

## 14.5: Acid-Base Titrations

### Learning Objectives

- Describe a titration experiment.
- Explain what an indicator does.
- Perform a titration calculation correctly.

The reaction of an acid with a base to make a salt and water is a common reaction in the laboratory, partly because many compounds can act as acids or bases. Another reason that acid-base reactions are so prevalent is because they are often used to determine quantitative amounts of one or the other. Performing chemical reactions quantitatively to determine the exact amount of a reagent is called a **titration**. A titration can be performed with almost any chemical reaction for which the balanced chemical equation is known. Here, we will consider titrations that involve acid-base reactions.

In a titration, one reagent has a known concentration or amount, while the other reagent has an unknown concentration or amount. Typically, the known reagent (the **titrant**) is added to the unknown quantity and is dissolved in solution. The unknown amount of substance (the **analyte**) may or may not be dissolved in solution (but usually is). The titrant is added to the analyte using a precisely calibrated volumetric delivery tube called a burette (also spelled buret; see Figure 14.5.1). The burette has markings to determine how much volume of solution has been added to the analyte. When the reaction is complete, it is said to be at the **equivalence point**; the number of moles of titrant can be calculated from the concentration and the volume, and the balanced chemical equation can be used to determine the number of moles (and then concentration or mass) of the unknown reactant.

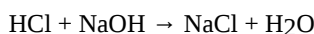


Figure 14.5.1 Equipment for Titrations. A burette is a type of liquid dispensing system that can accurately indicate the volume of liquid dispensed.

For example, suppose 25.66 mL (or 0.02566 L) of 0.1078 M HCl was used to titrate an unknown sample of NaOH. What mass of NaOH was in the sample? We can calculate the number of moles of HCl reacted:

$$\# \text{ mol HCl} = (0.02566 \text{ L})(0.1078 \text{ M}) = 0.002766 \text{ mol HCl}$$

We also have the balanced chemical reaction between HCl and NaOH:



So we can construct a conversion factor to convert to number of moles of NaOH reacted:

$$0.002766 \text{ mol } \cancel{\text{HCl}} \times \frac{1 \text{ mol NaOH}}{1 \text{ mol } \cancel{\text{HCl}}} = 0.002766 \text{ mol NaOH}$$

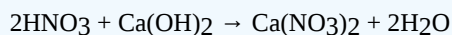
Then we convert this amount to mass, using the molar mass of NaOH (40.00 g/mol):

$$0.002766 \text{ mol } \cancel{\text{HCl}} \times \frac{40.00 \text{ g NaOH}}{1 \text{ mol } \cancel{\text{HCl}}} = 0.1106 \text{ g NaOH}$$

This type of calculation is performed as part of a titration.

### ✓ Example 14.5.1

What mass of  $\text{Ca(OH)}_2$  is present in a sample if it is titrated to its equivalence point with 44.02 mL of 0.0885 M  $\text{HNO}_3$ ? The balanced chemical equation is as follows:



#### Solution

In liters, the volume is 0.04402 L. We calculate the number of moles of titrant:

$$\# \text{ moles HNO}_3 = (0.04402 \text{ L})(0.0885 \text{ M}) = 0.00390 \text{ mol HNO}_3$$

Using the balanced chemical equation, we can determine the number of moles of  $\text{Ca(OH)}_2$  present in the analyte:

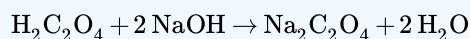
$$0.00390 \text{ mol } \cancel{\text{HNO}_3} \times \frac{1 \text{ mol } \text{Ca(OH)}_2}{2 \text{ mol } \cancel{\text{HNO}_3}} = 0.00195 \text{ mol } \text{Ca(OH)}_2$$

Then we convert this to a mass using the molar mass of  $\text{Ca(OH)}_2$ :

$$0.00195 \text{ mol } \cancel{\text{Ca(OH)}_2} \times \frac{74.1 \text{ g } \text{Ca(OH)}_2}{\text{mol } \cancel{\text{Ca(OH)}_2}} = 0.144 \text{ g } \text{Ca(OH)}_2$$

### ? Exercise 14.5.1

What mass of  $\text{H}_2\text{C}_2\text{O}_4$  is present in a sample if it is titrated to its equivalence point with 18.09 mL of 0.2235 M NaOH? The balanced chemical reaction is as follows:



**Answer**

0.182 g

How does one know if a reaction is at its equivalence point? Usually, the person performing the titration adds a small amount of an **indicator**, a substance that changes color depending on the acidity or basicity of the solution. Because different indicators change colors at different levels of acidity, choosing the correct one is important in performing an accurate titration.

## Summary

A titration is the quantitative reaction of an acid and a base. Indicators are used to show that all of the analyte has reacted with the titrant.

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