

## PS11.1: SO<sub>2</sub> and Acid Rain in NE US

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

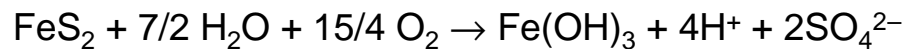
$$[\text{H}^+] = \left[ \frac{2.5 \cdot 10^6 \text{ t}_s}{y} \right] \left[ \frac{10^6 \text{ g}}{\text{t}} \right] \left[ \frac{\text{mole}_s}{32 \text{ g}} \right] \left[ \frac{2 \text{ mole}_{\text{H}^+}}{\text{mole}_s} \right] \left[ \frac{y}{1.5 \cdot 10^{15} \text{ L}} \right]$$

$$= 1.04 \cdot 10^{-4} \frac{\text{mole}_{\text{H}^+}}{\text{L}}$$

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

## PS11.3: Acid Mine Drainage

A. AMD results from oxidation of FeS<sub>2</sub>:



If  $[\text{SO}_4^{2-}] = 150 \text{ mg/L}$ ; what is the pH?

$$[\text{H}^+] = \left[ \frac{150 \text{ mg}_{\text{SO}_4^{2-}}}{\text{L}} \right] \left[ \frac{\text{g}}{10^3 \text{ mg}} \right] \left[ \frac{\text{mole}_{\text{SO}_4^{2-}}}{96 \text{ g}_{\text{SO}_4^{2-}}} \right] \left[ \frac{4 \text{ mole}_{\text{H}^+}}{2 \text{ mole}_{\text{SO}_4^{2-}}} \right]$$

$$= 0.0031 \frac{\text{mole}_{\text{H}^+}}{\text{L}}$$

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

## PS11.2: Acid Rain in Beijing

Assume  $6 \text{ g}(\text{SO}_4^{2-})/\text{m}^2\text{y}$ , in  $25 \text{ in/y}$  of rain:

$$[\text{H}^+] = \left[ \frac{6 \text{ g}_{\text{SO}_4^{2-}}}{\text{m}^2\text{y}} \right] \left[ \frac{\text{mole}_{\text{SO}_4^{2-}}}{96 \text{ g}_{\text{SO}_4^{2-}}} \right] \left[ \frac{2 \text{ mole}_{\text{H}^+}}{\text{mole}_{\text{SO}_4^{2-}}} \right] \left[ \frac{y}{25 \text{ in}} \right] \left[ \frac{39.4 \text{ in}}{\text{m}} \right] \left[ \frac{\text{m}^3}{10^3 \text{ L}} \right]$$

$$= 2 \cdot 10^{-4} \frac{\text{mole}_{\text{H}^+}}{\text{L}}$$

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

If S emissions (and SO<sub>4</sub><sup>2-</sup> deposition) are cut in half, the pH will increase by about 0.3 units, to 4.0.

## PS11.3: Acid Mine Drainage

B. Precipitation =  $100 \text{ cm/y}$ ;  $35 \text{ cm/y}$  into groundwater percolating through  $100 \text{ ha}$ . Total outflow of H<sup>+</sup>?

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

$$= 1.1 \cdot 10^6 \frac{\text{mole}_{\text{H}^+}}{y}$$

### PS11.3: Acid Mine Drainage

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

$$[H^+] = c = \frac{S}{V} = \frac{F\tau}{V} = \frac{\left[ \frac{1.1 \cdot 10^6 \text{ mole}_{H^+}}{y} \right] [2 y]}{20 \cdot 10^9 \text{ L}}$$
$$= 1.1 \cdot 10^{-4} \frac{\text{mole}_{H^+}}{\text{L}}$$

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

### PS11.4: Flue-gas Desulfurization

The molecular weight of calcium sulfate,  $\text{CaSO}_4$ , is  $40 + 32 + 4(16) = 136$  g/mole, so 32 tons of S will produce 136 tons of  $\text{CaSO}_4$ .

The molecular weight of  $\text{SO}_2$  is  $32 + 2(16) = 64$ , so a 10 Mt reduction in  $\text{SO}_2$  is a 5 Mt reduction in S:

$$\left[ \frac{10 \text{ Mt}_{\text{SO}_2}}{y} \right] \left[ \frac{32 \text{ Mt}_S}{64 \text{ Mt}_{\text{SO}_2}} \right] \left[ \frac{136 \text{ Mt}_{\text{CaSO}_4}}{32 \text{ Mt}_S} \right] = 21 \frac{\text{Mt}_{\text{CaSO}_4}}{y}$$

$$\left[ \frac{\$50}{\text{t}_{\text{CaSO}_4}} \right] \left[ \frac{136 \text{ Mt}_{\text{CaSO}_4}}{64 \text{ Mt}_{\text{SO}_2}} \right] = \frac{\$106}{\text{t}_{\text{SO}_2}}$$