Reaction Stoichiometry III
Yield, Concentration, and Solution Stoichiometry

1. If 5.05 g of $CuCl_2$ reacts with excess tin, what mass of copper is expected from the reaction?

$$CuCl_{2(aq)} + Sn \rightarrow SnCl_{2(aq)} + Cu_{(s)}$$

$$M_{CuCl_2} = 134.45\ \mathrm{g/mol} \qquad M_{Cu} = 63.546\ \mathrm{g/mol}$$

$$m_{Sn} = \left(\frac{5.05\text{ g CuCl}_2}{134.45\ \frac{\text{g CuCl}_2}{\text{mol CuCl}_2}}\right) \times \frac{1\text{ mol Cu}}{1\text{ mol CuCl}_2} \times 63.546\ \mathrm{g/mol}$$

$$m_{Sn} = 2.39\text{ g Cu (Theoretical Yield)}$$

What is the percentage yield if only 2.20 g of Cu is recovered? Where did the lost product go?

$$\%\text{yield} = \frac{2.20\text{ g}}{2.39\text{ g}} \times 100 = 92.2\%\text{ yield}$$

2. What is the molar concentration of a solution prepared by dissolving 5.84 g of NaCl in sufficient water to make 1.0 L of solution?

$$M_{NaCl} = 58.44\ \mathrm{g/mol} \qquad \text{definition: } C = \frac{n_{NaCl}}{V_{soln}}$$

$$n_{NaCl} = \frac{5.84\text{ g}}{58.44\ \mathrm{g/mol}} = 0.09993\text{ mol NaCl}$$

$$C = \frac{0.09993\text{ mol NaCl}}{1.0\text{ L}} = 0.10\text{ M NaCl}$$

Also written: $0.10\ \frac{\text{mol}}{\text{L}}$ and 0.10 mol L^{-1}

3. What mass of NaOH is necessary to prepare 500.0 mL of 0.250 M NaOH? (molar mass of NaOH = 40.00 g/mol)

$$C = \frac{n}{V}$$

$$n_{NaOH} = 0.250\ \frac{\text{mol NaOH}}{\text{L soln}} \times 0.5000\text{ L} = 0.125\text{ mol NaOH}$$

$$m_{NaOH} = 0.125\text{ mol NaOH} \times 40.00\ \frac{\text{g NaOH}}{\text{mol NaOH}} = 5.00\text{ g NaOH}$$

4. What quantity, in moles, of HCl are present in 10.00 mL of 0.125 M HCl? What would the new HCl concentration be if 10.00 mL of water were added to the original 10.00 mL of 0.125 M HCl?

$$n_{\mathrm{HCl}} = 0.01000\ \mathrm{L} \times 0.125\,\tfrac{\mathrm{mol\ HCl}}{\mathrm{L\ soln}} = 1.25\times10^{-3}\ \mathrm{mol\ HCl}$$

$$C_{\mathrm{new}} = \frac{1.25\times10^{-3}\ \mathrm{mol\ HCl}}{0.02000\ \mathrm{L}} = 0.0625\ \mathrm{M\ HCl}$$

5. What is the concentration of the solution prepared by diluting 10.00 mL of 0.125 M HCl to 40.00 mL?

$$C_1V_1 = C_2V_2$$

$$C_{\mathrm{new}} = \frac{(10.00\ \mathrm{mL})(0.125\ \mathrm{M})}{40.00\ \mathrm{mL}} = 0.0313\ \mathrm{M\ HCl}$$

6. How might you prepare 500.0 mL of 0.10 M HC1 from concentrated HCl (12 M)?

    1. Use the dilution equation to calculate the need volume of concentrated acid:

    $$C_{\mathrm{conc'd\ acid}}V_{\mathrm{conc'd\ acid}} = C_{\mathrm{dilution}}V_{\mathrm{dilution}}$$

    $$V_{\mathrm{conc'd\ acid}} = \frac{500.0\ \mathrm{mL} \times 0.10\ \mathrm{M}}{12\ \mathrm{M}} = 4.2\ \mathrm{mL}$$

    2. Pipette about 4 mL of concentrated HCl into a 500 mL volumetric flask and dilute up to the 500 mL mark with water.

7. What volume (in mL) of 0.15 M HCl will react with 2.50 g of Na_2CO_3 according to the equation

$$2\ \mathrm{HCl}_{(aq)} + \mathrm{Na_2CO_{3(s)}} \rightarrow 2\ \mathrm{NaCl}_{(aq)} + \mathrm{CO_2(g)} + \mathrm{H_2O}_{(l)}$$

$$M_{\mathrm{Na_2CO_3}} = 105.99\,\tfrac{\mathrm{g}}{\mathrm{mol}}$$

$$n_{\mathrm{Na_2CO_3}} = 2.50\ \mathrm{g\ Na_2CO_3} \times \frac{1\ \mathrm{mol\ Na_2CO_3}}{105.99\ \mathrm{g\ Na_2CO_3}} = 0.02359\ \mathrm{mol\ Na_2CO_3}$$

$$n_{\mathrm{HCl}} = 0.02359\ \mathrm{mol\ Na_2CO_3} \times \frac{2\ \mathrm{mol\ HCl}}{1\ \mathrm{mol\ Na_2CO_3}} = 0.04717\ \mathrm{mol\ HCl}$$

$$V_{\mathrm{HCl}} = 0.04717\ \mathrm{mol\ HCl} \times \frac{1\ \mathrm{L\ soln}}{0.15\ \mathrm{mol\ HCl}} \times 1000\,\tfrac{\mathrm{mL}}{\mathrm{L}} = 314\ \mathrm{mL\ HCl\ solution}$$

8. What is the concentration of a $KMnO_4$ solution if 15.16 mL of the $KMnO_4$ solution is required to titrate to equivalence point 25.00 mL of 0.08765 M $FeCl_2$?

$$5\ FeCl_2 + KMnO_4 + 8\ HCl \rightarrow 5\ FeCl_3 + MnCl_2 + KCl + 4\ H_2O$$

$$n_{FeCl_2} = 0.02500\ \text{L} \times 0.08765 \tfrac{\text{mol FeCl}_2}{\text{L soln}} = 0.0021913\ \text{mol FeCl}_2$$

$$n_{KMnO_4} = 0.0021913\ \text{mol FeCl}_2 \times \frac{1\ \text{mol KMnO}_4}{5\ \text{mol FeCl}_2} = 4.3825\times10^{-4}\ \text{mol KMnO}_4$$

$$C_{KMnO_4} = \frac{4.3825\times10^{-4}\ \text{mol KMnO}_4}{0.01516\ \text{L soln}} = 0.02891\ \text{M KMnO}_4$$

9. What is the percentage purity of a sample of impure oxalic acid ($H_2C_2O_4$, 90.04 g/mol) if 23.42 mL of the $KMnO_4$ from problem 8 was required to titrate 1.5960 g of the solid?

First, the hard part; write the balanced chemical equation

$$2\ KMnO_4 + 10\ H_2C_2O_4 + 6\ HCl \rightarrow 10\ CO_2 + 2\ MnCl_2 + 2\ KCl + 3\ H_2O$$

Definition: $\%\text{purity} = \dfrac{m_{H_2C_2O_4}}{m_{\text{sample}}} \times 100 \qquad m_{\text{sample}} = 0.1596\ \text{g}$

$$n_{KMnO_4} = 0.02342\ \text{L} \times 0.02891\ \text{M KMnO}_4 = 6.7703\times10^{-4}\ \text{mol KMnO}_4$$

$$n_{H_2C_2O_4} = 6.7703\times10^{-4}\ \text{mol KMnO}_4 \times \frac{10\ \text{mol H}_2\text{C}_2\text{O}_4}{2\ \text{mol KMnO}_4} = 3.3852\times10^{-3}\ \text{mol H}_2\text{C}_2\text{O}_4$$

$$m_{H_2C_2O_4} = 3.3852\times10^{-3}\ \text{mol H}_2\text{C}_2\text{O}_4 \times 90.04\ \text{g/mol} = 0.3048\ \text{g H}_2\text{C}_2\text{O}_4$$

$$\%\text{purity} = \frac{3.3048\ \text{g}}{1.5960\ \text{g}} \times 100 = 19.10\%\ \text{H}_2\text{C}_2\text{O}_4$$