

Solutions

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

2.1 Cr^{3+} green/grey-green; Mn^{2+} off-white/very pale precipitate, darkens in air; Fe^{2+} green; Fe^{3+} red-brown; Co^{2+} blue initially; Ni^{2+} green; Cu^{2+} pale blue; Zn^{2+} white. Observations on standing can differ because of oxidation/slow changes.

2.2 $\text{Mn}^{2+} + 2\text{OH}^- \rightarrow \text{Mn}(\text{OH})_2(\text{s})$; $\text{Ni}^{2+} + 2\text{OH}^- \rightarrow \text{Ni}(\text{OH})_2(\text{s})$; $\text{Fe}^{3+} + 3\text{NH}_3 + 3\text{H}_2\text{O} \rightarrow \text{Fe}(\text{OH})_3(\text{s}) + 3\text{NH}_4^+$. Hydrated-complex equivalents accepted.

2.3 $\text{Cr}(\text{OH})_3(\text{s}) + 3\text{OH}^- \rightarrow [\text{Cr}(\text{OH})_6]^{3-}$. The hydroxide reacts with both acids and bases.

3.1 $\text{VO}^{2+} + 2\text{H}^+ + \text{e}^- \rightarrow \text{V}^{3+} + \text{H}_2\text{O}$. Double it and combine $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$ to give $2\text{VO}^{2+} + 4\text{H}^+ + \text{Zn} \rightarrow 2\text{V}^{3+} + 2\text{H}_2\text{O} + \text{Zn}^{2+}$. $E^\circ = +1.10 \text{ V}$.

3.2 $2\text{Cr}(\text{OH})_3 + 3\text{H}_2\text{O}_2 + 4\text{OH}^- \rightarrow 2\text{CrO}_4^{2-} + 8\text{H}_2\text{O}$. Acidification favours dichromate without changing Cr(VI) oxidation state. CO/NO adsorb and react on the surface through weakened bonds/lower barrier; CO_2/N_2 desorb.

3.3 Theoretical mass = $0.0100 \times 250 = 2.50 \text{ g}$; yield = $1.75/2.50 \times 100 = 70.0\%$. Solubility/transfer loss or incomplete reaction lowers recovery; retained solvent/water or impurity raises apparent mass.

3.4 $E^\circ = -0.41 - (-0.76) = +0.35 \text{ V}$. $\text{Zn} + 2\text{Cr}^{3+} \rightarrow \text{Zn}^{2+} + 2\text{Cr}^{2+}$. Cr^{2+} is blue; oxygen readily oxidises it back to Cr^{3+} , so air changes the observed product.

3.5 $\text{Ni}(\text{OH})_2 + 6\text{NH}_3 \rightleftharpoons [\text{Ni}(\text{NH}_3)_6]^{2+} + 2\text{OH}^-$. $\text{Zn}(\text{OH})_2 + 4\text{NH}_3 \rightleftharpoons [\text{Zn}(\text{NH}_3)_4]^{2+} + 2\text{OH}^-$. Coordination counts differ, so changing both to the same ligand coefficient changes the specified complex and fails species/atom balance.

3.6 Peroxide is reduced while the chromium reduction half-reaction reverses to oxidation. $E_{\text{cell}} = 0.88 - (-0.13) = +1.01 \text{ V}$, so that direction is favoured under the stated conditions. Actual rate may be slow, or changing conditions changes the potentials.