PS11.1: SO_2 and Acid Rain in NE US

Harte states that 2.5 x 10^6 tonnes(S) is oxidized to sulfate and subsequently deposited in 1.5 x 10^{15} liters of precipitation:

$$[H^+] = \left[\frac{2.5 \cdot 10^6\ t_S}{y}\right]\left[\frac{10^6\ g}{t}\right]\left[\frac{mole_S}{32\ g}\right]\left[\frac{2\ mole_{H^+}}{mole_S}\right]\left[\frac{y}{1.5 \cdot 10^{15}\ L}\right]$$

$$= 1.04 \cdot 10^{-4}\ \frac{mole_{H^+}}{L}$$

$$pH = -\log_{10}[H^+] = -\log_{10}(10^{-4}) = 4.0$$

PS11.2: Acid Rain in Beijing

Assume 6 g(SO_4^{2-})/m^{2}y, in 25 in/y of rain:

$$\left[H^+\right] = \left[\frac{6\ g_{SO_4^{2-}}}{m^2 y}\right]\left[\frac{mole_{SO_4^{2-}}}{96\ g_{SO_4^{2-}}}\right]\left[\frac{2\ mole_{H^+}}{mole_{SO_4^{2-}}}\right]\left[\frac{y}{25\ in}\right]\left[\frac{39.4\ in}{m}\right]\left[\frac{m^3}{10^3\ L}\right]$$

$$= 2 \cdot 10^{-4}\ \frac{mole_{H^+}}{L}$$

$$pH = -\log_{10}\left[H^+\right] = -\log_{10}\left[2 \cdot 10^{-4}\right] = -(-3.7) = 3.7$$

If S emissions (and SO_4^{2-} deposition) are cut in half, the pH will increase by about 0.3 units, to 4.0.

PS11.3: Acid Mine Drainage

A. AMD results from oxidation of FeS_2:

$$FeS_2 + 7/2\ H_2O + 15/4\ O_2 \rightarrow Fe(OH)_3 + 4H^+ + 2SO_4^{2-}$$

If [SO_4^{2-}] = 150 mg/L; what is the pH?

$$[H^+] = \left[\frac{150\ mg_{SO_4^{2-}}}{L}\right]\left[\frac{g}{10^3\ mg}\right]\left[\frac{mole_{SO_4^{2-}}}{96\ g_{SO_4^{2-}}}\right]\left[\frac{4\ mole_{H^+}}{2\ mole_{SO_4^{2-}}}\right]$$

$$= 0.0031\ \frac{mole_{H^+}}{L}$$

$$pH = -\log_{10}[H^+] = -\log_{10}(0.0031) = 2.5$$

PS11.3: Acid Mine Drainage

B. Precipitation = 100 cm/y; 35 cm/y into groundwater percolating through 100 ha. Total outflow of H+?

$$F = \left[100\ ha\right]\left[\frac{10^4\ m^2}{ha}\right]\left[\frac{0.35\ m}{y}\right]\left[\frac{1000\ L}{m^3}\right]\left[\frac{0.0031\ mole_{H^+}}{L}\right]$$

$$= 1.1 \cdot 10^6\ \frac{mole_{H^+}}{y}$$

PS11.3: Acid Mine Drainage

C. AMD drains into lake with V = 20 billion L, τ = 2 y. If What is the pH of the lake water?

$$[H^+] = c = \frac{S}{V} = \frac{F\tau}{V} = \frac{\left[\frac{1.1\cdot 10^6 \text{ mole}_{H^+}}{\text{y}}\right]\left[2\text{ y}\right]}{20\cdot 10^9\text{ L}}$$

$$= 1.1\cdot 10^{-4}\,\frac{\text{mole}_{H^+}}{\text{L}}$$

$$\text{pH} = -\log_{10}\left(1.1\cdot 10^{-4}\right) = 4.0$$

PS11.4: Flue-gas Desulfurization

The molecular weight of calcium sulfate, $CaSO_4$, is 40 + 32 + 4(16) = 136 g/mole, so 32 tons of S will produce 136 tons of $CaSO_4$.

The molecular weight of SO_2 is 32 + 2(16) = 64, so a 10 Mt reduction in SO_2 is a 5 Mt reduction in S:

$$\left[\frac{10\,\text{Mt}_{SO_2}}{\text{y}}\right]\left[\frac{32\text{ Mt}_S}{64\text{ Mt}_{SO_2}}\right]\left[\frac{136\text{ Mt}_{CaSO_4}}{32\text{ Mt}_S}\right] = 21\,\frac{\text{Mt}_{CaSO_4}}{\text{y}}$$

$$\left[\frac{\$50}{t_{CaSO_4}}\right]\left[\frac{136\text{ Mt}_{CaSO_4}}{64\text{ Mt}_{SO_2}}\right] = \frac{\$106}{t_{SO_2}}$$