Grade 12 Acids and Bases

1. 3.68g of washing soda crystals ($Na_2CO_3.10H_2O$) are dissolved in water and made up to a volume of 275cm^3. 25 cm^3 of this sample is neutralised by 23.5cm^3 of HCl of concentration 0.11 mol.dm^{-3}. Calculate the percentage of Na_2CO_3 in commercial washing soda.

Balanced equation:

2. $30cm^3$ of a $0.2mol.dm^{-3}$ NaOH solution is titrated with a $0.3\ mol.dm^{-3}$ HCl solution. The HCl is in the burette and the NaOH is in a conical flask.

2.1. How would you measure exactly $30cm^3$ of NaOH into the conical flask?

2.2. Explain what is meant by the equivalence point of this titration.

2.3. How many cm^3 of the HCl solution needs to be added to reach the equivalence point of the titration?

2.4. Calculate the pH of the solution in the flask after $25cm^3$ of the HCl solution has been added.

2.5. Name a suitable indicator to show the end point of the titration.

3. A drain cleaner contains sodium hydroxide solution. In a titration experiment, the sodium hydroxide in a $25cm^3$ sample of the drain cleaner was neutralised $20cm^3$ of oxalic acid. The concentration of the oxalic acid is 0.5 $mol.dm^{-3}$.

The equation for the reaction is

$$2NaOH + (COOH)_2 \rightarrow Na_2(COO)_2 + 2H_20$$

3.1. Calculate the concentration of the sodium hydroxide in the drain cleaner.

3.2. Calculate the pH of the solution.

4. Typically, vinegar is 3 – 5 % acetic acid by mass, with the remaining mass being the solvent. To determine the percentage of acetic acid in the vinegar sample, it is titrated with a NaOH solution.
   A 10g sample of vinegar is titrated with a $0.309 mol.dm^{-3}$ NaOH solution.
   $19.57 cm^3$ of NaOH is required to reach the end point.

4.1. Write a balanced equation for the reaction.

4.2. Determine the mass of acetic acid in the 10g sample of vinegar.

4.3. What is the percentage mass of acetic acid in the sample that was titrated? Is the vinegar in the typical range?

4.4. Why is phenophthalein used as the indicator in this experiment? Will the salt formed be acidic, neutral, or basic?

4.5. Describe the colour change of the indicator at the endpoint.

ANSWERS

1. $Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_20$

   25 cm^3 23.5 cm^3

   0.11 $mol.dm^{-3}$

$n(HCl) = cV = 0.11 \times 0.0235 = 2.585 \times 10^{-3}$ mol

Ratio $n(HCl) : n(Na_2CO_3) = 2 : 1$

$$n(Na2CO3) = \frac{2.585 \times 10^{-3}}{2} = 1.2925 \times 10^{-3} \text{ mol}$$

Find $n(Na_2CO_3)$ in the original sample:

$$n(Na_2CO_3) = \frac{1.2925 \times 10^{-3}}{25} \times 275 = 1.42 \times 10^{-2} \text{ mol}$$

Calculate $m(Na_2CO_3)$ in the 275cm^3 sample.

$n = m/M$ therefore $m(Na_2CO_3) = nM = 1.42 \times 10^{-2} = 1.507g$

$$\% \text{ Purity} = \frac{\text{Theoretical mass}}{\text{Actual mass}} \times 100 = \frac{1.507}{3.68} \times 100 = 41\%$$

2.1. With a pipette.

2.2. The point in a titration where enough acid has been added to the base (or vice versa) to bring about a colour change in the indicator.

2.3. $NaOH + HCl \rightarrow NaCl + H_2O$

30cm^3 ? vol

0.2 $mol.dm^{-3}$ 0.3 $mol.dm^{-3}$

$$\frac{c_aV_a}{c_bV_b} = \frac{n_a}{n_b}$$

$$\frac{0.3 \times V_b}{0.2 \times 30} = \frac{1}{1}$$ therefore $V_a = 20cm^3$

2.4.

No of moles of HCl in the extra $5cm^3$: $n(HCl) = cV = 0.3 \times 0.005 = 1.5 \times 10^{-3}$ mol

Concentration of HCl in $55cm^3$ (total volume):

$$c(HCl) = n/V = \frac{1.5 \times 10^{-3}}{0.055} = 0.2727 \text{ mol.dm}^{-3}$$

HCl is a strong acid, ionises completely.

$[HCl] = [H_3O^+]$

$pH = -\log[H_3O^+] = 1.56$

2.5. Bromothymol blue: Blue to yellow

3.1. $2NaOH + (COOH)_2 \rightarrow Na_2(COO)_2 + 2H_2O$

25 cm^3 $20cm^3$ 0.5 mol.dm^{-3}

$$\frac{c_aV_a}{c_bV_b} = \frac{n_a}{n_b}$$

$$\frac{(0.5)(20)}{c_b\,(25)} = \frac{1}{2}$$

$C_b = 0.8 \text{ mol.dm}^{-3}$

3.2. Assume that NaOH dissociates completely.

$[OH^-] = 0.8 \text{ mol.dm}^{-3}$

$[OH^-][H_3O^+] = 1 \times 10^{-14}$

$[H_3O+] = 1.25 \times 10^{-14}$ mol.dm^{-3}

$pH = -\log[H_3O^+] = 13.9$

4.1. $NaOH + CH_3COOH \rightarrow CH_3COONa + H_2O$

0.309 mol.dm^{-3} 10g impure
19.57cm^3

4.2. $n(NaOH) = cV = 0.309 \times (19.57 \times 10^{-3}) = 6.047 \times 10^{-3}$ mol

$n(NaOH) = n(CH_3COOH)$

$n = m/M$, therefore

$m(CH_3COOH) = nM = 6.047 \times 10^{-3} \times 60 = 0.36282$g

4.3.

$$\% \text{ Mass} = \frac{\text{Theoretical mass}}{\text{Actual mass}} \times 100$$

$$= \frac{0.36282}{10} \times 100$$

$$= 3.63\%$$

It is in the typical range.

4.4. The reaction was a strong base with a weak acid. pH at the endpoint will be >7.

Hydrolysis of the salt: $CH_3COO^- + H_2O \rightarrow CH_3COOH + OH^-$

weak acid strong base

The salt will therefore be basic.

4.5. The base should go in the conical flask with the indicator. The acid should be in the burette. At the endpoint, the colour goes from pink to colourless.