Volumetric (Solution) Stoichiometry and Titration

1. A 45.00 mL sample of HNO_3 was titrated with 0.450 M NaOH. The equivalence point volume was 37.54 mL of NaOH. What is the concentration of the HNO_3? (Write a balanced equation)

$$HNO_3\ (aq)\ + NaOH\ (aq) \rightarrow\ NaNO_3\ (aq) + H_2O\ (l)$$

Moles of NaOH = V x M = 0.03254 L x 0.450 M = 0.01464 mol NaOH

At the equivalence point, all of the NaOH will have reacted with all of the acid. There is a 1:1 ratio of base to acid

$$0.01464\ mol\ NaOH \times \frac{1\ mol\ HNO_3}{1\ mol\ NaOH} = 0.01464\ mol\ HNO_3$$

$$\frac{0.01464\ mol\ HNO_3}{0.04500\ L} = \mathbf{0.325\ M}$$

2. What volume of 0.135 M $HClO_4$ is required to neutralize 50.00 mL of 0.0926 M $Ba(OH)_2$? Write a balanced equation.

$$2\ HClO_4\ (aq) + Ba(OH)_2\ (aq) \rightarrow Ba(ClO_4)_2\ (aq) + 2\ H_2O\ (l)$$

mol $Ba(OH)_2$ = 0.05000 L x 0.0926 M = 0.00463 mol $Ba(OH)_2$

$$0.00463\ mol\ Ba(OH)_2 \times \frac{2\ mol\ HClO_4}{1\ mol\ Ba(OH)_2} = 0.00926\ mol\ HClO_4$$

We know the molarity and the number of moles of acid. We solve for the volume in L and then convert to mL.

$$\frac{0.00926\ mol}{0.135\ \frac{mol}{L}} = \mathbf{0.0686\ L = 68.6\ mL}$$

3. Consider the following balanced chemical equation.

$$3\ CaCl_2\ (aq) + 2\ K_3PO_4\ (aq) \rightarrow Ca_3(PO_4)_2\ (s) + 6\ KCl\ (aq)$$

If 25.00 mL of 0.455 M $CaCl_2$ is mixed with 30.00 mL of 0.365 M K_3PO_4, how many grams of $Ca_3(PO_4)_2$ are formed?

moles of $CaCl_2$ = 0.02500 L x 0.455 mol/L = 0.011375 mol $CaCl_2$

moles of K_3PO_4 = 0.03000 L x 0.365 mol/L = 0.01095 mol K_3PO_4

Find limiting reactant:

$$0.011375\ mol\ CaCl_2 \times \frac{1\ mol\ Ca_3(PO_4)_2}{3\ mol\ CaCl_2} = 0.003792\ mol\ Ca_3(PO_4)_2$$

$$0.01095\ mol\ K_3PO_4 \times \frac{1\ mol\ Ca_3(PO_4)_2}{2\ mol\ K_3PO_4} = 0.005475\ mol\ Ca_3(PO_4)_2$$

The $CaCl_2$ is the limiting reactant. The M_m $(Ca_3(PO_4)_2$ = 310.18 g/mol

$$0.003792\ mol\ Ca_3(PO_4)_2 \times \frac{310.18\ g}{1\ mol\ Ca_3(PO_4)_2} = \mathbf{1.18\ g\ Ca_3(PO_4)_2}$$