Redox Titrations part 1

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Fe^{2+}/MnO_4^-

This is a **redox titration**. It is specifically mentioned in the specification but it could be any redox reaction. MnO_4^- is just a common oxidising agent.

MnO_4^- is usually added to the burette. **No indicator** is added as MnO_4^- is a deep purple colour, which acts as an indicator.

When MnO_4^- is added to the Fe^{2+} solution, the Fe^{2+} **reduces** it to Mn^{2+}. The purple colour **vanishes** as Mn^{2+} is not coloured → colourless solution. This happens throughout the titration **until** the end point.

The end point is **colourless to pink** not purple to colourless.

Why? The end point is when the reaction is over. In this case, when all the Fe^{2+} is used up. At this point the MnO_4^- cannot be reduced to Mn^{2+} anymore. Therefore, a very slight excess of MnO_4^- is now in the conical flask and the solution changes from colourless to a pink colour.

✓ As it is only one extra drop of MnO_4^- we add at the end point, the colour appears pink rather than an intense purple.

Half-equations

This is just balancing half-equations as you should have done about a zillion times by now.

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

$$Fe^{2+} \rightarrow Fe^{3+} + e^-$$

Adding them together i.e. Fe^{2+} equation **x 5** to **balance electrons**:

$$MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$$

✓ remember the point of these half equations is just to get the ratio.

✓ the acid used with MnO_4^- has to be **H_2SO_4**. If HCl is used, the Cl^- gets oxidised by the MnO_4^-. If HNO_3 is used, then it oxidises the Fe^{2+} instead of the MnO_4^- as it is a strong oxidising agent. If **no acid** is used then an MnO_2 precipitate is produced. All these scenarios will mess up your titre.

Example

The first 3 steps in the example below are usually consistent in most titration questions.

Patients suffering from iron deficiency are often prescribed tablets containing $FeSO_4.7H_2O$. Several tablets, 6.0 g, were dissolved in water and made up to 200 cm^3 in a volumetric flask. 25 cm^3 portions of this solution were then titrated against 0.020 mol dm^{-3} $KMnO_4$ solution. The mean titre was 20.10 cm^3.

Calculate the percentage of $FeSO_4.7H_2O$ in the tablets.

Step 1: moles of MnO_4^- (use the titre)

n = 0.020 x 20.10/1000 = **0.000402 moles** of MnO_4^-

Step 2: use the ratio → moles Fe^{2+}

Using the equation we can see it is a 1:5 ratio therefore x 5.

$$\mathbf{MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O}$$

Moles of Fe^{2+} = **0.00201 moles** of Fe^{2+}

✓ remember this is only the moles in 25 cm^3

Step 3: moles in 200 cm^3

We need the moles in the original solution, so we need to scale it up from 25 → 200 cm^3.

0.00201 x 200/25 = **0.01608 moles** of Fe^{2+}

Step 4: answer the question

This is where the questions will vary. In this question, they are looking for a percentage by mass, so we need a mass:

Moles of Fe^{2+} x M_r of $FeSO_4.7H_2O$

= 0.01608 x **278**

= **4.47 g**

✓ students often get confused which mass to multiply by. You have to read the question. It asks for $FeSO_4.7H_2O$ so we multiply by its M_r **NOT** by that of Fe. If it asked how much Fe in the tablet, then yes, multiply by 56 for Fe.

✓ students then say but we are using Fe^{2+} and not $FeSO_4.7H_2O$ in the titration. True but the Fe^{2+} is just the reactive species in the titration that has come from the $FeSO_4.7H_2O$. We are assuming the moles of Fe^{2+} and $FeSO_4.7H_2O$ are the same.

Finally…….. **divide the mass above by the original mass → percentage**

= 4.47/6.0 x 100%

= 74.5%

In summary:

1. Work out **moles** of the species of "**known**" concentration.
2. Use the equation → **ratio** → moles of the species you are interested in.
3. Check if you need to "**scale up**" from for example 25 cm^3 → 250 cm^3.
4. **Convert** moles into whatever they are asking for e.g. percentage, concentration, calculate x etc.

Exam advice

✓ You must be able to tell quickly which **"type"** of titration they are doing. Is it "normal" or is something in excess etc.

✓ **Write out equations** and put them one on top of the other (if there are multiple equations). It is much easier to see what is going on when you do this. Sometimes the equations aren't given or are all over the place. Try to give it some sort of organisation.

✓ No matter how difficult it seems, always try to do the usual steps:

- **Calculate moles** of the species of known concentration

- **Use the ratios** to calculate the moles of the unknown

- **Check if you need to multiply x10** for example (25 cm^3 → 250 cm^3) if they took a portion out to do the titration

- **Finish the question**…they often get you to calculate percentage purity, calculate x in xH_2O, concentration or the M_r of a compound. All of which involve converting moles into something else.

✓ Simplicity is the key here. It is just redox. Think your way through it. Look for the steps that you know. Pick up the easy marks. Remember that a lot of the "extra" steps and numbers are just preparation.

- ✓ If you can understand why they are doing things, you will never have a problem with these questions. The problem isn't the calculation or the maths, it's lack of understanding in the first place.

- ✓ If it really is an awful question, you don't need to get 6 out of 6. Sometimes 3 or 4 out of 6 is good enough in these situations.

- ✓ They have focussed upon MnO_4^- and Fe^{2+} but it is just a redox reaction. They could put anything in a question but the principles are the same. For example it is very common to see MnO_4^- and $C_2O_4^{2-}$ (see AQA specimen paper 3 Q4.3).

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