Q8.

(a) When anhydrous aluminium chloride reacts with water, solution **Y** is formed that contains a complex aluminium ion, **Z**, and chloride ions.

Give an equation for this reaction.

_____

(1)

(b) Give an equation to show how the complex ion **Z** can act as a Brønsted–Lowry acid with water.

_____

(1)

(c) Describe **two** observations you would make when an excess of sodium carbonate solution is added to solution **Y**.

Give an equation for the reaction. In your equation, include the formula of each complex aluminium species.

Observation 1 _____

_____

Observation 2 _____

_____

Equation _____

(3)

(d) Aqueous potassium hydroxide is added, until in excess, to solution **Y**.

Describe **two** observations you would make.
For each observation give an equation for the reaction that occurs.
In your equations, include the formula of each complex aluminium species.

Observation 1 _____

_____

Equation 1 _____

Observation 2 _____

_____

Equation 2 _____

(4)
(Total 9 marks)

Q9.

Iron forms many complexes that contain iron in oxidation states +2 and +3.

(a)   Hexaaquairon(III) ions react with an excess of hydrochloric acid in a ligand substitution reaction.

Write an equation for this reaction.

_____

(1)

(b)   Explain why the initial and final iron(III) complexes in the equation above have different shapes.

_____

_____

_____

_____

_____

(2)

(c)   Hexaaquairon(II) ions react with an excess of $H_2NCH_2CH_2NH_2$ in a ligand substitution reaction.

Draw the structure of the iron(II) complex formed showing its charge.

(2)

(d)   Hexaaquairon(II) ions react with an excess of $H_2NCH_2CH_2NH_2$ in a ligand substitution reaction.

Which of the following shows the correct change in entropy for a reaction of hexaaquairon(II) ions with $H_2NCH_2CH_2NH_2$?

Tick (✓) **one** box.

change in entropy is negative ☐

change in entropy is close to zero ☐

change in entropy is positive ☐

(1)

(e)   The percentage of iron(II) sulfate in iron tablets can be determined by titration with potassium manganate(VII) in acidic solution.

Deduce an ionic equation for the reaction of iron(II) ions with manganate(VII) ions.

_____

(1)

(f)   A student dissolved 1980 mg of iron tablets in an excess of dilute sulfuric acid. The solution was titrated with 0.0200 mol dm⁻³ potassium manganate(VII) solution. A 32.50 cm³ volume of potassium manganate(VII) solution was required to reach the end point in the titration.

Calculate the percentage of iron in the sample of iron tablets.
Give your answer to the appropriate number of significant figures.

Percentage _____ %

(4)

(g)   State the colour change at the end point in this titration.

_____

(1)
(Total 12 marks)

Q10.

(a) A co-ordinate bond is formed when a transition metal ion reacts with a ligand.

Explain how this co-ordinate bond is formed.

_____

_____

_____

_____

_____

(2)

(b) Describe what you would observe when dilute aqueous ammonia is added dropwise, to excess, to an aqueous solution containing copper(II) ions.
Write equations for the reactions that occur.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(c) When the complex ion $[Cu(NH_3)_4(H_2O)_2]^{2+}$ reacts with 1,2-diaminoethane, the ammonia molecules but not the water molecules are replaced.

Write an equation for this reaction.

_____

(1)

(d)   Suggest why the enthalpy change for the reaction in part **(c)** is approximately zero.

_____

_____

_____

_____

_____

(2)

(e)   Explain why the reaction in part **(c)** occurs despite having an enthalpy change that is approximately zero.

_____

_____

_____

_____

_____

(2)
(Total 11 marks)

Q11.

What forms when a solution of sodium carbonate is added to a solution of gallium(III) nitrate?

A   A white precipitate of gallium(III) carbonate.

B   A white precipitate of gallium(III) hydroxide.

C   A white precipitate of gallium(III) carbonate and bubbles of carbon dioxide.

D   A white precipitate of gallium(III) hydroxide and bubbles of carbon dioxide.

(Total 1 mark)

Q12.

Which compound gives a colourless solution when an excess of dilute aqueous ammonia is added?

A $MgCl_2$

B $AgCl$

C $CuCl_2$

D $AlCl_3$

(Total 1 mark)

Q13.

What is the final species produced when an excess of aqueous ammonia is added to aqueous aluminium chloride?

A $[Al(NH_3)_6]^{3+}$

B $[Al(OH)_3(H_2O)_3]$

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

D $[Al(OH)(H_2O)_5]^{2+}$

(Total 1 mark)

Q14.

Corrosion can be defined as the degradation of a material when it comes into contact with the environment. For iron, this process is called rusting.

(a)   When iron rusts it reacts with oxygen and water vapour in the air initially to form a brown, flaky solid that can be regarded as iron(III) hydroxide

Write an equation, including state symbols, for the overall reaction of the iron with oxygen and water vapour to form iron(III) hydroxide.

_____

(2)

(b)   Explain why this type of corrosion is not seen on aluminium structures that have been exposed to the environment for a similar time as iron structures.

_____

_____

_____

(2)

(Total 4 marks)

Q15.

(a)   A sample of solid chromium(III) hydroxide displays amphoteric character when treated separately with dilute hydrochloric acid and with dilute aqueous sodium hydroxide.

Write an ionic equation for each of these reactions. Include the formula of each complex ion formed.
Describe the changes that you would observe in each reaction.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(5)

(b)   Aqueous solutions of copper(II) sulfate and cobalt(II) sulfate undergo ligand substitution reactions when treated separately with an excess of dilute aqueous ammonia.

Write equations for these reactions. Include the formulae for any complex ions.
Describe the changes that you would observe in each reaction.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)
(Total 11 marks)

Q16.

A green solution, **X**, is thought to contain $[Fe(H_2O)_6]^{2+}$ ions.

(a) The presence of these ions can be confirmed by reacting separate samples of solution **X** with aqueous ammonia and with aqueous sodium carbonate.

Write equations for each of these reactions and describe what you would observe.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(b) A 50.0 cm³ sample of solution **X** was added to 50 cm³ of dilute sulfuric acid and made up to 250 cm³ of solution in a volumetric flask.

A 25.0 cm³ sample of this solution from the volumetric flask was titrated with a 0.0205 mol dm⁻³ solution of $KMnO_4$
At the end point of the reaction, the volume of $KMnO_4$ solution added was 18.70 cm³.

(i) State the colour change that occurs at the end point of this titration and give a reason for the colour change.

_____

_____

_____

_____

(2)

(ii)   Write an equation for the reaction between iron(II) ions and manganate(VII) ions.

Use this equation and the information given to calculate the concentration of iron(II) ions in the original solution **X**.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(5)
(Total 11 marks)

Mark Scheme

Q9.

Iron forms many complexes that contain iron in oxidation states +2 and +3.

(a) Hexaaquairon(III) ions react with an excess of hydrochloric acid in a ligand substitution reaction.

Write an equation for this reaction.

(1)

(b) Explain why the initial and final iron(III) complexes in the equation above have different shapes.

(2)

(c) Hexaaquairon(II) ions react with an excess of $H_2NCH_2CH_2NH_2$ in a ligand substitution reaction.

Draw the structure of the iron(II) complex formed showing its charge.

(2)

(d) Hexaaquairon(II) ions react with an excess of $H_2NCH_2CH_2NH_2$ in a ligand substitution reaction.

Which of the following shows the correct change in entropy for a reaction of hexaaquairon(II) ions with $H_2NCH_2CH_2NH_2$?

Tick (✓) **one** box.

change in entropy is negative ☐

change in entropy is close to zero ☐

change in entropy is positive ☐

(1)

(e) The percentage of iron(II) sulfate in iron tablets can be determined by titration with potassium manganate(VII) in acidic solution.

Deduce an ionic equation for the reaction of iron(II) ions with manganate(VII) ions.

(1)

(f)   A student dissolved 1980 mg of iron tablets in an excess of dilute sulfuric acid.
The solution was titrated with 0.0200 mol dm^{-3} potassium manganate(VII) solution. A
32.50 cm^3 volume of potassium manganate(VII) solution was required to reach the end
point in the titration.

Calculate the percentage of iron in the sample of iron tablets.
Give your answer to the appropriate number of significant figures.

Percentage _____ %

(4)

(g)   State the colour change at the end point in this titration.

(1)

(Total 12 marks)

Q10.

(a)   A co-ordinate bond is formed when a transition metal ion reacts with a ligand.

Explain how this co-ordinate bond is formed.

(2)

(b)   Describe what you would observe when dilute aqueous ammonia is added dropwise, to
excess, to an aqueous solution containing copper(II) ions.
Write equations for the reactions that occur.

(4)

(c)   When the complex ion $[Cu(NH_3)_4(H_2O)_2]^{2+}$ reacts with 1,2-diaminoethane, the ammonia
molecules but not the water molecules are replaced.

Write an equation for this reaction.

(1)

(d)   Suggest why the enthalpy change for the reaction in part **(c)** is approximately zero.

(2)

(e)   Explain why the reaction in part **(c)** occurs despite having an enthalpy change that is
approximately zero.

(2)

(Total 11 marks)

Q11.

What forms when a solution of sodium carbonate is added to a solution of gallium(III) nitrate?

A   A white precipitate of gallium(III) carbonate.

B   A white precipitate of gallium(III) hydroxide.

C   A white precipitate of gallium(III) carbonate and
            bubbles of carbon dioxide.

D   A white precipitate of gallium(III) hydroxide and
            bubbles of carbon dioxide.

(Total 1 mark)

Q12.

Which compound gives a colourless solution when an excess of dilute aqueous ammonia is added?

A $MgCl_2$

B   AgCl

C $CuCl_2$

D $AlCl_3$

(Total 1 mark)

Q13.

What is the final species produced when an excess of aqueous ammonia is added to aqueous aluminium chloride?

A $[Al(NH_3)_6]^{3+}$

B $[Al(OH)_3(H_2O)_3]$

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

D $[Al(OH)(H_2O)_5]^{2+}$

(Total 1 mark)

Q14.

Corrosion can be defined as the degradation of a material when it comes into contact with the environment. For iron, this process is called rusting.

(a)   When iron rusts it reacts with oxygen and water vapour in the air initially to form a brown, flaky solid that can be regarded as iron(III) hydroxide

         Write an equation, including state symbols, for the overall reaction of the iron with oxygen and water vapour to form iron(III) hydroxide.

(2)

(b)　Explain why this type of corrosion is not seen on aluminium structures that have been exposed to the environment for a similar time as iron structures.

(2)

(Total 4 marks)

Q15.

(a)　A sample of solid chromium(III) hydroxide displays amphoteric character when treated separately with dilute hydrochloric acid and with dilute aqueous sodium hydroxide.

Write an ionic equation for each of these reactions. Include the formula of each complex ion formed.
Describe the changes that you would observe in each reaction.

(5)

(b)　Aqueous solutions of copper(II) sulfate and cobalt(II) sulfate undergo ligand substitution reactions when treated separately with an excess of dilute aqueous ammonia.

Write equations for these reactions. Include the formulae for any complex ions.
Describe the changes that you would observe in each reaction.

(6)

(Total 11 marks)

Q16.

A green solution, **X**, is thought to contain $[Fe(H_2O)_6]^{2+}$ ions.

(a)　The presence of these ions can be confirmed by reacting separate samples of solution **X** with aqueous ammonia and with aqueous sodium carbonate.

Write equations for each of these reactions and describe what you would observe.

(4)

(b)　A 50.0 cm³ sample of solution **X** was added to 50 cm³ of dilute sulfuric acid and made up to 250 cm³ of solution in a volumetric flask.

A 25.0 cm³ sample of this solution from the volumetric flask was titrated with a 0.0205 mol dm⁻³ solution of $KMnO_4$
At the end point of the reaction, the volume of $KMnO_4$ solution added was 18.70 cm³.

(i)　State the colour change that occurs at the end point of this titration and give a reason for the colour change.

(2)

(ii)　Write an equation for the reaction between iron(II) ions and manganate(VII) ions.

Use this equation and the information given to calculate the concentration of iron(II) ions in the original solution **X**.

(5)

(Total 11 marks)