OCR Manganate(VII) redox titrations

(OCR student book ISBN 978-0-19-835197-0, p380)

Manganate(VII) titrations can be used to analyse many different reducing agents, for example Fe(II) ions / Fe^{2+}(aq).

A student tried to answer the following question recently. The answer the student got was out by a factor of 10, and the student could not work out why this was. Here's the solution:

Q5

A metal ore contains Fe(II). 6.46g of the ore is dissolved in sulfuric acid and the resulting solution is made up to 250.0cm^3. 25.0cm^3 of this solution is titrated against 21.40cm^3 of 0.0200mol dm^{-3} potassium manganate(VII) solution. Calculate the percentage by mass of iron(II) in the sample of ore. (1 mark)

Answer:

Start off by listing everything you know from the question in a neat list with everything labelled.

m(ore) = 6.46g

V_{total}(ore) = 250.0cm^3 = 0.250dm^3

Don't forget to convert cm^3 to dm^3!

V_{used}(ore) = 25.0cm^3 = 0.0250dm^3

$V_{used}(MnO_4^-)$ = 21.40cm^3 = 0.02140dm^3

$c(MnO_4^-)$ = 0.0200mol dm^{-3}

$m(Fe^{2+})$ = ?

1. From what we know we can calculate the moles of MnO_4^-:

   $n_{used}(MnO_4^-) = c\ V$ = 0.02140dm^3 x 0.0200mol dm^{-3} = 4.28 x 10^{-4}mol

2. You should know from the course and your redox titrations that the reaction is based on the reaction:

   MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) -> Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l).

   Therefore the molar ratio between MnO_4^- and Fe^{2+} is 1 : 5.
   Use this to calculate the moles of Fe^{2+} used in the titration:

   $n_{used}(Fe^{2+})$ = 5 x 4.28 x 10^{-4}mol = 2.14 x 10^{-3}mol

3. These are the moles used in the experiment. We know that we used only $\frac{1}{10}$ of the original solution of MnO_4^- (25cm^3 instead of 250cm^3).

The total number of moles in the total solution is therefore 10x the amount just calculated in step 2:

$n_{total}(MnO_4^-)$ = 10 x 2.14 x 10^{-3}mol = 2.14 x 10^{-2}mol

This is where the factor of 10 was dropped by the student.

4. Now we can calculate the mass of Fe^{2+} in the ore:

   $m_{in\ ore}(Fe^{2+}) = n\ M$ = 2.14 x 10^{-2}mol x 55.85g mol^{-1} = 1.19519g

5. Now we're nearly there as all that's left now it to calculate the percentage by mass of Fe(II) in the ore:

   % = $\frac{1.19519}{6.46}$ x 100 = 18.5%