[AQA A2 Paper 1 2017]

This question is about compounds containing ethanedioate ions.

A white solid is a mixture of sodium ethanedioate ($Na_2C_2O_4$), ethanedioic acid dihydrate ($H_2C_2O_4.2H_2O$) and an inert solid. A volumetric flask contained 1.90 g of this solid mixture in 250 cm^3 of aqueous solution.

Redox

Two different titrations were carried out using this solution.
In the first titration 25.0 cm^3 of the solution were added to an excess of sulfuric acid in a conical flask. The flask and contents were heated to 60 °C and then titrated with a 0.0200 $moldm^{-3}$ solution of potassium manganate(VII). When 26.50 cm^3 of potassium manganate(VII) had been added the solution changed colour. The equation for this reaction is:

$$2MnO_4^- + 5C_2O_4^{2-} + 16H+ \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$$

Acid - Base

In the second titration 25.0 cm^3 of the solution were titrated with a 0.100 $moldm^{-3}$ solution of sodium hydroxide using phenolphthalein as an indicator. The indicator changed colour after the addition of 10.45 cm^3 of sodium hydroxide solution. The equation for this reaction is:

$$H_2C_2O_4 + 2OH^- \rightarrow C_2O_4^{2-} + 2H_2O$$

a question like this is worth up to 8 marks.

a) Calculate the percentage by mass of sodium ethanedioate in the white solid.Give your answer to the appropriate number of significant figures. Show your working.

in this question there are two different reactions:

① Acid - Base

② Redox Titration

⇒ Only the acid reacts with the base but they both react in the redox reaction. This means the moles of sodium ethanedioate can be found:

[moles from redox reaction − moles from acid-base reaction = moles of $Na_2C_2O_4$]

① Use the Acid-base reaction to find the moles of ethanedioic acid in the mixture:

$\text{moles} = \frac{\text{conc.} \times \text{vol.}}{1000}$

$$\text{moles of NaOH} = \frac{10.45 \times 0.100}{1000}$$

$$= 1.045 \times 10^{-3} \text{ moles of base}$$

use molar ratio.

$$\Rightarrow \text{moles of } C_2O_4^{2-} \text{ in acid} = \frac{1}{2} \times 1.045 \times 10^{-3}$$

$$= 5.224 \times 10^{-4} \text{ moles (in } 25\text{cm}^3\text{)}$$

② Use the Redox reaction to find the total moles of oxalate ions ($C_2O_4^{2-}$) in the mixture:

$$\text{moles of } MnO_4^- \text{ ions} = \frac{26.50 \times 0.0200}{1000}$$

$$= 5.30 \times 10^{-4} \text{ moles}$$

use molar ratio.

$$\Rightarrow \text{moles of } C_2O_4^{2-} \text{ in mixture} = \frac{5}{2} \times 5.30 \times 10^{-4}$$

$$= 1.325 \times 10^{-3} \text{ moles (in } 25\text{cm}^3\text{)}$$

③ Find the moles of $Na_2C_2O_4$ in 25 cm^3:

$$\Rightarrow 1.325 \times 10^{-3} - 5.224 \times 10^{-4} = 8.025 \times 10^{-4} \text{ moles}$$

④ Scale up to find the moles of $Na_2C_2O_4$ in the 250cm^3 sample:

$$\Rightarrow 8.025 \times 10^{-4} \times 10 = 8.025 \times 10^{-3} \text{ moles}$$

⑤ Calculate the Mr of $Na_2C_2O_4$:

$Mr = (2 \times 23.0) + (2 \times 12.0) + (4 \times 16.0)$

$= 134.0$

⑥ Use this to find the mass of $Na_2C_2O_4$ present:

$mass = 8.025 \times 10^{-3} \times 134.0$

$= 1.0753... g$

⑦ Express this mass as a percentage of the original sample:

$\% = \frac{1.0753...}{1.90} \times 100$

$= 56.594...$

$\Rightarrow \underline{56.6\%}$ (3sf)

↖ 3sf is appropriate to the question.

⇒ A question like this is often used towards the end of a paper as an A/A* differentiator.