Determination of the M_r of an Unknown Solid Acid using Titration (3A/ABT)

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31/10/2017

1 Aim

To determine the M_r of an unknown solid acid (A) using a titrimetric method of analysis.

2 Results and Analysis

$$\begin{aligned}\text{Batch of HCl used} &: B\\ \text{Concentration of HCl} &: 0.1029\,\text{mol}\,\text{dm}^{-3}\\ \text{Batch of NaOH Used} &: B\end{aligned}$$

2.1 Titration between NaOH and HCl

$$\text{HCl(aq)} + \text{NaOH(aq)} \longrightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)} \tag{2.1.1}$$

Phenolphthalein was used as the indicator (colour change from pink to colourless at the end point).

Table 1: Results from titrating $25.00\,\text{cm}^3$ of NaOH with HCl.

Run	Start Volume / cm^3	End Volume / cm^3	Titre / cm^3
1	6.60	30.95	24.35
2	2.00	25.85	23.85
3	4.20	28.30	24.10
4	4.45	28.55	24.10

$$\text{Average titre} = \frac{24.10\,\text{cm}^3 + 24.10\,\text{cm}^3}{2} = 24.10\,\text{cm}^3$$

$$\begin{aligned}\text{Moles of HCl in titre} &= 24.10\,\text{cm}^3 \times (\frac{1\,\text{dm}}{10\,\text{cm}})^3 \times 0.1029\,\text{mol}\,\text{dm}^{-3}\\ &= 24.10 \times 10^{-3}\,\text{dm}^3 \times 0.1029\,\text{mol}\,\text{dm}^{-3}\\ &= 2.480 \times 10^{-3}\,\text{mol}\end{aligned}$$

From equation 2.1.1 there is a 1:1 molar ratio between HCl and NaOH.

$$\begin{aligned}\therefore \text{Moles of NaOH in } 25.00\,\text{cm}^3 &= 2.480 \times 10^{-3}\,\text{mol}\\ \text{Concentration of NaOH} &= \frac{2.480 \times 10^{-3}\,\text{mol}}{25.00\,\text{cm}^3 \times (\frac{1\,\text{dm}}{10\,\text{cm}})^3}\\ &= \frac{2.480 \times 10^{-3}\,\text{mol}}{25.00 \times 10^{-3}\,\text{dm}^3}\\ &= 0.099\,20\,\text{mol}\,\text{dm}^{-3}\end{aligned}$$

2.2 Titration between NaOH and Unknown Acid A

For HA being the unknown acid A and assuming HA is monobasic:

$$\text{HA(aq)} + \text{NaOH(aq)} \longrightarrow \text{NaA(aq)} + \text{H}_2\text{O(l)} \tag{2.2.1}$$

Phenolphthalein was used as the indicator (colour change from pink to colourless at the end point).

A mass of 1.8525 g of HA was dissolved with distilled water in a $200.00\,\text{cm}^3$ volumetric flask.

$$\text{Average titre} = \frac{20.10\,\text{cm}^3 + 20.15\,\text{cm}^3}{1\,^2} = 20.13\,\text{cm}^3$$

Table 2: Results from titrating $20.00\,\mathrm{cm}^3$ of NaOH with HA.

Run	Start Volume / cm^3	End Volume / cm^3	Titre / cm^3
1	4.00	24.90	20.90
2	4.00	24.10	20.10
3	4.05	24.20	20.15

$$\begin{aligned}\text{Moles of NaOH in } 20.00\,\mathrm{cm}^3 \text{ aliquot} &= 20.00\,\mathrm{cm}^3 \times (\frac{1\,\mathrm{dm}}{10\,\mathrm{cm}})^3 \times 0.099\,20\,\mathrm{mol\,dm}^{-3} \\ &= 20.00 \times 10^{-3}\,\mathrm{dm}^3 \times 0.099\,20\,\mathrm{mol\,dm}^{-3} \\ &= 1.984 \times 10^{-3}\,\mathrm{mol}\end{aligned}$$

From equation 2.2.1 there is a 1:1 molar ratio between NaOH and HA.

$$\begin{aligned}\therefore \text{Moles of HA in } 20.13\,\mathrm{cm}^3 &= 1.984 \times 10^{-3}\,\mathrm{mol} \\ \text{Concentration of HA} &= \frac{1.984 \times 10^{-3}\,\mathrm{mol}}{20.13\,\mathrm{cm}^3 \times (\frac{1\,\mathrm{dm}}{10\,\mathrm{cm}})^3} \\ &= \frac{1.984 \times 10^{-3}\,\mathrm{mol}}{20.13 \times 10^{-3}\,\mathrm{dm}^3} \\ &= 0.098\,55\,\mathrm{mol\,dm}^{-3}\end{aligned}$$

Hence for the whole $200.00\,\mathrm{cm}^3$ volumetric flask:

$$\begin{aligned}\text{Moles of HA} &= 0.098\,55\,\mathrm{mol\,dm}^{-3} \times 200.00\,\mathrm{cm}^3 \times (\frac{1\,\mathrm{dm}}{10\,\mathrm{cm}})^3 \\ &= 0.098\,55\,\mathrm{mol\,dm}^{-3} \times 200.00 \times 10^{-3}\,\mathrm{dm}^3 \\ &= 0.019\,71\,\mathrm{mol}\end{aligned}$$

Since:

$$\text{Amount mol} = \frac{\text{Mass g}}{M_r\ \mathrm{g\,mol}^{-1}}$$

$$M_r\ \mathrm{g\,mol}^{-1} = \frac{\text{Mass g}}{\text{Amount mol}}$$

Hence:

$$M_r \text{ of HA} = \frac{1.8525\,\mathrm{g}}{0.019\,71\,\mathrm{mol}} = 93.98\,\mathrm{g\,mol}^{-1}$$