

5.2.2 Separate precipitation, ligand exchange and acid–base changes

Name: _____ Class: _____ Date: _____ Total: 21 marks

KEY WORDS evidence • conditions

Objective

Separate precipitation, ligand exchange and acid–base changes. All questions and marking guidance are original.

1 Key knowledge and worked examples

Small amounts of ammonia can remove protons from coordinated water and precipitate a hydroxide. Excess ammonia can then replace ligands for some metals. Copper changes from pale blue precipitate to deep blue solution; zinc gives a white precipitate then a colourless solution. Excess hydroxide dissolves amphoteric zinc and chromium(III) hydroxides.

■ Worked method

$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightleftharpoons [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$ is ligand exchange. Copper stays +2. In $2\text{CrO}_4^{2-} + 2\text{H}^+ \rightleftharpoons \text{Cr}_2\text{O}_7^{2-} + \text{H}_2\text{O}$, chromium stays +6: the colour change is not redox. Check charge, ligands and oxidation state separately.

2 Practice

2.1 State the initial Fe^{2+} and Fe^{3+} hydroxide precipitate colours. Give a change that complicates an Fe^{2+} test left in air. [3]

2.2 Compare zinc and copper with a small amount and then excess ammonia. [4]

2.3 Write the ionic equation for $\text{Zn}(\text{OH})_2$ dissolving in excess hydroxide to $[\text{Zn}(\text{OH})_4]^{2-}$. [2]

3 Exam-style questions

3.1 Balance $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + \text{NH}_3 \rightarrow \text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + \text{NH}_4^+$. Explain ammonia's role here. [3]

3.2 Pink $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ is in equilibrium with blue $[\text{CoCl}_4]^{2-}$. Write ligand exchange and predict the effect of adding much water. [3]

3.3 Acid turns yellow chromate(VI) orange. Give the equation and explain why the change is not redox. Separately state V(V), V(IV), V(III), V(II) colours in acidic solutions. [6]

Solutions

Original marking guidance: M1 method, A1 accuracy, B1 explanation.

2.1 Fe^{2+} : green; Fe^{3+} : red-brown. Fe^{2+} hydroxide oxidises and turns brown in air.

2.2 Zinc gives a white precipitate, dissolving to a colourless solution in excess. Copper gives pale blue precipitate, dissolving to deep blue solution in excess.

2.3 $\text{Zn}(\text{OH})_2(\text{s}) + 2\text{OH}^- \rightarrow [\text{Zn}(\text{OH})_4]^{2-}$. Correct species, coefficients/charge.

3.1 $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow \text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 2\text{NH}_4^+$. NH_3 accepts protons, acting as a base.

3.2 $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightleftharpoons [\text{CoCl}_4]^{2-} + 6\text{H}_2\text{O}$. Water favours pink aqueous complex through dilution of chloride/reversal of exchange.

3.3 $2\text{CrO}_4^{2-} + 2\text{H}^+ \rightleftharpoons \text{Cr}_2\text{O}_7^{2-} + \text{H}_2\text{O}$. Cr stays +6. V(V) yellow, V(IV) blue, V(III) green, V(II) violet.