Redox Titrations part 2

Click here for redox titrations part 1

There are many variations in titrations. AQA have been quite nice with their titration examples so far and nothing that different to what we have looked at. Just the standard steps.

They did however did a slightly tricky question in the June 2017 paper 1 that involved **TWO** titrations.

The theory

They wanted to know how much of **one** species was in a **mixture**.

when there are two titrations, it usually involves a **mixture**.

Let's say there are two species in a mixture and we do two titrations:

- One of the titrations reacts with **BOTH** of the species in the mixture.
- The other titration only reacts with **ONE** of the species.
- If we subtract these values we must get the **second** species as well. Clever eh?

Example

This is the June 2017 example. I've watered it down a bit as they put far too many words in it.

A white solid contains a mixture of sodium ethanedioate ($Na_2C_2O_4$) and ethanedioic acid dihydrate ($Na_2C_2O_4.2H_2O$). A volumetric flask contains 1.9 g of this solid in 250 cm^3.

Titration 1: 25 cm^3 of this solution was titrated with 0.02 mol dm^{-3} $KMnO_4$. After 26.50 cm^3 of $KMnO_4$ was added the solution changed colour. The equation for this reaction:

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

Titration 2: 25 cm^3 of the solution was titrated with 0.1 mol dm^{-3} NaOH. After 10.45 cm^3 of NaOH was added the solution changed colour. The equation for this reaction:

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

Calculate the percentage by mass of the sodium ethanedioate in the white solid.

Analysis

It is vital to firstly understand the above theory I mentioned about the two titrations and a mixture.

The problem with this question is that the two species in the mixture are very similar looking, they both contain C_2O_4, and immediately this causes problems.

The difference between the titrations

Titration 1

All the $C_2O_4^{2-}$ is reacting. **Both** species (salt and acid) in the mixture contain this ion.

Sodium ethanedioate: $Na_2C_2O_4$ is a salt and dissociates → $2Na^+$ and $\mathbf{C_2O_4^{2-}}$

Ethanedioic acid: $H_2C_2O_4$ is an acid and dissociates → $2H^+$ and $\mathbf{C_2O_4^{2-}}$

Same ion!

✓ They both contain the $C_2O_4^{2-}$ ion and therefore **both are oxidised** by the $KMnO_4$.

Titration 2

ONLY the $\mathbf{H_2C_2O_4}$ is reacting. This is an **acid** so they deliberately reacted it with base as they know the **salt will not react with base**. Therefore they have differentiated between the two species.

I'll say it again…the salt DOES NOT react with the NaOH.

✓ This is the key to understanding the whole question. This is the reason students can't do it. It has **nothing** to do with their ability to do titrations as the titration calculation part is easier than AS (see below).

Titres

Look at the **two titres**….titration 1 = 26.50 cm^3 and titration 2 = 10.45 cm^3. From the magnitude of those volumes alone we can tell that titration 1 reacts with **both** species and titration 2 only reacts with **one** species.

Titration 1: this is a simple redox titration. The calculation is very very easy. So let's do it:

Step 1: moles = conc v vol of $KMnO_4$

$$= 0.02 \times 26.5/1000$$

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

Step 2: ratios

We can see that is a **2:5 ratio** between $KMnO_4$ and $C_2O_4^{2-}$. Therefore x 5/2:

$$= 5.30 \times 10^{-4} \times 5/2$$

$$= 1.325 \times 10^{-3} \text{ moles } C_2O_4^{2-}$$

✓ Everyone should be able to do that! That's just AS moles calculation style. 2 marks straight away. It's actually easier than an AS titration question.

Titration 2: This is an acid base titration which you did at AS. And it's an extremely easy version. Just the usual two steps again:

Step 1: moles = conc x vol

$$= 0.1 \times 10.45/1000$$

$$= 1.045 \times 10^{-3}$$

Step 2: ratios

The ratio of NaOH to $H_2C_2O_4$ is 2:1 therefore divide by 2:

$$= 1.045 \times 10^{-3}/2$$

$$= 5.225 \times 10^{-4} \text{ moles } H_2C_2O_4$$

- ✓ At this point you now have **4 marks!** For doing more or less nothing.
- ✓ The harder part comes next but we already have 4 marks so it's less important than it was at the beginning.
- ✓ The big problem students have is that they get overwhelmed by the question and the quantity of information. You must break it down into sections. **The aim is to gain marks**. If you treat each titration **individually**, then you are on your way! Worry about the final final answer at the end, not at the beginning.

Finish the question

The question asks for the amount of the **salt** (ethanedioate) in the mixture. So far we have the total $C_2O_4^{2-}$ moles and the $H_2C_2O_4$ moles. So using our theory above:

total $C_2O_4^{2-}$ moles - $H_2C_2O_4$ moles = ethanedioate moles

Subtract:

$$= 1.325 \times 10^{-3} - 5.225 \times 10^{-4}$$

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

Portions:

As with all titrations it is important to look for portions. They took 25 cm^3 from the original 250 cm^3 to do each titration therefore we need to **multiply by 10**:

$$= 8.025 \times 10^{-4} \times 10$$

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

✓ I'm guessing some students may get confused here as well. They might think as there are two titrations each taking 25 cm^3 that they need to add them together → 50 cm^3 and therefore multiply x5 rather than x10? Nope. Remember we are **only** interested in the ethanedioate and it doesn't even take part in titration 2.

Mass: Moles x Mr

= 8.025 x 10^{-3} x 134

= 1.075 g

Percentage: calculated mass/original mass x 100

= 1.075/1.9 x 100

= 56.6%

Summary

- All the steps are easy except the subtraction part. That's where the understanding is vital. But you can do the rest of the question no problem. Always look at these questions from an "easy point of view" rather than trying to solve it in your head in 20 seconds then freaking out coz you can't do it.

- Take the easy marks…every single time. Not just in titrations but any exam question.

- The titration part is so easy here and they give you 4 marks for doing the same thing twice!

- To one person this question is hell and they will complain on the student room. To someone else it is a gift 4 marks at least. It just depends how you approach it….so approach it from the…"where are the easy marks?" perspective.

- Even the end was easy…calculating mass then percentage…everyone can do that. That's very common. A tip…**finish the question**. Realise that the end is easy, the start is easy, it's that dam part in the middle that is a problem. But what if you just ignored the part in the middle and took 6 marks out of 8? You could do those 6 marks in about 3 minutes. Then the subtraction part becomes less important or just don't bother and move on.

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