# 4. Redox Titrations

*Find an unknown concentration by slowly adding a known concentration until the equivalence point.*

## *a) Find Concentration of a Reducing Agent*

**i) Procedure:** 1. Titrate the reducing agent with $KMnO_4$ (powerful oxidizing agent)
2. The reducing agent will change $MnO_4^-$ into $Mn^{2+}$ :

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

3. Equivalence point is when you see the first hint of purple in the flask. There is no longer any reducing agent left to convert the purple $MnO_4^-$ into colourless $Mn^{2+}$

**ii) Calculation Sample (very similar to acid-base titration)**

**25.00 ml of unknown [$Cu^+$] is titrated to equivalence point with 18.73 ml of 0.200 M $KMnO_4$ solution. What is the [$Cu^+$]?**

*1st write the overall reaction and balance*

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

$Cu^+ \rightarrow Cu^{2+} + 1e^-$ (we know $Cu^+$ is being oxidized)

$\mathbf{MnO_4^- + 8H^+ + 5Cu^+ \rightarrow Mn^{2+} + 4H_2O + 5\,Cu^{2+}}$ (overall redox)

*2nd Find moles $MnO_4^-$*

moles = M x L = (0.200 M)(0.01873 L) = 0.003746 mol $MnO_4^-$

*3rd Convert to moles $Cu^+$*

$$0.003746 \text{ moles } MnO_4^- \times \frac{5 \text{ mol } Cu^+}{1 \text{ mol } MnO_4^-} = 0.01873 \text{ mol } Cu^+$$

*4th Find [$Cu^+$]*

[$Cu^+$] = mol/L = 0.01873 mol / 0.02500 L = **0.749 M**

**iii) Calculation Example**

**25.00 ml of unknown [$Cr^{+2}$] is titrated to equivalence point with 28.45 ml of 0.150 M $KMnO_4$ solution. What is the [$Cr^{+2}$]?**

*1st write the overall reaction and balance*

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

$Cr^{+2} \rightarrow Cr^{+3} + 1e^-$ (we know $Cr^{+2}$ is being oxidized)

$\mathbf{MnO_4^- + 8H^+ + 5Cr^{+2} \rightarrow Mn^{2+} + 4H_2O + 5Cr^{+3}}$ (overall redox)

*2nd Find moles $MnO_4^-$*

moles = M x L = (0.150 M)(0.02845 L) = 0.004268 mol $MnO_4^-$

*3rd Convert to moles $Cr^{+2}$*

$$0.004268 \text{ moles } MnO_4^- \times \frac{5 \text{ mol } Cr^{+2}}{1 \text{ mol } MnO_4^-} = 0.02134 \text{ mol } Cr^{+2}$$

*4th Find [$Cr^{+2}$]*

[$Cr^{+2}$] = mol/L = 0.02134 mol / 0.02500 L = **0.854 M**

## *b) Find Concentration of an Oxidizing Agent*

**i) Procedure:** 1. Titrate the oxidizing agent with I-
2. The oxidizing agent will change $I^-$ into $I_2$ :

$$2I^- \rightarrow I_2 + 2e^-$$

3. It is difficult to detect the disappearance of $I^-$
4. We then titrate the $I_2$ with $Na_2S_2O_3$

$$2S_2O_3^{-2} + I_2 \rightarrow S_4O_6^{-2} + 2I^-$$

5. Use starch as the indicator. Starch is blue is presence of $I_2$!
6. Equivalence point is when you see the blue colour in the flask disappear. There is no longer any $I_2$ left to "blue" the starch.
7. If know moles of $S_2O_3^{-2}$, we can find moles of $I_2$. If know moles of $I_2$, can find moles of oxidizing agent from balanced redox reaction.

**ii) Calculation Sample**

**A 20.00 ml sample of NaOCl is reacted with NaI according to the reaction:**

$$2H^+ + OCl^- + 2I^- \rightarrow Cl^- + H_2O + I_2$$

**What is the [OCl⁻] if the $I_2$ produced required 34.77 mL of 0.500 M $Na_2S_2O_3$ to reach the equivalence point?**

*1st Find moles of $S_2O_3^{-2}$*

moles = M x L = (0.500 M)(0.03477 L) = 0.01738 mol $S_2O_3^{-2}$

*2nd Convert to moles $I_2$ (using $2S_2O_3^{-2} + I_2 \rightarrow S_4O_6^{-2} + 2I^-$)*

$$0.01738 \text{ moles } S_2O_3^{-2} \times \frac{1 \text{ mol } I_2}{2 \text{ mol } S_2O_3^{-2}} = 0.00869 \text{ mol } I_2$$

*3rd Conver to moles $OCl^-$*

$$0.00869 \text{ mol } I_2 \times \frac{1 \text{ mol } OCl^-}{1 \text{ mol } I_2} = 0.00869 \text{ mol } OCl^-$$

*4th Find $[OCl^-]$*

$[OCl^-]$ = mol / L = 0.00869 mol / 0.02000 L = **0.434 M**

**iii) Calculation Example**

**A 15.00 ml sample of NaOCl is reacted with KI according to the reaction:**

$$2H^+ + OCl^- + 2I^- \rightarrow Cl^- + H_2O + I_2$$

**What is the $[OCl^-]$ if the $I_2$ produced required 19.50 mL of 0.240 M $Na_2S_2O_3$ to reach the equivalence point?**

moles $S_2O_3^{-2}$ = M x L = (0.240 M)(0.01950 L) = 0.00468 mol $S_2O_3^{-2}$

$$0.00468 \text{ moles } S_2O_3^{-2} \times \frac{1 \text{ mol } I_2}{2 \text{ mol } S_2O_3^{-2}} = 0.00234 \text{ mol } I_2$$

$$0.00234 \text{ mol } I_2 \times \frac{1 \text{ mol } OCl^-}{1 \text{ mol } I_2} = 0.00234 \text{ mol } OCl^-$$

$[OCl^-]$ = mol / L = 0.00234 mol / 0.01500 L = **0.156 M**

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