Chapter 22

THE GROUP 12 ELEMENTS

Exercises

22.1 (a) $Zn(s) + Br_2(l) \rightarrow ZnBr_2(s)$

(b) $ZnCO_3(s) \rightarrow ZnO(s) + CO_2(g)$

22.3 React zinc metal with a dilute acid, such as hydrochloric acid, then add a soluble carbonate, such as sodium carbonate:

$$Zn(s) + 2\ H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$$

$$Zn^{2+}(aq) + CO_3^{2-}(aq) \rightarrow ZnCO_3(s)$$

22.5 (a) Zinc and magnesium have the following similarities: their cations are 2+ ions of similar size, they are colorless, and they both form hexahydrates. Both elements form soluble chlorides and sulfates, and insoluble carbonates. The anhydrous chlorides are covalently bonded and hygroscopic. However, zinc hydroxide is amphoteric, whereas magnesium hydroxide is basic.

(b) Although both metals form colorless cations, that of zinc has a +2 oxidation state and that of aluminum has a +3 oxidation state. In fact, the only two common features are that both zinc and aluminum are amphoteric metals, reacting with both acids and bases, and they are both strong Lewis acids, their soluble salts forming strongly acidic solutions.

22.7 The charging reactions will be

$$Cd(OH)_2(s) + 2\ e^- \rightarrow Cd(s) + 2\ OH^-(aq)$$

$$2\ Ni(OH)_2(s) + 2\ OH^-(aq) \rightarrow 2\ NiO(OH)(s) + 2\ H_2O(l) + 2\ e^-$$

22.9 Cadmium metal was used as a coating for paper clips primarily because it was a ‘sacrificial anode’ – meaning that it was oxidized to give white cadmium compounds rather than the iron of the paper clip itself which would rust and stain the paper document. Cadmium was used in preference to zinc probably because cadmium melts at only 321°C, compared with 419°C for zinc, making it easier to dip the paper clip wire

into molten cadmium easier than with molten zinc. As cadmium compounds are highly toxic, cadmium plating has been discontinued.

22.11 $Zn(s) + 2\ H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$

$Zn(OH_2)_6^{2+}(aq) + 4\ NH_3(aq) \rightarrow Zn(NH_3)_4^{2+}(aq) + 6\ H_2O(l)$

$Zn^{2+}(aq) + 2\ OH^-(aq) \rightarrow Zn(OH)_2(s)$

$Zn(OH)_2(s) + 2\ OH^-(aq) \rightarrow Zn(OH)_4^{2-}(aq)$

$Zn(OH)_2(s) \rightarrow ZnO(s) + H_2O(l)$

$ZnO(s) + 2\ H^+(aq) \rightarrow Zn^{2+}(aq) + H_2O(l)$

$ZnCO_3(s) \rightarrow ZnO(s) + CO_2(g)$

Beyond the Basics

22.13 Mercury(I) undergoes a disproportionation equilibrium:

$Hg_2^{2+}(aq) \rightarrow Hg(l) + Hg^{2+}(aq)$

This equilibrium is driven to the right by the formation of highly insoluble (high lattice energy) compounds such as mercury(II) selenide:

$Hg^{2+}(aq) + Se^{2-}(aq) \rightarrow HgSe(s)$

22.15 For metals to mix, they must have atoms of similar sizes and adopt the same crystal packing arrangement (see Chapter 4). The metals are very different in size, and data tables show that they have different packing arrangements (lead is cubic close-packed while zinc is hexagonal close-packed).

22.17 Sulfur. Mercury(II) is a soft acid. Sulfur is a soft base whereas oxygen is a hard base.

22.19 (a) $Zn(NH_2)_2(NH_3) + 2\ NH_4^+(NH_3) \rightarrow Zn(NH_3)_4^{2+}(NH_3)$

(b) $Zn(NH_2)_2(NH_3) + 2\ NH_2^-(NH_3) \rightarrow Zn(NH_2)_4^{2-}(NH_3)$

22.21 Zinc oxide. The (+2)(–2) ionic attractions will be greater than those between (+2) and (–1) ions. In other words, the lattice energy of zinc oxide will be much greater than that of zinc chloride. [In fact, zinc oxide has a melting point of 1975°C while that of zinc chloride is 732°C].

22.23 Hydrogen sulfide is in a two-step equilibrium with the sulfide ion.

$H_2S(aq) + H_2O(l) \rightarrow H_3O^+(aq) + HS^-(aq)$

$HS^-(aq) + H_2O(l) \rightarrow H_3O^+(aq) + S^{2-}(aq)$

In neutral conditions, $[S^{2-}]$ must be greater than the value necessary for the K_{sp} for zinc sulfide to be exceeded. However, when acidified, the increased hydronium-ion concentration will "drive" the equilibria to the left; presumably sufficiently to decrease $[S^{2-}]$ below the necessary value for zinc sulfide precipitation.