

TITRATION PROBLEMS

1. Calculate the volume of 0.500 mol/L $\text{NaOH}_{(\text{aq})}$ required to titrate 300.0 mL of 0.200 mol/L $\text{HCl}_{(\text{aq})}$?

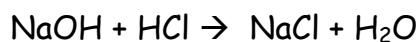
NaOH $V = ?$ $C = 0.500 \text{ mol/L}$ $n_{\text{NaOH}} = n_{\text{OH}^-}$ HCl $V = 300.0 \text{ mL or } 0.300 \text{ L}$ $C = 0.200 \text{ mol/L}$ $n_{\text{HCl}} = n_{\text{H}^+}$

$$n_{\text{HCl}} = C \times V = (0.200)(0.300) = 0.0600 \text{ mol}$$

$$n_{\text{H}^+} = 0.0600 \text{ mol} = n_{\text{OH}^-} = n_{\text{NaOH}} \text{ at equivalence point}$$

$$V_{\text{NaOH}} = n/c = 0.0600 \text{ mol} / 0.500 \text{ mol/L} = 0.120 \text{ L or } 120 \text{ mL}$$

OR



$$n_{\text{HCl}} = C \times V = (0.200)(0.300) = 0.0600 \text{ mol}$$

$$n_{\text{HCl}} = n_{\text{NaOH}}$$

$$V_{\text{NaOH}} = n/c = 0.0600 \text{ mol} / 0.500 \text{ mol/L} = 0.120 \text{ L or } 120 \text{ mL}$$

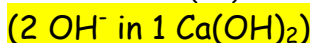
2. If 250.0 mL of 0.300M Ca(OH)_2 is required to titrate 600.0 mL of $\text{HNO}_{3(\text{aq})}$, what is the concentration of $\text{HNO}_{3(\text{aq})}$?



$V = 250.0 \text{ mL or } 0.250 \text{ L}$

$C = 0.300 \text{ mol/L}$

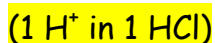
$n_{\text{OH}^-} = 2 \times n_{\text{Ca(OH)}_2}$



$v = 600.0 \text{ mL or } 0.600 \text{ L}$

$c = ?$

$n_{\text{HCl}} = n_{\text{H}^+}$

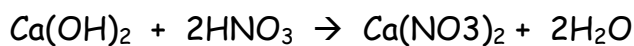


$n_{\text{Ca(OH)}_2} = C \times V = (0.300)(0.250) = 0.0750 \text{ mol}$

$n_{\text{OH}^-} = 2(0.0750) = 0.150 \text{ mol} = n_{\text{H}^+} = n_{\text{HNO}_3} \text{ at equivalence point}$

$C_{\text{HNO}_3} = 0.150\text{mol}/0.600 \text{ L} = 0.250 \text{ M}$

OR



$n_{\text{Ca(OH)}_2} = C \times V = (0.300)(0.250) = 0.0750 \text{ mol}$

$n_{\text{HNO}_3} = 2(0.0750) = 0.150 \text{ mol}$

$C_{\text{HNO}_3} = 0.150\text{mol}/0.600 \text{ L} = 0.250 \text{ M}$

3. Calculate the mass of NaOH required to titrate 400.0 mL of 0.50 M $\text{HBr}_{(\text{aq})}$.

NaOH

$m = ?$

HBr

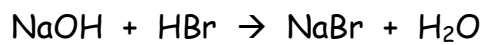
$V = 400.0 \text{ mL or } 0.400 \text{ L}$

$C = 0.50 \text{ M}$

$$n_{\text{HBr}} = (.400)(0.50) = 0.200 \text{ mol} = n_{\text{H}^+} = n_{\text{OH}^-} = n_{\text{NaOH}}$$

$$m_{\text{NaOH}} = n \times mm = (0.200 \text{ mol})(40.00 \text{ g/mol}) = 8.00 \text{ g}$$

OR



$$n_{\text{HBr}} = (.400)(0.50) = 0.200 \text{ mol}$$

$$n_{\text{HBr}} = n_{\text{NaOH}}$$

$$m_{\text{NaOH}} = n \times mm = (0.200 \text{ mol})(40.00 \text{ g/mol}) = 8.00 \text{ g}$$

4. If 8.75 g of $\text{Ba}(\text{OH})_2$ neutralizes 8.00 L of $\text{HCl}_{(\text{aq})}$, what is the concentration of $\text{HCl}_{(\text{aq})}$?

$$\frac{\text{Ba}(\text{OH})_2}{m = 8.75 \text{ g}}$$

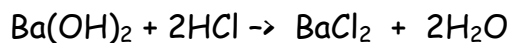
$$\frac{\text{HCl}}{V = 8.00 \text{ L}} \\ C = ?$$

$$n_{\text{Ba}(\text{OH})_2} = m/M = 8.75 \text{ g} / 171.31 \text{ g/mol} = 0.511 \text{ mol}$$

$$n_{\text{OH}^-} = 2 (0.511) = 0.102 \text{ mol} = n_{\text{H}^+} = n_{\text{HCl}}$$

$$C_{\text{HCl}} = n/v = 0.102 \text{ mol} / 8.00 \text{ L} = 0.0128 \text{ mol/L}$$

OR

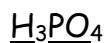


$$n_{\text{Ba}(\text{OH})_2} = m/M = 8.75 \text{ g} / 171.31 \text{ g/mol} = 0.511 \text{ mol}$$

$$n_{\text{HCl}} = 2(0.511) = 0.102 \text{ mol}$$

$$C_{\text{HCl}} = n/v = 0.102 \text{ mol} / 8.00 \text{ L} = 0.0128 \text{ mol/L}$$

5. Calculate the volume of calcium hydroxide required to titrate 500.0 mL of 0.030 M phosphoric acid.



$$C = 0.10 \text{ M}$$

$$V = 500.0 \text{ mL or } 0.500 \text{ L}$$

$$V = ?$$

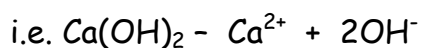
$$C = 0.030 \text{ M}$$

$$n_{\text{H}_3\text{PO}_4} = (0.030)(0.500) = 0.0150 \text{ mol}$$

$$n_{\text{H}^+} = 3(0.0150) = 0.0450 \text{ mol} \quad \text{since 3 mol of H}^+ \text{ will be released from 1 mol of H}_3\text{PO}_4$$

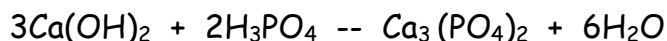
$$n_{\text{OH}^-} = 0.0450 \text{ mol} \quad \text{since at equivalence point}$$

$$n_{\text{Ca(OH)}_2} = 0.0450/2 = 0.0225 \text{ mol} \quad \text{since 2 mol of OH are in 1 mol of Ca(OH)}_2$$



$$V_{\text{Ca(OH)}_2} = n/c = 0.0225 \text{ mol}/0.020 \text{ mol/L} = 1.13 \text{ L}$$

OR



$$n_{\text{H}_3\text{PO}_4} = (0.030)(0.500) = 0.0150 \text{ mol}$$

$$n_{\text{Ca(OH)}_2} = 0.0150/2 \times 3 = 0.0225 \text{ mol}$$

$$V_{\text{Ca(OH)}_2} = n/c = 0.0225 \text{ mol}/0.020 \text{ mol/L} = 1.13 \text{ L}$$

6. A 8.24 g sample of a solid organic acid is dissolved in water. It is found that 47.3 mL of 0.100 M NaOH are needed to titrate the acidic solution. Assuming that there is only one hydrogen in the acidic solid, determine the molar mass of the solid acid. What would the molar mass be if the acid has two hydrogens?

Acid

$$m = 5.25 \text{ g}$$

Formula: HA

NaOH

$$V = 47.3 \text{ mL} = 0.0473 \text{ L}$$

$$C = 0.100 \text{ M}$$

$$n_{\text{NaOH}} = cxv = (0.0473)(0.100) = 0.00473 \text{ mol}$$

$$n_{\text{OH}^-} = 0.00473 \text{ mol}$$

$$n_{\text{H}^+} = 0.00473 \text{ mol}$$

$$n_{\text{HA}} = 0.00473 \text{ mol} \quad \text{if acid is monoprotic}$$

$$\text{mm} = m/n = 8.24 \text{ g}/0.00473 \text{ mol} = 1742 \text{ g/mol}$$

If acid is Diprotic H_2A then $n_{\text{acid}} = 0.00473/2 = 0.00237 \text{ mol}$

And $\text{mm} = 8.24\text{g}/0.00237 \text{ mol} = 3477 \text{ g/mol}$

OR

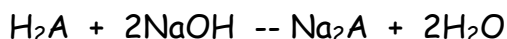


$$n_{\text{NaOH}} = cxv = (0.0473)(0.100) = 0.00473 \text{ mol}$$

$$n_{\text{HA}} = 0.00473 \text{ mol}$$

$$\text{mm} = m/n = 8.24 \text{ g}/0.00473 \text{ mol} = 1742 \text{ g/mol}$$

If acid is diprotic:



$$n_{\text{NaOH}} = cxv = (0.0473)(0.100) = 0.00473 \text{ mol}$$

$$n_{\text{HA}} = 0.00473/2 = 0.00237 \text{ mol}$$

$$\text{mm} = 8.24\text{g}/0.00237 \text{ mol} = 3477 \text{ g/mol}$$