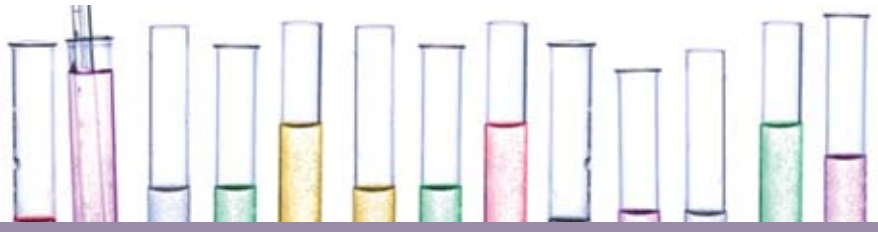

Set 22: Solutions of Acids and Bases

1. (a) $Na_2CO_{3(s)} \rightarrow 2Na^+_{(aq)} + CO_3^{2-}{}_{(aq)}$

$M(Na_2CO_3) = 105.99 \text{ g mol}^{-1}$

$$[Na_2CO_3]_{\text{in g L}^{-1}} = \frac{m}{V} = \frac{25.6}{0.200} = 128 \text{ g L}^{-1}$$

(b) $$n(Na_2CO_3) = \frac{m}{M} = \frac{25.6}{105.99} = 0.2415 \text{ mol}$$

$$[Na_2CO_3] = \frac{n}{V} = \frac{0.2415}{0.200} = 1.21 \text{ mol L}^{-1}$$

(c) $n(Na_2CO_3)_{\text{in 20 mL}} = cV = 1.21 \times 0.0200 = 0.02415 \text{ mol}$

$n(Na^+)_{\text{in 100 mL dilute}} = n(Na^+)_{\text{in 20 mL conc}} = 2 \times n(Na_2CO_3)_{\text{in 20 mL}}$
$= 2 \times 0.02415 = 0.048306 \text{ mol}$

$$[Na^+]_{\text{in 100 mL dilute}} = \frac{n}{V} = \frac{0.048306}{0.100} = 0.483 \text{ mol L}^{-1}$$

2. (a) $HC\ell_{(aq)} \rightarrow H^+_{(aq)} + C\ell^-_{(aq)}$

$[C\ell^-] = [HC\ell] = 0.200 \text{ mol L}^{-1}$

(b) $H_2SO_{4(aq)} \rightarrow H^+_{(aq)} + HSO_4^-{}_{(aq)}$ (Fully ionised)
$HSO_4^-{}_{(aq)} \rightarrow H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$ (Only ionised to about 10%)

$[H^+]$ will therefore be a little larger than $[H_2SO_4]$ ie a little larger than 2.56 mol L^{-1} but definitely not 5.12 mol L^{-1}.

I did indicate that this was not a good example to use for this question.

(c) $Ba(OH)_{2(s)} \rightarrow Ba^{2+}_{(aq)} + 2OH^-_{(aq)}$

$[OH^-] = 2 \times [Ba(OH)_2] = 2 \times 2.02 \times 10^{-3} = 4.04 \times 10^{-3} \text{ mol L}^{-1}$

3. (a) $Ca(NO_3)_{2\,(s)} \rightarrow Ca^{2+}_{(aq)} + 2NO_3^-{}_{(aq)}$

$M(Ca(NO_3)_2) = 164.1 \text{ g mol}^{-1}$

$$n(Ca^{2+}) = n(Ca(NO_3)_2) = \frac{m}{M} = \frac{10.0}{164.1} = 0.060938 \text{ mol}$$

$$[Ca^{2+}] = \frac{n}{V} = \frac{0.060938}{0.220} = 0.277 \text{ mol L}^{-1}$$

(b) $[NO_3^-] = 2 \times [Ca^{2+}] = 2 \times 0.277 = 0.554 \text{ mol L}^{-1}$

4. $c_1V_1 = c_2V_2$

$10.0 \times V_1 = 0.500 \times 0.500$

$V_1 = 0.025\ \text{L} = 25.0\ \text{mL}$

5. $n(OH^-)_{\text{from NaOH}} = n(\text{NaOH}) = cV = 0.20 \times 0.360 = 0.0900\ \text{mol}$

$n(OH^-)_{\text{from KOH}} = n(\text{KOH}) = cV = 1.20 \times 0.675 = 0.810\ \text{mol}$

$n(OH^-)_{\text{Total}} = n(OH^-)_{\text{from NaOH}} + n(OH^-)_{\text{from KOH}} = 0.900 + 0.810 = 0.900\ \text{mol}$

$$[OH^-]_{\text{total}} = \frac{n_{\text{total}}}{V_{\text{total}}} = \frac{0.900}{1.035} = 0.870\ \text{mol L}^{-1}$$

6. $c_1V_1 = c_2V_2$

$1.10 \times 0.150 = 0.210 \times V_2$

$V_2 = 0.786\ \text{L}$

$V(H_2O)_{\text{to add}} = V_2 - V_1 = 0.786 - 0.150 = 0.636\ \text{L} = 636\ \text{mL}$

7.

$$m(H_2SO_4) = \frac{98}{100} \times 1.00 = 0.980\ \text{kg} = 980\ \text{g}$$

$$[H_2SO_4]_{(\text{in gL}^{-1})} = \frac{m(H_2SO_4)}{m(\text{Solution})} = \frac{980}{3.00} = 327\ \text{g L}^{-1}$$

8.

$$n(HC\ell) = cV = 0.100 \times 0.300 = 0.0300\ \text{mol}$$

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

$$m(HC\ell) = nM = 0.0300 \times 36.458 = 1.09\ \text{g}$$

9. (a)

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

$$n(Ca^{2+}) = n(Ca(OH)_2) = \frac{n}{M} = \frac{10\times10^{-3}}{74.096} = 1.35\times10^{-4} \text{ mol}$$

$$[Ca^{2+}] = \frac{n(Ca^{2+})}{V(Solution)} = \frac{1.35\times10^{-4}}{1.00} = 1.35\times10^{-4} \text{ mol L}^{-1}$$

(b)

$$n(OH^-) = 2\times n(Ca(OH)_2) = 2\times\frac{n}{M} = \frac{2\times10\times10^{-3}}{74.096} = 2.70\times10^{-4} \text{ mol}$$

$$[OH^-] = \frac{n(OH^-)}{V(Solution)} = \frac{2.70\times10^{-4}}{1.00} = 2.70\times10^{-4} \text{ mol L}^{-1}$$

10. (a)

$H^+(aq) + NO_3^-(aq) + NH_3(g) \rightarrow NH_4^+(aq) + NO_3^-(aq) \rightarrow NH_4NO_3(s)$

$2H^+(aq) + SO_4^{2-}(aq) + 2K^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(\ell) + 2K^+(aq) + SO_4^{2-}(aq) \rightarrow K_2SO_4(s)$

$Ca_3(PO_4)_2(s) + 12H^+(aq) \rightarrow 3Ca^+(aq) + 6H_2PO_4^-(aq) \rightarrow 3Ca(H_2PO_4)_2(s)$

(b) (i)

$$n(NH_4NO_3) = cV = 1.50\times10.0 = 15.0 \text{ mol}$$

$$M(NH_4NO_3) = 2(14.01) + 4(1.008) + 3(16.00) = 80.052 \text{ g mol}^{-1}$$

$$m(NH_4NO_3) = nM = 15.0\times80.052 = 1.20 \text{ kg}$$

(ii)

$$n(K_2SO_4) = cV = 2.80\times2.50 = 7.00 \text{ mol}$$

$$M(K_2SO_4) = 2(39.10) + (32.06) + 4(16.00) = 174.26 \text{ g mol}^{-1}$$

$$m(K_2SO_4) = nM = 7.00\times174.26 = 1.22 \text{ kg}$$

(iii)

$$n(Ca(H_2PO_4)_2) = cV = 0.100\times0.500 = 0.050 \text{ mol}$$

$$M(Ca(H_2PO_4)_2) = 40.08 + 4(1.008) + 2(30.97) + 8(16.00) = 234.052 \text{ g mol}^{-1}$$

$$m(Ca(H_2PO_4)_2) = nM = 0.050\times234.052 = 11.7 \text{ g}$$

11.

$$n(H_2SO_4)_{required} = cV = 2.50 \times 0.800 = 2.00 \text{ mol}$$

$$V(H_2SO_4)_{concentrated} = \frac{n}{c} = \frac{2.00}{18.0} = 0.111 \text{ L} = 111 \text{ mL}$$

12.

$n(H^+)_{\text{in nitric acid solution}} = cV = 14.3 \times 0.360 = 5.148 \text{ mol}$

$n(H^+)_{\text{in hydrochloric acid solution}} = cV = 12.1 \times 0.675 = 8.1675 \text{ mol}$

$n(H^+)_{\text{Total}} = n(H^+)_{\text{in nitric acid solution}} + n(H^+)_{\text{in hydrochloric acid solution}} = 5.148 + 8.1675 = 13.3155 \text{ mol}$

$V(\text{Solution})_{\text{Total}} = 0.360 + 0.675 = 1.035 \text{ L}$

$$[H+] = \frac{n}{V} = \frac{13.3155}{1.035} = 12.9 \text{ mol L}^{-1}$$

13. (a)

$n(H^+)_{\text{in bore water}} = cV = 3.60 \times 10^{-4} \times 3000 = 1.08 \text{ mol}$

$$V(\text{Mixed water}) = \frac{n}{c} = \frac{1.08}{1.00 \times 10^{-6}} = 1.08 \times 10^{6} \text{ L}$$

$V(\text{Rain water}) = V(\text{Mixed water}) - V(\text{Bore water}) = 1.08 \times 10^{6} - 3000 = 1.08 \times 10^{6} \text{ L}$

(b) No. Volume of rain water required is too large.

(c) Addition of low cost oxides, hydroxides or carbonates. Examples include calcium carbonate, sodium carbonate, calcium oxide or hydroxide etc.

14. $n(H^+)_{\text{in conc acid}} = cV = 5.50 \times 0.150 = 0.825 \text{ mol}$

$$V(\text{Dilute acid}) = \frac{n}{c} = \frac{0.825}{0.500} = 1.65 \text{ L}$$

$V(\text{Water}) = V(\text{Dilute acid}) - V(\text{Concentrated acid}) = 1.65 - 0.150 = 1.50 \text{ L}$