Stoichiometry in Indirect Titration

Problem 4-54

A 25.00-mL sample of HCl(aq) was added to a 0.1000-g sample of $CaCO_3$. All the $CaCO_3$ reacted, leaving some excess HCl(aq).

$$CaCO_3(s) + 2\ HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

The excess HCl(aq) required 43.82 mL of 0.01185 M $Ba(OH)_2(aq)$ to complete the following reaction. What is the molarity of the original HCl(aq)?

$$2\ HCl(aq) + Ba(OH)_2(aq) \rightarrow BaCl_2(aq) + 2\ H_2O(l)$$

Solution:

This is two individual problems. The first part is to calculate how much HCl(aq) reacted with the $CaCO_3$ and the second part is to calculate how much HCl(aq) was left over. The sum of the two molar quantities of HCl(aq) is the total amount in the original 25 mL sample.

First, the amount of HCl that reacted with $CaCO_3$:

$$n_{HCl} = \left(0.1000\ \text{g } CaCO_3 \Big/ 100.09\ \tfrac{\text{g}}{\text{mol}} \right) \times \frac{2\ \text{mol HCl}}{1\ \text{mol } CaCO_3} = 0.0019982\ \text{mol HCl}$$

Now, the remaining amount of HCl from the titration:

$$n_{HCl} = \left(0.01185\ \tfrac{\text{mol } Ba(OH)_2}{\text{L soln}} \times 0.04382\ \text{L soln} \right) \times \frac{2\ \text{mol HCl}}{1\ \text{mol } Ba(OH)_2} = 0.0010385\ \text{mol HCl}$$

The total amount of HCl in the original 25.00 mL is

$$n_{total} = 0.0019982\ \text{mol} + 0.0010385\ \text{mol} = 0.003037\ \text{mol HCl}$$

And the concentration is:

$$C_{HCl} = \frac{0.003037\ \text{mol HCl}}{0.02500\ \text{L}} = 0.1215\ \text{M HCl}$$