

**Q1.**

This question is about complexes containing the aluminium ion.

- (a) Give the electron configuration of the Al^{3+} ion.

(1)

- (b) When anhydrous aluminium sulfate, $\text{Al}_2(\text{SO}_4)_3$, is added to water a solution forms that contains the complex aluminium ion, $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$

Give the equation for the reaction.

(1)

- (c) Explain why the solution containing $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ is acidic.

(2)

- (d) State why the concentration of aluminium sulfate solution can **not** be determined by colorimetry.

(1)

- (e) An excess of aqueous ammonia is added to a solution containing $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$

Give an ionic equation for the reaction and state one observation.

Equation

Observation _____

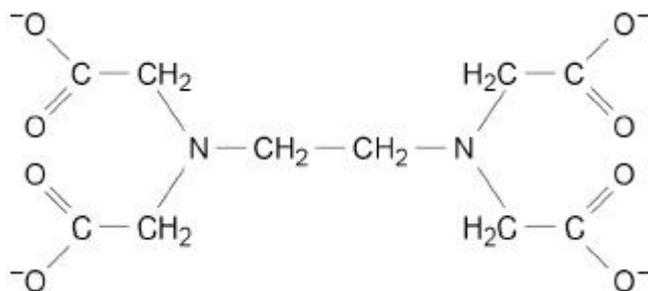
(2)



- (f) An excess of dilute sulfuric acid is added to the products of the reaction in part (e).
Identify the aluminium species produced.

(1)

- (g) The figure below shows the structure of the EDTA^{4-} ion.



Atoms of two different elements in EDTA^{4-} can form co-ordinate bonds with an aluminium ion.

On the figure above, draw circles around the atoms of **two** different elements that would link to an aluminium ion by a co-ordinate bond.

(2)



(h) Hydrated aluminium sulfate, $\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$, is soluble in water.

The relative formula mass and value of x can be found from a titration experiment.

Aqueous $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ ions react to form a stable complex when treated with an excess of EDTA^{4-} ions.

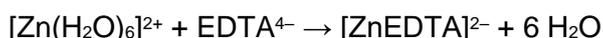
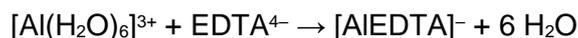
The excess of EDTA^{4-} ions is determined by titration with ZnSO_4 solution.

Method

- Dissolve 1.036 g of $\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$ in distilled water and make up to 250 cm^3
- Add 25.0 cm^3 of this solution to 50.0 cm^3 of a solution containing EDTA^{4-} ions of concentration $0.0100 \text{ mol dm}^{-3}$
- Determine the excess of EDTA^{4-} ions by titrating with ZnSO_4 solution in the presence of an indicator.

The excess of EDTA^{4-} ions requires 18.00 cm^3 of $0.0105 \text{ mol dm}^{-3}$ ZnSO_4 solution to react completely.

The equations for the reactions are



For $\text{Al}_2(\text{SO}_4)_3$ $M_r = 342.3$

Use the information given to calculate the M_r of $\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$

Calculate x

Give your answer as an integer.

M_r _____

x _____

(7)

(Total 17 marks)

**Q2.**

A student is given two aqueous solutions, **L** and **M**, that both contain iron salts.

The student does a series of tests on the solutions.

The table below shows these tests and the observations.

| Test | Observations with L | Observations with M |
|---|--|--|
| Add ammonia solution slowly until in excess. | A red-brown precipitate forms that is insoluble in excess. | A green precipitate forms that is insoluble in excess. |
| Add sodium carbonate solution. | A red-brown precipitate forms. Effervescence is seen. | A green precipitate forms. |
| Add dilute nitric acid and then divide into two portions. | No change is seen. | No change is seen. |
| Add barium chloride solution to the first portion. | No change is seen. | A white precipitate forms. |
| Add silver nitrate solution to the second portion. | A white precipitate forms. | No change is seen. |

Identify **L** and **M** using the results in the table.

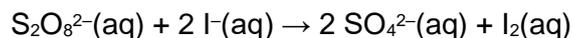
In your answer:

- identify all precipitates
- explain why effervescence is seen in the reaction of sodium carbonate with **L** but **not** with **M**
- give ionic equations for all reactions.

(Total 6 marks)



- (b) Fe^{2+} ions catalyse the reaction between peroxodisulfate(VI) ions and iodide ions in aqueous solution.



Explain why this reaction is slow before the catalyst is added.
Give **two** equations to show how Fe^{2+} ions catalyse this reaction.

Why reaction is slow before catalyst added _____

Equation 1

Equation 2

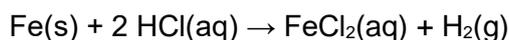
(4)

- (c) Give a reason why Zn^{2+} ions do **not** catalyse the reaction in part (b).

(1)



- (d) Iron reacts with dilute hydrochloric acid to form iron(II) chloride and hydrogen.



A 0.998 g sample of pure iron is added to 30.0 cm³ of 1.00 mol dm⁻³ hydrochloric acid.

One of these reagents is in excess and the other reagent limits the amount of hydrogen produced in the reaction.

Calculate the maximum volume, in m³, of hydrogen gas produced at 30 °C and 100 kPa.

Give your answer to 3 significant figures.

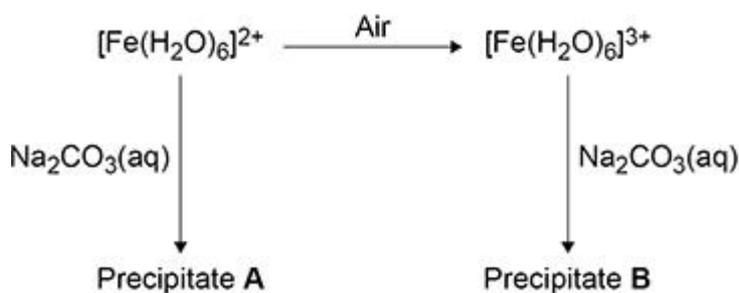
In your answer you should identify the limiting reagent in the reaction.

The gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

Volume of hydrogen _____ m³

(6)

The figure below shows some reactions of iron ions in aqueous solution.



- (e) Identify **A** and state its colour.

Identity _____

Colour _____

(2)



- (f) Give the formula of **B** and state its colour.

Give an ionic equation for the reaction of $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ with aqueous Na_2CO_3 to form **B**.

Formula _____

Colour _____

Ionic equation

(3)

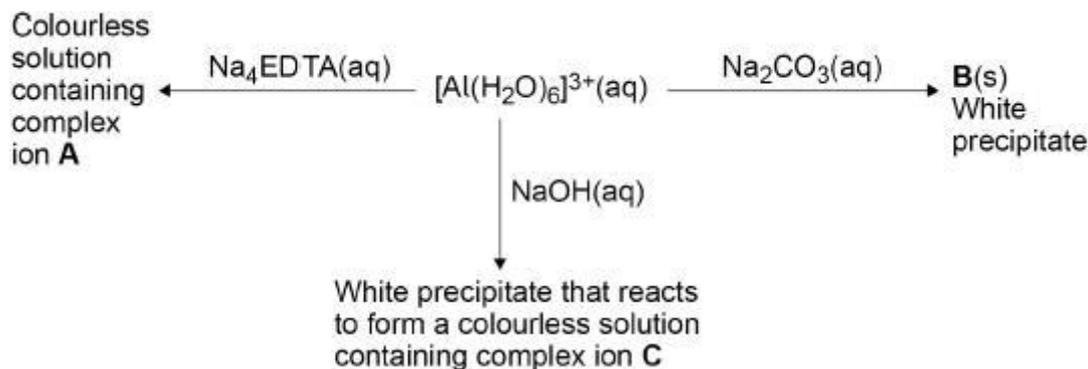
- (g) Explain why an aqueous solution containing $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ ions has a lower pH than an aqueous solution containing $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ ions.

(3)

(Total 25 marks)

**Q4.**

Some reactions of the $[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ ion are shown.



- (a) Give the formula of the white precipitate **B**.

State **one** other observation when $\text{Na}_2\text{CO}_3(\text{aq})$ is added to a solution containing $[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ ions.

Give an equation for this reaction.

Formula of **B** _____

Observation _____

Equation

(3)

- (b) Give the formula of the complex ion **C**.

State **one** condition needed for the formation of **C** from $[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ and $\text{NaOH}(\text{aq})$.

Give an equation for this reaction.

Formula of **C** _____

Condition _____

Equation

(3)

- (c) Deduce the formula of the complex ion **A**.

(1)



- (d) Explain, with the use of an equation, why a solution containing $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ has a pH < 7

Equation

Explanation

(3)

(Total 10 marks)

Q5.

Which compound decolourises acidified potassium manganate(VII) solution?

A $\text{Al}_2(\text{SO}_4)_3$

B CuSO_4

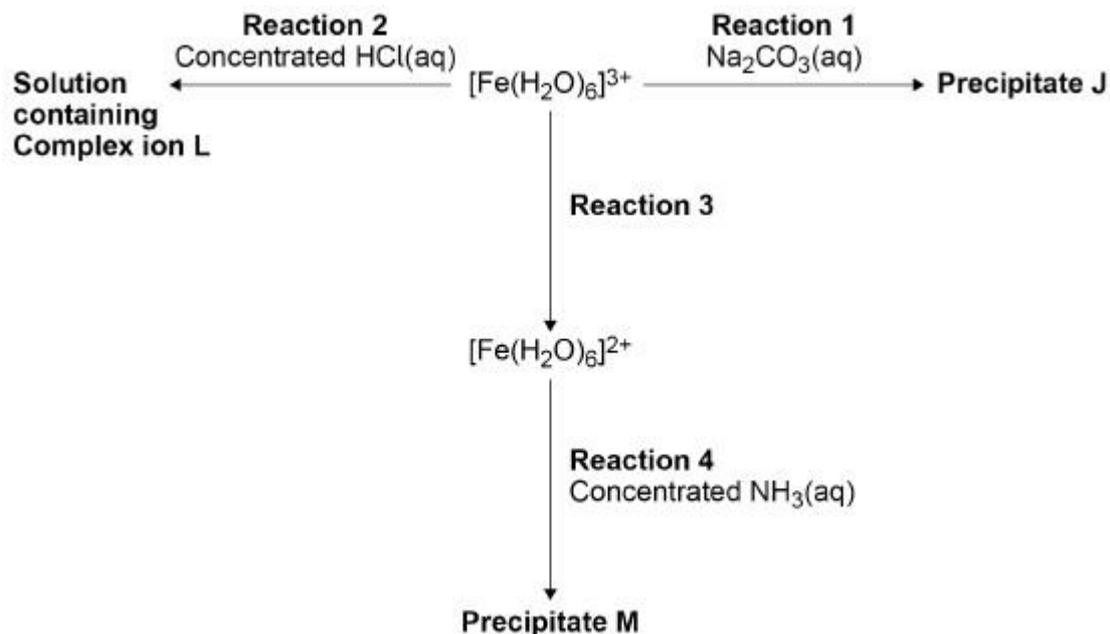
C FeSO_4

D $\text{Fe}_2(\text{SO}_4)_3$

(Total 1 mark)

**Q6.**

The diagram shows some reactions of aqueous iron ions.



- (a) Give the formula of **Precipitate J** and state its colour.

Give an equation for **Reaction 1**.

Formula of **J** _____

Colour _____

Equation _____

(3)

- (b) Give the formula of **L** and an equation for **Reaction 2**.

Formula of **L** _____

Equation _____

(2)

- (c) Suggest a reagent for **Reaction 3**.

(1)

**Q7.**

The following tests were carried out to identify an unknown green salt **Y**.

An aqueous solution of **Y** gave a cream precipitate of compound **A** when reacted with silver nitrate solution.

Compound **A** gave a colourless solution when reacted with concentrated ammonia solution.

Another aqueous solution of **Y** gave a green precipitate **B** when reacted with sodium carbonate solution.

The green precipitate **B** was filtered and dried and then reacted with sulfuric acid to give a pale green solution containing compound **C** and a colourless gas **D**.

- (a) Identify by name or formula the compounds **A**, **B**, **C**, **D** and **Y**.

Identity of **A** _____

Identity of **B** _____

Identity of **C** _____

Identity of **D** _____

Identity of **Y** _____

(5)

- (b) Write the simplest ionic equation for the reaction of silver nitrate solution with the anion that is present in compound **Y**.

(1)

- (c) Write the simplest ionic equation for the reaction that occurs between the green precipitate **B** and sulfuric acid.

(1)

(Total 7 marks)



Mark Scheme

Q1.

This question is about complexes containing the aluminium ion.

(a) Give the electron configuration of the Al^{3+} ion. (1)

(b) When anhydrous aluminium sulfate, $\text{Al}_2(\text{SO}_4)_3$, is added to water a solution forms that contains the complex aluminium ion, $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$

Give the equation for the reaction. (1)

(c) Explain why the solution containing $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ is acidic. (2)

(d) State why the concentration of aluminium sulfate solution can **not** be determined by colorimetry. (1)

(e) An excess of aqueous ammonia is added to a solution containing $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$

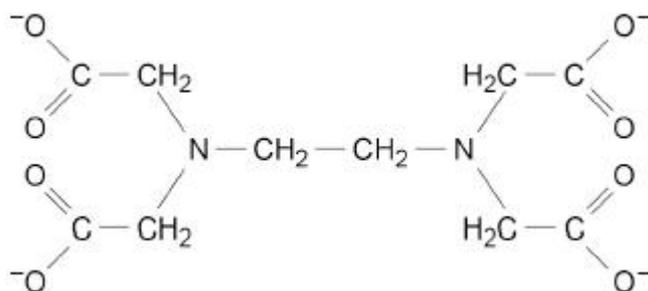
Give an ionic equation for the reaction and state one observation.

Equation (2)

(f) An excess of dilute sulfuric acid is added to the products of the reaction in part (e).

Identify the aluminium species produced. (1)

(g) The figure below shows the structure of the EDTA^{4-} ion.



Atoms of two different elements in EDTA^{4-} can form co-ordinate bonds with an aluminium ion.

On the figure above, draw circles around the atoms of **two** different elements that would link to an aluminium ion by a co-ordinate bond. (2)

(h) Hydrated aluminium sulfate, $\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$, is soluble in water.



The relative formula mass and value of x can be found from a titration experiment.

Aqueous $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ ions react to form a stable complex when treated with an excess of EDTA^{4-} ions.

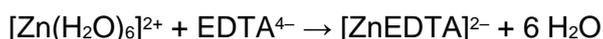
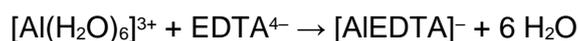
The excess of EDTA^{4-} ions is determined by titration with ZnSO_4 solution.

Method

- Dissolve 1.036 g of $\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$ in distilled water and make up to 250 cm^3
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- Determine the excess of EDTA^{4-} ions by titrating with ZnSO_4 solution in the presence of an indicator.

The excess of EDTA^{4-} ions requires 18.00 cm^3 of $0.0105 \text{ mol dm}^{-3}$ ZnSO_4 solution to react completely.

The equations for the reactions are



For $\text{Al}_2(\text{SO}_4)_3$ $M_r = 342.3$

Use the information given to calculate the M_r of $\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$

Calculate x

Give your answer as an integer.

(7)

(Total 17 marks)

Q2.

A student is given two aqueous solutions, **L** and **M**, that both contain iron salts.

The student does a series of tests on the solutions.

The table below shows these tests and the observations.

| Test | Observations with L | Observations with M |
|---|--|--|
| Add ammonia solution slowly until in excess. | A red-brown precipitate forms that is insoluble in excess. | A green precipitate forms that is insoluble in excess. |
| Add sodium carbonate solution. | A red-brown precipitate forms. Effervescence is seen. | A green precipitate forms. |
| Add dilute nitric acid and then divide into two portions. | No change is seen. | No change is seen. |



| | | |
|--|----------------------------|----------------------------|
| Add barium chloride solution to the first portion. | No change is seen. | A white precipitate forms. |
| Add silver nitrate solution to the second portion. | A white precipitate forms. | No change is seen. |

Identify **L** and **M** using the results in the table.

In your answer:

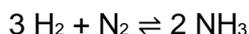
- identify all precipitates
- explain why effervescence is seen in the reaction of sodium carbonate with **L** but **not** with **M**
- give ionic equations for all reactions.

(Total 6 marks)

Q3.

This question is about iron and its ions.

- (a) Discuss the role of iron as a heterogeneous catalyst in the Haber process.

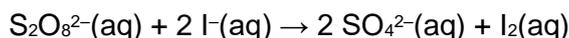


Your answer should include:

- the meaning of the term heterogeneous catalyst
- how iron acts as a heterogeneous catalyst
- the factors that affect the efficiency and lifetime of the catalyst.

(6)

- (b) Fe^{2+} ions catalyse the reaction between peroxodisulfate(VI) ions and iodide ions in aqueous solution.



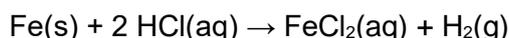
Explain why this reaction is slow before the catalyst is added.
Give **two** equations to show how Fe^{2+} ions catalyse this reaction.

(4)

- (c) Give a reason why Zn^{2+} ions do **not** catalyse the reaction in part (b).

(1)

- (d) Iron reacts with dilute hydrochloric acid to form iron(II) chloride and hydrogen.



A 0.998 g sample of pure iron is added to 30.0 cm³ of 1.00 mol dm⁻³ hydrochloric acid.

One of these reagents is in excess and the other reagent limits the amount of hydrogen produced in the reaction.

Calculate the maximum volume, in m³, of hydrogen gas produced at 30 °C and 100 kPa.



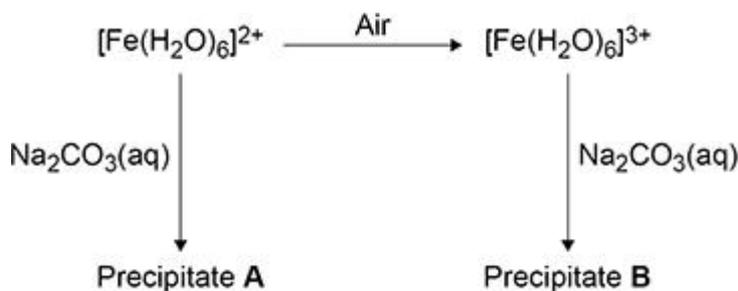
Give your answer to 3 significant figures.

In your answer you should identify the limiting reagent in the reaction.

The gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

(6)

The figure below shows some reactions of iron ions in aqueous solution.



(e) Identify **A** and state its colour.

(2)

(f) Give the formula of **B** and state its colour.

Give an ionic equation for the reaction of $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ with aqueous Na_2CO_3 to form **B**.

(3)

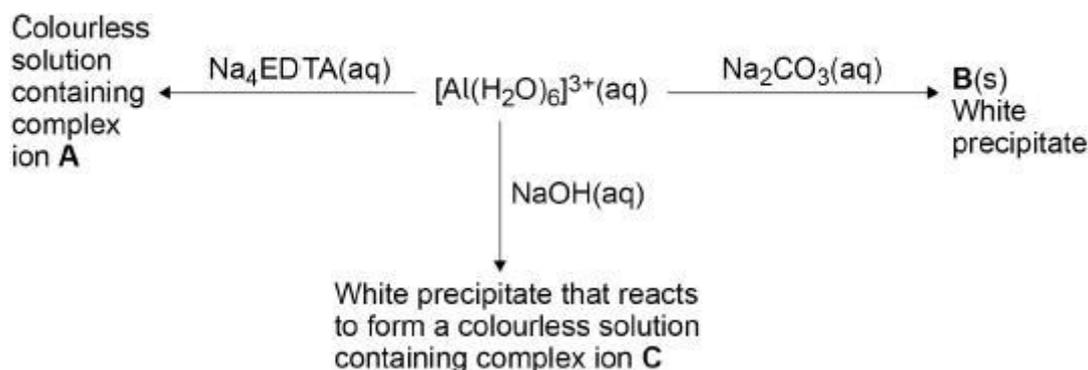
(g) Explain why an aqueous solution containing $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ ions has a lower pH than an aqueous solution containing $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ ions.

(3)

(Total 25 marks)

Q4.

Some reactions of the $[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ ion are shown.



(a) Give the formula of the white precipitate **B**.

State **one** other observation when $\text{Na}_2\text{CO}_3(\text{aq})$ is added to a solution containing $[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ ions.

Give an equation for this reaction.

(3)



(b) Give the formula of the complex ion **C**.

State **one** condition needed for the formation of **C** from $[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ and $\text{NaOH}(\text{aq})$.

Give an equation for this reaction.

(3)

(c) Deduce the formula of the complex ion **A**.

(1)

(d) Explain, with the use of an equation, why a solution containing $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ has a $\text{pH} < 7$

(3)

(Total 10 marks)

Q5.

Which compound decolourises acidified potassium manganate(VII) solution?

A $\text{Al}_2(\text{SO}_4)_3$

B CuSO_4

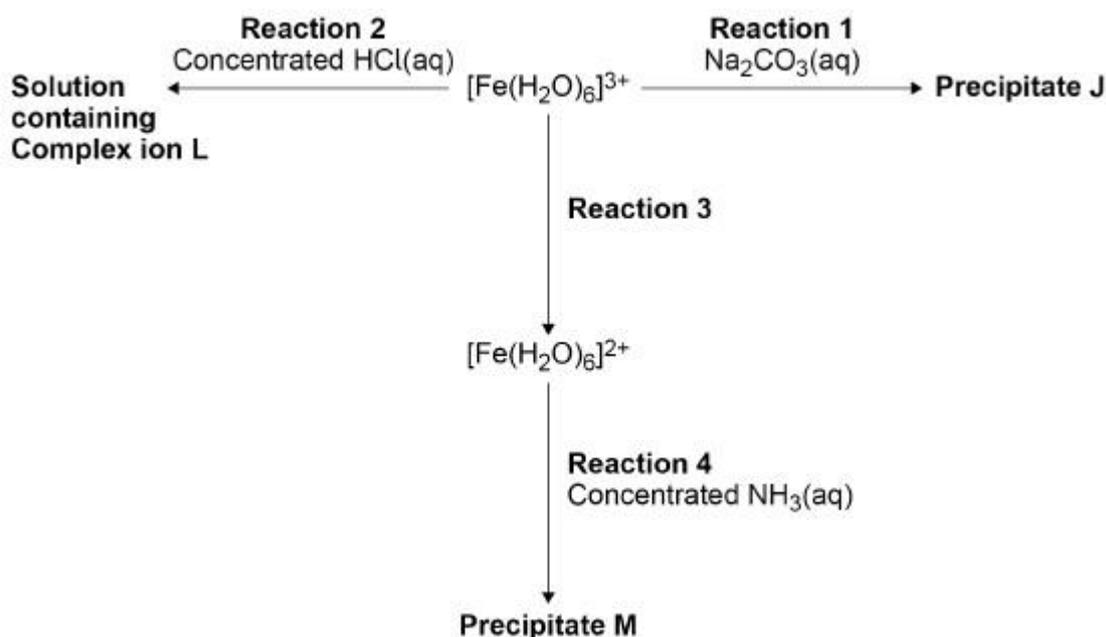
C FeSO_4

D $\text{Fe}_2(\text{SO}_4)_3$

(Total 1 mark)

Q6.

The diagram shows some reactions of aqueous iron ions.



(a) Give the formula of **Precipitate J** and state its colour.

Give an equation for **Reaction 1**.



- Formula of **J** _____
- Colour _____
- Equation _____
- (3)**
- (b) Give the formula of **L** and an equation for **Reaction 2**.
- Formula of **L** _____
- Equation _____
- (2)**
- (c) Suggest a reagent for **Reaction 3**.
- (1)**
- (d) Give the formula of **Precipitate M** and state its colour.
- Formula of **M** _____
- Colour _____
- (2)**
- (e) Transition metal complexes have different shapes and many show isomerism.
- Describe the different shapes of complexes and show how they lead to different types of isomerism.
- Use examples of complexes of cobalt(II) and platinum(II).
- You should draw the structures of the examples chosen.
- (6)**
- (Total 14 marks)**

Q7.

The following tests were carried out to identify an unknown green salt **Y**.

An aqueous solution of **Y** gave a cream precipitate of compound **A** when reacted with silver nitrate solution.

Compound **A** gave a colourless solution when reacted with concentrated ammonia solution.

Another aqueous solution of **Y** gave a green precipitate **B** when reacted with sodium carbonate solution.

The green precipitate **B** was filtered and dried and then reacted with sulfuric acid to give a pale green solution containing compound **C** and a colourless gas **D**.

- (a) Identify by name or formula the compounds **A**, **B**, **C**, **D** and **Y**.
- (5)**
- (b) Write the simplest ionic equation for the reaction of silver nitrate solution with the anion that is present in compound **Y**.
- (1)**



- (c) Write the simplest ionic equation for the reaction that occurs between the green precipitate **B** and sulfuric acid.

(1)

(Total 7 marks)

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.

(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.

(4)

(Total 9 marks)