$) were collected.

(a) Write an equation for the reaction between iron(II) sulfate and sodium ethanedioate.

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(1)

(b) Calculate the amount, in moles, of $FeSO_4.7H_2O$ in 6.95 g of hydrated iron(II) sulfate. Show your working.

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(c) Calculate the amount, in moles, of sodium ethanedioate in 150 cm^3 of 0.20 mol dm^{-3} sodium ethanedioate solution.

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(d) Calculate the percentage yield of iron(II) ethanedioate dihydrate (M_r = 179.8) formed in this reaction.
Give your answer to the appropriate precision. Show your working.

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(e) In this experiment, no side reactions take place, the reagents are pure and the reaction goes to completion.

Suggest **one** reason why the yield of iron(II) ethanedioate dihydrate in this experiment is less than 100%.

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(f) When dissolved in dilute sulfuric acid, the number of moles of ethanedioate ions in a pigment can be determined by titration with acidified potassium manganate(VII).

Explain why the titration of a sample of iron(II) ethanedioate would require a different amount of potassium manganate(VII) than a titration of an equimolar amount of copper(II) ethanedioate.

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(Total 9 marks)

Q2.(a) Explain the meaning of the terms *ligand* and *bidentate* as applied to transition metal complexes.

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(b) Aqueous cobalt(II) ions react separately with an excess of chloride ions and with an excess of ammonia.

For each reaction, draw a diagram to illustrate the structure of, the shape of and the charge on the complex ion formed.

In each case, name the shape and indicate, on the diagram, a value for the ligand-metal-ligand bond angle.

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(c) The complex ion formed in aqueous solution between cobalt(II) ions and chloride ions is a different colour from the $[Co(H_2O)_6]^{2+}$ ion.

Explain why these complex ions have different colours.

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(d) In aqueous ammonia, cobalt(II) ions are oxidised to cobalt(III) ions by hydrogen peroxide. The H_2O_2 is reduced to hydroxide ions.

Calculate the minimum volume of 5.00 mol dm^{-3} H_2O_2 solution required to oxidise the

Co^{2+} ions in 9.87 g of $CoSO_4.7H_2O$

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(Total 16 marks)

Q3. You may find the following electrode potential data helpful when answering this question.

Electrode half-equation	$E^{\ominus}$ / V
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	+1.33
$O_2(g) + 4H^+(aq) + 4e^- \longrightarrow 2H_2O(l)$	+1.23
$Cr^{3+}(aq) + e^- \longrightarrow Cr^{2+}(aq)$	–0.44
$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$	–0.76
$Cr^{2+}(aq) + 2e^- \longrightarrow Cr(s)$	–0.91

(a) Describe the colour changes that you would observe when an excess of zinc is added to an acidified solution of potassium dichromate(VI) in the absence of air.

For each colour change, identify the coloured ions responsible and write an equation for each reaction that occurs with zinc.
In the equations, you should represent the ions in their simplest form, for example Cr^{3+}.

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(b) Describe what you would observe when dilute aqueous sodium hydroxide is added, dropwise until in excess, to a dilute aqueous solution containing chromium(III) ions.

Write **two** equations to illustrate your observations.
In these equations you should give the full formula of each of the complexes, for example $[Cr(H_2O)_6]^{3+}$.

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(c) When an aqueous solution containing $[Cr(H_2O)_6]^{3+}$ ions is warmed in the presence of Cl^- ions, $[Cr(H_2O)_5Cl]^{2+}$ ions are formed and the colour of the solution changes.

Name this type of reaction.

Suggest, in terms of electrons, why the colours of the complex ions are different.

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(3)

(d) The chromium(II) ion $[Cr(H_2O)_6]^{2+}$ has different properties from the $[Cr(H_2O)_6]^{3+}$ ion.

Use data from the table above to explain why, in an open container, $[Cr(H_2O)_6]^{2+}$(aq) ions change into $[Cr(H_2O)_6]^{3+}$(aq) ions.

Suggest the identity of the products formed in each case when sodium carbonate solution is added to separate solutions containing $[Cr(H_2O)_6]^{2+}$(aq) ions and $[Cr(H_2O)_6]^{3+}$(aq) ions.

Explain why the $[Cr(H_2O)_6]^{3+}$(aq) ions behave differently from the $[Cr(H_2O)_6]^{2+}$(aq) ions.

In your answer to this part of the question, equations are **not** required.

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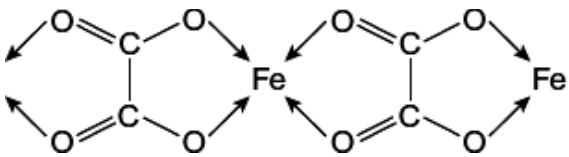
(Total 19 marks)

Q4. Solid iron(II) ethanedioate dihydrate ($FeC_2O_4.2H_2O$) has a polymeric structure.
Two repeating units in the polymer chain are shown.



Each iron ion is also bonded to two water molecules. These are **not** shown in the diagram.

(a) Name the type of bond that is represented by the arrows.

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(b) In terms of electrons explain how the water molecules, **not** shown in the diagram, form bonds to the iron.

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(2)

(c) Predict the value of the bond angle between the two bonds to iron that are formed by these two water molecules.

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(1)

(d) Iron(II) ethanedioate dihydrate can be analysed by titration using potassium manganate(VII) in acidic solution. In this reaction, manganate(VII) ions oxidise iron(II) ions and ethanedioate ions.

A 1.381 g sample of impure $FeC_2O_4.2H_2O$ was dissolved in an excess of dilute sulfuric acid and made up to 250 cm^3 of solution.
25.0 cm^3 of this solution decolourised 22.35 cm^3 of a 0.0193 mol dm^{-3} solution of potassium manganate(VII).

(i) Use the half-equations given below to calculate the reacting ratio of moles of manganate(VII) ions to moles of iron(II) ethanedioate.

$$MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$$

$$Fe^{2+} \longrightarrow Fe^{3+} + e^-$$

$$C_2O_4^{2-} \longrightarrow 2CO_2 + 2e^-$$

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(ii) Calculate the percentage by mass of $FeC_2O_4.2H_2O$ in the original sample.

(If you have been unable to answer part (d)(i) you may assume that three moles of manganate(VII) ions react with seven moles of iron(II) ethanedioate. This is **not** the correct ratio.)

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