



A-Level Chemistry

Transition Metal Catalysts

Question Paper

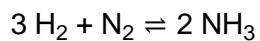
Time available: 70 minutes
Marks available: 64 marks

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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.

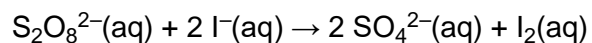


Your answer should include:

- 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.

Why reaction is slow before catalyst added _____

Equation 1

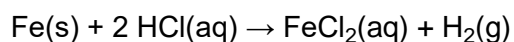
Equation 2

(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.

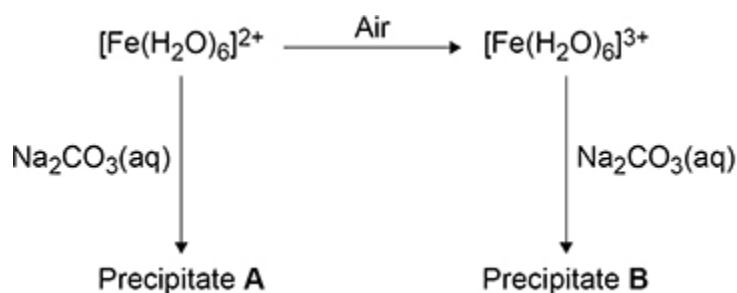
In your answer you should identify the limiting reagent in the reaction.

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)

2.

A student weighed out a 2.29 g sample of impure $\text{K}_3[\text{Fe}(\text{C}_2\text{O}_4)_3] \cdot 3\text{H}_2\text{O}$ and dissolved it in water. This solution was added to a 250 cm^3 volumetric flask and made up to 250 cm^3 with distilled water.

A 25.0 cm^3 portion was pipetted into a conical flask and an excess of acid was added.

The mixture was heated to 60°C and titrated with $0.0200 \text{ mol dm}^{-3}$ KMnO_4 solution.

26.40 cm^3 of KMnO_4 solution were needed for a complete reaction.

In this titration only the $\text{C}_2\text{O}_4^{2-}$ ions react with the KMnO_4 solution.

- (a) The reaction between $\text{C}_2\text{O}_4^{2-}$ ions and MnO_4^- ions is autocatalysed.

Explain what is meant by the term autocatalysed and identify the catalyst in the reaction.

(2)

- (b) Select from the list the most suitable substance used to acidify the solution in the conical flask.

Put a tick (✓) in the correct box.

$\text{H}_2\text{C}_2\text{O}_4$

☐

H_2SO_4

☐

HCl

☐

HNO_3

☐

(1)

- (c) The reaction between $\text{C}_2\text{O}_4^{2-}$ ions and MnO_4^- ions is very slow at first.
Explain why the reaction is initially slow.

(3)

- (d) Write an equation for the reaction between $\text{C}_2\text{O}_4^{2-}$ ions and MnO_4^- ions in acidic solution.
Calculate the percentage purity of the original sample of $\text{K}_3[\text{Fe}(\text{C}_2\text{O}_4)_3] \cdot 3\text{H}_2\text{O}$.
Give your answer to 3 significant figures.

(7)

- (e) A solution of KMnO_4 has an unknown concentration.

Describe briefly how colorimetry can be used to determine the concentration of this solution.

(3)

(Total 16 marks)

3.

The redox reaction, in aqueous solution, between acidified potassium manganate(VII) and sodium ethanedioate is autocatalysed.

- (a) Write an equation for this redox reaction.

Identify the species that acts as the catalyst.

Explain how the properties of the species enable it to act as a catalyst in this reaction.

(6)

- (b) Sketch a graph to show how the concentration of MnO_4^- ions varies with time in this reaction.

Explain the shape of the graph.

(4)

(Total 10 marks)

4.

When iodine molecules are dissolved in aqueous solutions containing iodide ions, they react to form triiodide ions (I_3^-).



The reaction above between I^- ions and $\text{S}_2\text{O}_8^{2-}$ ions has a high activation energy and $\text{S}_2\text{O}_8^{2-}$ ions are only reduced slowly to SO_4^{2-} ions.

The reaction is catalysed by Fe^{2+} ions.

- (a) Explain why the reaction between I^- ions and $\text{S}_2\text{O}_8^{2-}$ ions is slow.

(1)

- (b) Other than having variable oxidation states, explain why Fe^{2+} ions are good catalysts for this reaction.

(1)

- (c) Write a half-equation for the reduction of $\text{S}_2\text{O}_8^{2-}$ ions to SO_4^{2-} ions.

(1)

- (d) Construct an overall equation for the reaction between $\text{S}_2\text{O}_8^{2-}$ ions and I^- ions.

(1)

(Total 4 marks)

5.

Transition metal compounds have a range of applications as catalysts.

- (a) State the general property of transition metals that allows the vanadium in vanadium(V) oxide to act as a catalyst in the Contact Process.

(1)

- (b) Write **two** equations to show how vanadium(V) oxide acts as a catalyst in the Contact Process.

Equation 1

Equation 2

(2)

- (c) In the Contact Process, vanadium(V) oxide acts as a heterogeneous catalyst.

- (i) Give the meaning of the term *heterogeneous*.

(1)

- (ii) Give **one** reason why impurities in the reactants can cause problems in processes that use heterogeneous catalysts.

(1)

- (d) The oxidation of $\text{C}_2\text{O}_4^{2-}$ ions by MnO_4^- ions in acidic solution is an example of a reaction that is autocatalysed.

- (i) Give the meaning of the term *autocatalysed*.

(1)

- (ii) Identify the autocatalyst in this reaction.

(1)

- (iii) Write **two** equations to show how the autocatalyst is involved in this oxidation of $\text{C}_2\text{O}_4^{2-}$ ions.

Equation 1

Equation 2

(2)

(Total 9 marks)