Access Tuition

A-Level Chemistry

Reactions of Metal Aqua Ions

Question Paper

Time available: 78 minutes
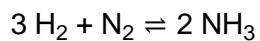## Marks available: 70 marks

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1. This question is about iron and its ions.

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

$$3 H_2 + N_2 \rightleftharpoons 2 NH_3$$

Your answer should include:

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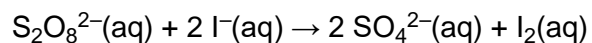- the factors that affect the efficiency and lifetime of the catalyst.

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(6)

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

$$S_2O_8^{2-}(aq) + 2\ I^-(aq) \rightarrow 2\ SO_4^{2-}(aq) + I_2(aq)$$

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 _____

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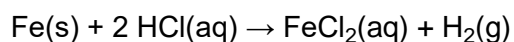
_____

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.

$$Fe(s) + 2\ HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$$

A 0.998 g sample of pure iron is added to 30.0 cm^3 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 m^3, of hydrogen gas produced at 30 °C and 100 kPa.

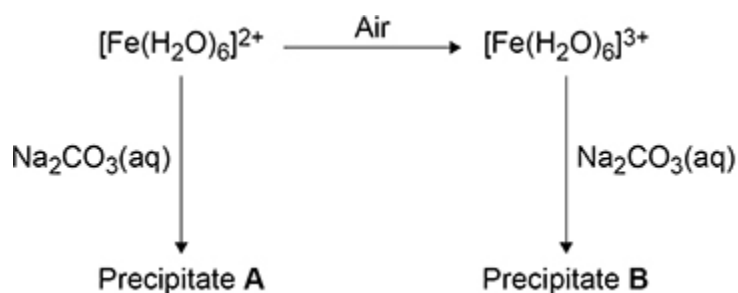Give your answer to 3 significant figures.

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

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

Volume of hydrogen _____ m^3

(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 $[Fe(H_2O)_6]^{3+}$ with aqueous Na_2CO_3 to form **B**.

Formula _____

Colour _____

Ionic equation

_____

(3)

(g)   Explain why an aqueous solution containing $[Fe(H_2O)_6]^{3+}$ ions has a lower pH than an aqueous solution containing $[Fe(H_2O)_6]^{2+}$ ions.

_____

_____

_____

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(3)
(Total 25 marks)

2. Some reactions of the $[Al(H_2O)_6]^{3+}(aq)$ ion are shown.

Colourless solution containing complex ion **A** ← Na$_4$EDTA(aq) ← $[Al(H_2O)_6]^{3+}(aq)$ → Na$_2$CO$_3$(aq) → **B**(s) White precipitate

$[Al(H_2O)_6]^{3+}(aq)$ → NaOH(aq) → White precipitate that reacts to form a colourless solution containing complex ion **C**
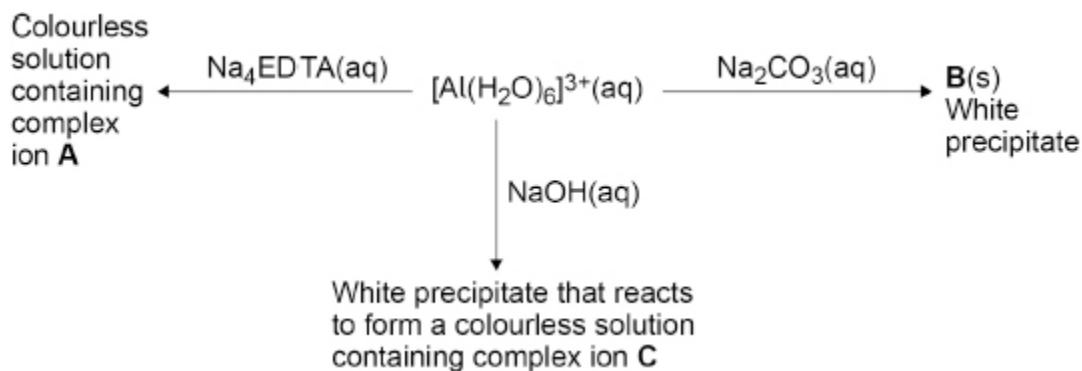
(a) Give the formula of the white precipitate **B**.

State **one** other observation when $Na_2CO_3(aq)$ is added to a solution containing $[Al(H_2O)_6]^{3+}(aq)$ 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 $[Al(H_2O)_6]^{3+}(aq)$ and NaOH(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 $[Al(H_2O)_6]^{3+}$ has a pH <7

Equation

_____
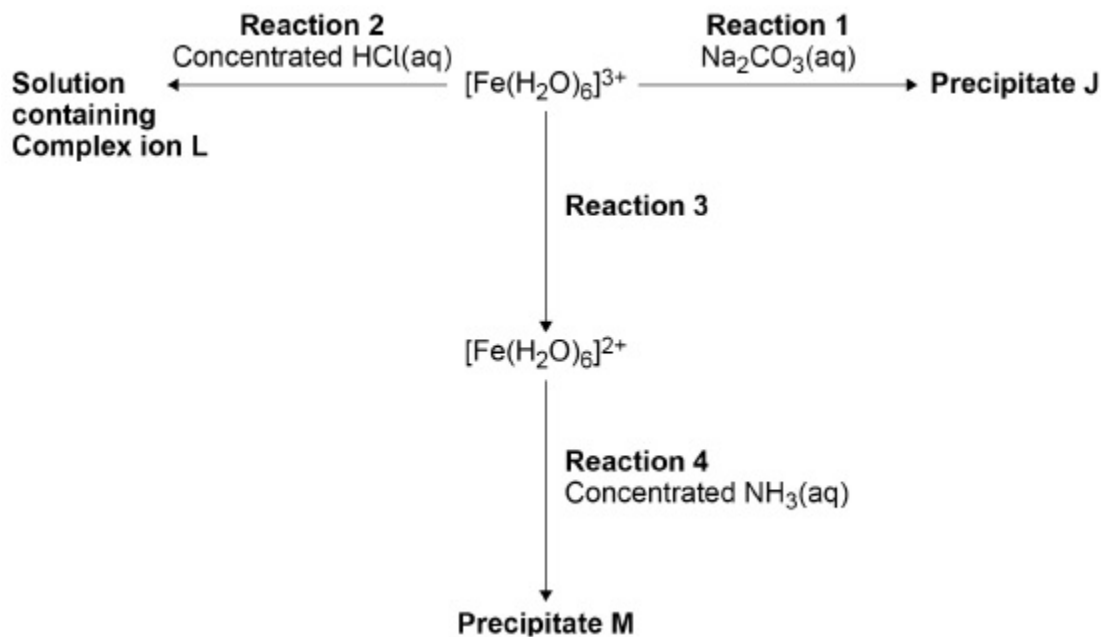
Explanation _____

_____

_____

_____

_____

(3)

(Total 10 marks)

3. 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.

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(6)
(Total 14 marks)

4. (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 _____
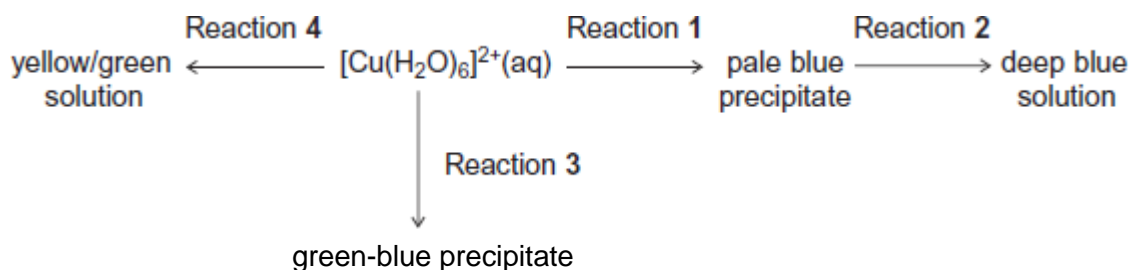
_____

Equation 1 _____

Observation 2 _____

_____

Equation 2 _____

(4)
(Total 9 marks)

5. Consider the following reaction scheme that starts from aqueous $[Cu(H_2O)6]^{2+}$ ions.

yellow/green solution $\xleftarrow{\text{Reaction 4}}$ $[Cu(H_2O)_6]^{2+}(aq)$ $\xrightarrow{\text{Reaction 1}}$ pale blue precipitate $\xrightarrow{\text{Reaction 2}}$ deep blue solution

$\downarrow$ **Reaction 3**

green-blue precipitate

For each of the reactions **1** to **4**, identify a suitable reagent, give the formula of the copper-containing species formed and write an equation for the reaction.

(a)   Reaction **1**

Reagent _____

Copper-containing species _____

Equation _____

(3)

(b)   Reaction **2**

Reagent _____

Copper-containing species _____

Equation _____

(3)

(c)   Reaction **3**

Reagent _____

Copper-containing species _____

Equation _____

(3)

(d)   Reaction **4**

Reagent _____

Copper-containing species _____

Equation _____

(3)
(Total 12 marks)