

Solutions to Titration Problems

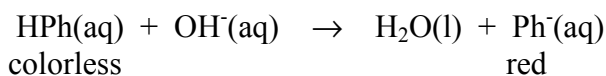
1. Write a description of the general steps for the titration procedure to determine the molarity of a solution of a substance.

Typical steps for this process are listed below.

- A specific volume of the solution to be titrated (solution #2) is added to an Erlenmeyer flask.
 - A solution of a substance that reacts with the solute in the solution in the Erlenmeyer flask is added to a buret. This solution in the buret, which has a known concentration, is the titrant. The buret is set up over the Erlenmeyer flask so the titrant can be added to the solution to be titrated.
 - An indicator is added to the solution being titrated. The indicator is a substance that changes color when the reaction is complete.
 - The titrant is slowly added to the solution being titrated until the indicator changes color, showing that the reaction is complete. This stage in the procedure is called the endpoint.
 - The volume of titrant added from the buret is measured.
2. Write a description of how phenolphthalein is able to show when the endpoint is reached in the titration of an acid with a base.

Phenolphthalein is a complex, organic weak acid. In acidic conditions, it is in the acid form. The symbol HPh represents the acid form of phenolphthalein. In basic conditions, the acidic hydrogen atom is removed forming an anion, symbolized by Ph^- . The uncharged acid form of phenolphthalein, HPh, is colorless, and the ionized base form, Ph^- , is red.

When enough base solution is added to react with all of the H^+ ions, the reaction is complete. When a small amount of extra base solution is added, perhaps one drop of NaOH solution, there will be an excess of hydroxide ions, OH^- , in solution. These react with the phenolphthalein molecules, HPh, changing them from the acid form to the base form, Ph^- . Because the base form is red, the solution turns red, telling us that the reaction is complete (or just slightly beyond complete).



3. The molarity of a hydrochloric acid solution can be determined by titrating a known volume of the solution with a sodium hydroxide solution of known concentration. If 14.7 mL of 0.102 M NaOH is required to titrate 25.00 mL of a hydrochloric acid, HCl, solution, what is the molarity of the hydrochloric acid?

$$\frac{? \text{ mol HCl}}{\text{L HCl soln}} = \frac{14.7 \text{ mL NaOH soln}}{25.00 \text{ mL HCl soln}} \left(\frac{0.102 \text{ mol NaOH}}{10^3 \text{ mL NaOH soln}} \right) \left(\frac{1 \text{ mol HCl}}{1 \text{ mol NaOH}} \right) \left(\frac{10^3 \text{ mL}}{1 \text{ L}} \right)$$

$$= \mathbf{0.0579 \text{ M HCl}}$$

4. If 36.2 mL of 0.152 M NaOH is required to neutralize 25.00 mL of an acetic acid, HC₂H₃O₂, solution, what is the molarity of the acetic acid? (Obj #25)

$$\frac{? \text{ mol HC}_2\text{H}_3\text{O}_2}{\text{L HC}_2\text{H}_3\text{O}_2 \text{ soln}} = \frac{36.2 \text{ mL NaOH soln}}{25.00 \text{ mL HC}_2\text{H}_3\text{O}_2 \text{ soln}} \left(\frac{0.152 \text{ mol NaOH}}{10^3 \text{ mL NaOH soln}} \right) \left(\frac{1 \text{ mol HC}_2\text{H}_3\text{O}_2}{1 \text{ mol NaOH}} \right) \left(\frac{10^3 \text{ mL}}{1 \text{ L}} \right)$$

$$= \mathbf{0.220 \text{ M HC}_2\text{H}_3\text{O}_2}$$

5. The molarity of a sodium hydroxide solution can be determined by titrating a known volume of the solution with a hydrochloric acid solution of known concentration. If 19.1 mL of 0.118 M HCl is required to neutralize 25.00 mL of a sodium hydroxide solution, what is the molarity of the sodium hydroxide?

$$\frac{? \text{ mol NaOH}}{\text{L NaOH soln}} = \frac{19.1 \text{ mL HCl soln}}{25.00 \text{ mL NaOH soln}} \left(\frac{0.118 \text{ mol HCl}}{10^3 \text{ mL HCl soln}} \right) \left(\frac{1 \text{ mol NaOH}}{1 \text{ mol HCl}} \right) \left(\frac{10^3 \text{ mL}}{1 \text{ L}} \right)$$

$$= \mathbf{9.02 \times 10^{-2} \text{ M NaOH}}$$

6. If 7.3 mL of 1.25 M HNO₃ is required to neutralize 25.00 mL of a potassium hydroxide solution, what is the molarity of the potassium hydroxide?

$$\frac{? \text{ mol KOH}}{\text{L KOH soln}} = \frac{7.3 \text{ mL HNO}_3 \text{ soln}}{25.00 \text{ mL KOH soln}} \left(\frac{0.152 \text{ mol HNO}_3}{10^3 \text{ mL HNO}_3 \text{ soln}} \right) \left(\frac{1 \text{ mol KOH}}{1 \text{ mol HNO}_3} \right) \left(\frac{10^3 \text{ mL}}{1 \text{ L}} \right)$$

$$= \mathbf{0.044 \text{ M KOH}}$$

7. If 12.0 mL of 1.34 M NaOH is required to neutralize 25.00 mL of a sulfuric acid, H₂SO₄, solution, what is the molarity of the sulfuric acid?

$$\frac{? \text{ mol H}_2\text{SO}_4}{\text{L H}_2\text{SO}_4 \text{ soln}} = \frac{12.0 \text{ mL NaOH soln}}{25.00 \text{ mL H}_2\text{SO}_4 \text{ soln}} \left(\frac{1.34 \text{ mol NaOH}}{10^3 \text{ mL NaOH soln}} \right) \left(\frac{1 \text{ mol H}_2\text{SO}_4}{2 \text{ mol NaOH}} \right) \left(\frac{10^3 \text{ mL}}{1 \text{ L}} \right)$$

$$= \mathbf{0.322 \text{ M H}_2\text{SO}_4}$$

8. If 46.2 mL of 2.50 M NaOH is required to neutralize 25.00 mL of a phosphoric acid, H_3PO_4 , solution, what is the molarity of the phosphoric acid?

$$\frac{? \text{ mol H}_3\text{PO}_4}{\text{L H}_3\text{PO}_4 \text{ soln}} = \frac{46.2 \text{ mL NaOH soln}}{25.00 \text{ mL H}_3\text{PO}_4 \text{ soln}} \left(\frac{2.50 \text{ mol NaOH}}{10^3 \text{ mL NaOH soln}} \right) \left(\frac{1 \text{ mol H}_3\text{PO}_4}{3 \text{ mol NaOH}} \right) \left(\frac{10^3 \text{ mL}}{1 \text{ L}} \right)$$
$$= \mathbf{1.54 \text{ M H}_3\text{PO}_4}$$

9. If 11.3 mL of 0.110 M HCl is required to neutralize 25.00 mL of a barium hydroxide solution, what is the molarity of the barium hydroxide?

$$\frac{? \text{ mol Ba(OH)}_2}{\text{L Ba(OH)}_2 \text{ soln}} = \frac{11.3 \text{ mL HCl soln}}{25.00 \text{ mL Ba(OH)}_2 \text{ soln}} \left(\frac{0.110 \text{ mol HCl}}{10^3 \text{ mL HCl soln}} \right) \left(\frac{1 \text{ mol Ba(OH)}_2}{2 \text{ mol HCl}} \right) \left(\frac{10^3 \text{ mL}}{1 \text{ L}} \right)$$
$$= \mathbf{0.0249 \text{ M Ba(OH)}_2}$$

10. If 8.6 mL of 0.0994 M HNO_3 is required to neutralize 25.00 mL of a strontium hydroxide solution, what is the molarity of the strontium hydroxide?

$$\frac{? \text{ mol Sr(OH)}_2}{\text{L Sr(OH)}_2 \text{ soln}} = \frac{8.6 \text{ mL HNO}_3 \text{ soln}}{25.00 \text{ mL Sr(OH)}_2 \text{ soln}} \left(\frac{0.0994 \text{ mol HNO}_3}{10^3 \text{ mL HNO}_3 \text{ soln}} \right) \left(\frac{1 \text{ mol Sr(OH)}_2}{2 \text{ mol HNO}_3} \right) \left(\frac{10^3 \text{ mL}}{1 \text{ L}} \right)$$
$$= \mathbf{0.0171 \text{ M Sr(OH)}_2}$$