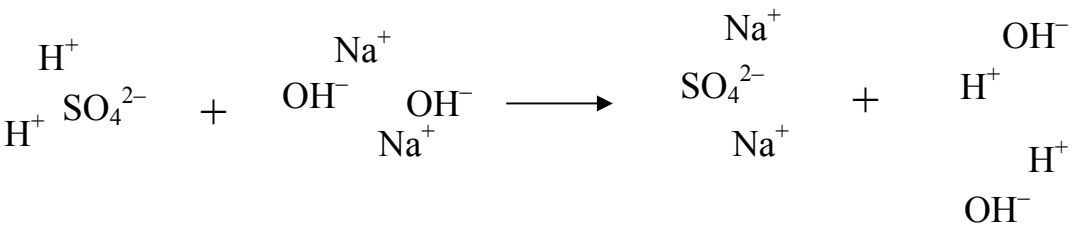
Titration Problems Answer Key

1. (a)



(b) According to the diagram, two moles of sodium hydroxide must be present to neutralize one mole of sulfuric acid.

(c) $H_3PO_4(aq) + 3KOH(aq) \rightarrow K_3PO_4(aq) + 3H_2O(\ell)$

$$7.2\,\text{mol KOH} \times \frac{1\,\text{mol } H_3PO_4}{3\,\text{mol KOH}} = 2.4\,\text{mol } H_3PO_4(aq)$$

1.4 moles of phosphoric acid are required to neutralize 7.2 moles of potassium hydroxide.

2. $HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(\ell)$

$$0.025\,00\,\text{L NaOH} \times 0.150\frac{\text{mol}}{\text{L}}\text{NaOH} \times \frac{1\,\text{mol } HNO_3}{1\,\text{mol NaOH}} \times \frac{1}{0.017\,85\,\text{L}}HNO_3 = 0.210\frac{\text{mol}}{\text{L}}HNO_3(aq)$$

When the pH is 7.0, the concentration of the nitric acid is 0.210 mol/L.

3. $H_2SO_4(aq) + 2NH_3(aq) \rightarrow (NH_4)_2SO_4(aq)$

$$0.0328\,\text{L } NH_3 \times 0.116\frac{\text{mol}}{\text{L}}NH_3 \times \frac{1\,\text{mol } H_2SO_4}{2\,\text{mol } NH_3} \times \frac{1}{0.0250\,\text{L}}H_2SO_4 = 0.0761\frac{\text{mol}}{\text{L}}H_2SO_4(aq)$$

The concentration of the sulfuric acid is 0.0761 mol/L.

4. $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(\ell)$

$$\text{Volume of NaOH used} = \text{Initial volume of NaOH} - \text{Final volume of NaOH}$$

$$V_{NaOH} = 23.08\,\text{mL} - 1.06\,\text{mL} = 22.02\,\text{mL} = 0.022\,02\,\text{L}$$

$$0.010\,00\,\text{L HCl} \times 0.235\frac{\text{mol}}{\text{L}}\text{HCl} \times \frac{1\,\text{mol NaOH}}{1\,\text{mol HCl}} \times \frac{1}{0.022\,02\,\text{L}}\text{NaOH} = 0.107\frac{\text{mol}}{\text{L}}\text{NaOH(aq)}$$

The concentration of the sodium hydroxide solution was 0.107mol/L.

5. $H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(\ell)$

$$0.0372\,\text{L KOH} \times 0.650\frac{\text{mol}}{\text{L}}\text{KOH} \times \frac{1\,\text{mol } H_2SO_4}{2\,\text{mol KOH}} \times \frac{\text{L}}{0.250\,\text{mol}}H_2SO_4 = 0.0484\,\text{L } H_2SO_4(aq)$$

48.4 mL of sulfuric acid is needed to react completely.

6. $CH_3COOH(aq) + NaOH(aq) \rightarrow NaCH_3COO(aq) + H_2O(\ell)$

$$0.0425\,\text{L NaOH} \times 1.02\frac{\text{mol}}{\text{L}}\text{NaOH} \times \frac{1\,\text{mol } CH_3COOH}{1\,\text{mol NaOH}} \times \frac{1}{0.0500\,\text{L}}CH_3COOH$$

$$= 0.867\frac{\text{mol}}{\text{L}}CH_3COOH(aq)$$

The concentration of ethanoic acid is 0.867 mol/L.

7. $2HCl(aq) + Ba(OH)_2(aq) \rightarrow BaCl_2(aq) + 2H_2O(\ell)$

$$\text{Volume of HCl used} = \text{Initial volume of HCl} - \text{Final volume of HCl}$$

$$\text{Trial 1: } V_{HCl} = 50.00\,\text{mL} - 37.32\,\text{mL} = 12.68\,\text{mL}$$

$$\text{Trial 2: } V_{HCl} = 37.32\,\text{mL} - 24.56\,\text{mL} = 12.76\,\text{mL}$$

$$\text{Trial 3: } V_{HCl} = 24.56\,\text{mL} - 11.78\,\text{mL} = 12.78\,\text{mL}$$

Concentration of $Ba(OH)_2$:

Trial 1:

$$0.012\,68\,\text{L HCl} \times 0.250\frac{\text{mol}}{\text{L}}\text{HCl} \times \frac{1\,\text{mol } Ba(OH)_2}{2\,\text{mol HCl}} \times \frac{1}{0.010\,00\,\text{L}}Ba(OH)_2 = 0.159\frac{\text{mol}}{\text{L}}Ba(OH)_2(aq)$$

Trial 2:

$$0.012\,76\,\text{L HCl} \times 0.250\frac{\text{mol}}{\text{L}}\text{HCl} \times \frac{1\,\text{mol } Ba(OH)_2}{2\,\text{mol HCl}} \times \frac{1}{0.010\,00\,\text{L}}Ba(OH)_2 = 0.160\frac{\text{mol}}{\text{L}}Ba(OH)_2(aq)$$

Trial 3:

$$0.012\,78\,\text{L HCl} \times 0.250\frac{\text{mol}}{\text{L}}\text{HCl} \times \frac{1\,\text{mol } Ba(OH)_2}{2\,\text{mol HCl}} \times \frac{1}{0.010\,00\,\text{L}}Ba(OH)_2 = 0.160\frac{\text{mol}}{\text{L}}Ba(OH)_2(aq)$$

$$\text{Average concentration of } Ba(OH)_2 = \frac{\left(0.159\frac{\text{mol}}{\text{L}} + 0.160\frac{\text{mol}}{\text{L}} + 0.160\frac{\text{mol}}{\text{L}}\right)}{3}$$

$$\text{Average concentration of } Ba(OH)_2 = 0.160\frac{\text{mol}}{\text{L}}$$