EDTA Titration Calculations

The hardness of water is due in part to the presence of Ca^{2+} ions in water. The concentration of Ca^{2+} ions is usually expressed as ppm $CaCO_3$ in the water sample. This is equivalent to 1 gram of $CaCO_3$ in 10^6 grams of sample. In the lab 1 ppm $CaCO_3$ is expressed as 1 mg $CaCO_3$ per 1 Liter of sample or ppm is mg $CaCO_3$ per L of sample.

Calcium ions can be analyzed by titration with EDTA using an appropriate indicator. EDTA is ethylene diamine tetraacetic acid or $H_4C_{10}H_{12}N_2O_4$. EDTA itself is not very water soluble so the disodium salt is used, $Na_2H_2C_{10}H_{12}N_2O_4$. For the purpose of simplicity, Y will stand for $C_{10}H_{12}N_2O_4$. The EDTA we use is thus Na_2H_2Y. The part that reacts with calcium ions is H_2Y^{2-} according to the following equation.

$$H_2Y^{2-} + Ca^{2+} \rightarrow CaY^{2-} + 2H^+$$

The procedure is done in 3 steps 1) Preparation of a standard Ca^{2+} solution, 2) Standardization of EDTA with the standard calcium solution and, 3) Analysis of an unknown Ca^{2+} sample with the standardized EDTA solution.

1. Standard calcium solution.

0.405 g of $CaCO_3$ is dissolved in HCl and diluted to a volume of 250.00 mL. What is the molarity of calcium ions in the solution?

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow Ca^{2+}{}_{(aq)} + 2Cl^{1-}{}_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

$$\left(0.405 g CaCO_3\right)\left(\frac{1 mol CaCO_3}{100.09 g CaCO_3}\right)\left(\frac{1 mol Ca^{+2}}{1 mol CaCO_3}\right) = 0.004505 \text{ mol } Ca^{2+} \text{ ions}$$

$$\text{Molarity of } Ca^{2+} = \frac{0.00405 mol Ca^{2+}}{0.250 L} = 0.0162 \text{ M } Ca^{2+} \text{ ions}$$

2. Standardization of EDTA.

A 25.00 mL aliquot (a portion or part) of the standard calcium solution reacts with 27.25 mL of the EDTA solution. What is the molarity of the EDTA?

$$\left(\frac{0.0162 mol Ca^{2+}}{L}\right)\left(\frac{0.02500 L}{1}\right)\left(\frac{1 mol EDTA}{1 mol Ca^{2+}}\right) = 0.000405 \text{ mol EDTA}$$

$$\text{Molarity of EDTA} = \frac{0.000405 mol EDTA}{0.02725 L} = 0.0149 \text{ M EDTA}$$

3. Ca^{2+} concentration in an unknown solution $CaCO_3$ reported as ppm $CaCO_3$.

A 50.00 mL unknown solution requires 25.55 ml of the standardized EDTA solution for complete reaction. What is the Ca^{2+} concentration in the unknown reported as ppm $CaCO_3$?

$$\left(\frac{0.0149 molEDTA}{L}\right)\left(\frac{0.02555 L}{1}\right)\left(\frac{1 molCa^{2+}}{1 molEDTA}\right) = 0.000381 \text{mol } Ca^{2+}$$

$$0.000381 molCa^{2+}\left(\frac{1 molCaCO_3}{1 molCa^{2+}}\right)\left(\frac{100.09 gCaCO_3}{1 molCaCO_3}\right) = 0.0381 \text{g } CaCO_3$$

$$\text{ppm } CaCO_3 = \frac{mgCaCO_3}{LSolution} = 0.0381 gCaCO_3\left(\frac{1000 mgCaCO_3}{1.000 gCaCO_3}\right)\left(\frac{1}{0.05000 LSolution}\right) = 762$$