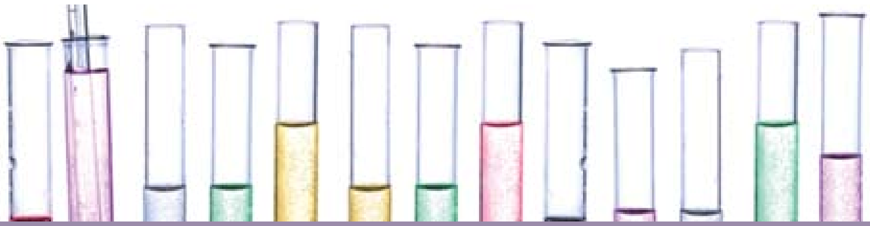

Set 23: Acid and Base Reaction Stoichiometry

1. (a)

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

$$n(H^{+})_{\text{in 90,000L}} = 1.00\times10^{-4}\times90{,}000 = 9.00 \text{ g}$$

$$n(H^{+})_{\text{in 90,000L}} = \frac{m}{M} = \frac{9.00}{1.008} = 8.93 \text{ mol}$$

$$n(Zn)_{\text{dissolved}} = \tfrac{1}{2}n(H^{+}) = \tfrac{1}{2}8.93 = 4.465 \text{ mol}$$

$$m(Zn)_{\text{dissolved}} = nM = 4.465\times65.38 = 291.9 \text{ g} = 0.292 \text{ kg}$$

(b)

$$n(Zn^{2+})_{\text{dissolved}} = n(Zn) = 4.465 \text{ mol}$$

$$[Zn^{2+}] = \frac{n}{V} = \frac{4.465}{90{,}000} = 4.96\times10^{-5} \text{ mol L}^{-1}$$

2. $Ca(OH)_2(s) + 2H^{+}(aq) \longrightarrow 2H_2O(\ell) + Ca^{2+}(aq)$

$$M(Ca(OH)_2) = 40.08 + 2(16.00) + 2(1.008) = 74.096 \text{ g mol}^{-1}$$

$$n(Ca(OH)_2)_{\text{in one square metre}} = \frac{m}{M} = \frac{100}{74.096} = 1.3496 \text{ mol}$$

$$n(H^{+})_{\text{in one square metre}} = 2n(Ca(OH)_2) = 2\times1.3496 = 2.70 \text{ mol}$$

3. $A\ell(OH)_3(s) + 3H^{+}(aq) \longrightarrow 3H_2O(\ell) + A\ell^{3+}(aq)$

$$M(A\ell(OH)_3) = 26.98 + 3(16.00) + 3(1.008) = 78.004 \text{ g mol}^{-1}$$

$$n(A\ell(OH)_3)_{\text{used for 20 mL}} = \frac{m}{M} = \frac{10.4\times10^{-3}}{78.004} = 1.333\times10^{-4} \text{ mol}$$

$$n(A\ell(OH)_3)_{\text{used for 250 mL}} = \frac{250}{20}\times1.333\times10^{-4} = 1.666\times10^{-3} \text{ mol}$$

$$n(HC\ell) = n(H^{+}) = 3n(A\ell(OH)_3) = 3\times1.666\times10^{-3} = 40999\times10^{-3} \text{ mol}$$

$$M(HC\ell) = 1.008 + 35.45 = 36.458 \text{ g mol}^{-1}$$

$$m(HC\ell) = nM = 40999\times10^{-3}\times36.458 = 0.182 \text{ g} = 182 \text{ mg}$$

4. $Ca(OH)_{2(s)} + 2H^+_{(aq)} \rightarrow 2H_2O_{(\ell)} + Ca^{2+}_{(aq)}$

$$m(H^+) = cV = 1.00\times10^{-5}\times10.0\times10^{-3} = 1.00\times10^{-7}\ g$$
$$n(H^+) = \frac{m}{M} = \frac{1.00\times10^{-7}}{1.008} = 9.921\times10^{-8}\ mol$$
$$n(Ca(OH)_2) = \tfrac{1}{2}n(H^+) = \tfrac{1}{2}\times9.921\times10^{-8} = 4.960\times10^{-8}\ mol$$
$$M(Ca(OH)_2) = 40.08 + 2(16.00) + 2(1.008) = 74.096\ g\ mol^{-1}$$
$$m(Ca(OH)_2) = nM = 4.960\times10^{-8}\times74.096 = 3.675\times10^{-6}\ g = 3.68\ \mu g$$

5. (a)

$$M(Na_2CO_3.10H_2O) = 2(22.99) + 12.01 + 3(16.00) + 10(18.016) = 286.15\ g\ mol^{-1}$$
$$n(Na_2CO_3) = n(Na_2CO_3.10H_2O) = \frac{m}{M} = \frac{2.50}{286.15} = 1.0498\ mol$$
$$[Na_2CO_3] = \frac{n}{V} = \frac{1.0498}{2.10} = 0.4998 = 0.500\ mol\ L^{-1}$$

(b) $2Na^+_{(aq)} + CO_3^{2-}{}_{(aq)} + 2H^+_{(aq)} + 2C\ell^-_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(\ell)} + 2Na^+_{(aq)} + 2C\ell^-_{(aq)}$

$$n(NaC\ell) = n(Na^+)\ or\ n(C\ell^-) = 2n(NaCO_3) = 2(1.00498) = 2.0996\ mol$$
$$M(NaC\ell) = 22.99 + 35.45 = 58.44\ g\ mol^{-1}$$
$$m(NaC\ell) = nM = 2.0996\times58.44 = 122.7 = 123\ g$$

6. $CaCO_{3\,(s)} + 2H^+_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(\ell)} + 2Ca^{2+}_{(aq)}$

$m(CaCO_3)_{Dissolved} = m(CaCO_3)_{Initial} - m(CaCO_3)_{Left} = 5.60 - 5.09 = 0.51\ g$

$M(CaCO_3) = 40.08 + 12.01 + 3(16.00) = 100.09\ mol\ L^{-1}$

$$n(CaCO_3)_{Dissolved} = \frac{m}{M} = \frac{0.51}{100.09} = 5.0954\times10^{-3}\ mol$$
$$n(HC\ell) = n(H^+) = 2n(CaCO_3)_{Dissolved} = 2(5.0954\times10^{-3}) = 0.01019\ mol$$
$$[HC\ell] = \frac{n}{V} = \frac{0.01019}{0.0200} = 0.510\ mol\ L^{-1}$$

7. $CaCO_{3\,(s)} + 2H^+_{(aq)} \rightarrow CO_{2(g)} + H_2O_{(\ell)} + 2Ca^{2+}_{(aq)}$

$n(H^+) = n(HC\ell) = cV = 2.50 \times 0.0107 = 0.02675\ mol$

$n(CaCO_3)_{in\ sample} = ½\ n(H^+) = ½\ (0.02675 = 0.013375\ mol$

$M(CaCO_3) = 40.08 + 12.01 + 3(16.00) = 100.09\ mol\ L^{-1}$

$m(CaCO_3)_{in\ sample} = nM = 0.013375 \times 100.09 = 1.3387\ g$

$$\%CaCO_3 = \frac{m(CaCO_3)}{m(sample)}\times100 = \frac{1.3387}{2.89}\times100 = 46.3\%$$

8. $CaCO_{3(s)} + 2H^+_{(aq)} \rightarrow CO_{2(aq)} + H_2O_{(\ell)} + Ca^{2+}_{(aq)}$

The mass change is due to the release of carbon dioxide.

$m(CO_2)$ = m(acid and beaker) + m(limestone sample) − m(beaker and contents after reaction)

$110.61 + 2.59 - 112.22 = 0.98$ g

$$M(CO_2) = 12.01 + 2(16.00) = 44.01 \text{ g mol}^{-1}$$

$$n(CO_2) = \frac{n}{M} = \frac{0.98}{44.01} = 0.02227 \text{ mol}$$

$$n(CaCO_3) = n(CO_2) = 0.02227 \text{ mol}$$

$$M(CaCO_3) = 40.08 + 12.01 + 3(16.00) = 100.09 \text{ g mol}^{-1}$$

$$m(CaCO_3) = nM = 0.02227 \times 100.09 = 2.23 \text{ g}$$

$$\%CaCO_3 = \frac{m(CaCO_3) \times 100}{m(sample)} = \frac{2.23 \times 100}{2.59} = 82.9\%$$