Activity 5B: Redox titrations

Ans p. 26

1. The reaction between oxalic acid in solution, $H_2C_2O_4(aq)$, and potassium permanganate solution, $KMnO_4(aq)$ is slow; so, for a titration to be effective, the solution of oxalic acid is heated before the permanganate solution is added.

20.00 mL of 0.0524 mol L^{-1} oxalic acid was pipetted into a conical flask and heated to 60 °C. Acidified potassium permanganate solution was added from the burette until the purple colour remained in the flask. The process was repeated to give the following concordant results:

18.54 mL, 18.68 mL, 18.72 mL.

The equation for the reaction is:

$$2MnO_4^- + 5H_2C_2O_4 + 6H^+ \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$$

Calculate the concentration of the potassium permanganate solution.

2. The level of alcohol, CH_3CH_2OH, in the blood can be determined using potassium dichromate solution. The equation for the reaction is:

$$2Cr_2O_7^{2-} + CH_3CH_2OH + 16H^+ \rightarrow 4Cr^{3+} + 2CO_2 + 11H_2O$$

If 25.46 mL of 0.0596 mol L^{-1} $Cr_2O_7^{2-}$ are needed to titrate 28.00 mL of blood, what is the concentration of alcohol in the blood?

3. 25.00 mL of sodium sulfite was completely oxidised by 22.36 mL of 0.0200 mol L^{-1} acidified potassium permanganate solution. Calculate the concentration of the sodium sulfite solution. The equation for the reaction is:

$$5SO_3^{2-} + 2MnO_4^- + 6H^+ \rightarrow 5SO_4^{2-} + 2Mn^{2+} + 3H_2O$$

4. The concentration of hypochlorite, $OCl^-(aq)$, in a bleach solution can be determined by:

- *first* reacting the OCl^- with iodide, I^-, with acid, to produce iodine, I_2
- *then* reacting the iodine with a standardised solution of sodium thiosulfate, $Na_2S_2O_3(aq)$.

The equations for the reactions occurring at each step are:

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

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

The overall equation is:

$$OCl^- + 2H^+ + 2S_2O_3^{2-} \rightarrow Cl^- + S_4O_6^{2-} + H_2O$$

A bleach solution containing OCl^- ions was diluted by taking 25.00 mL and diluting to 250.0 mL in a volumetric flask. 20.00 mL of the diluted solution was pipetted into a conical flask; 0.5 g of potassium iodide, KI(*s*), and 5 mL of diluted sulfuric acid, H_2SO_4 were also added to the conical flask.

The mixture was titrated against a standard solution of sodium thiosulfate, with concentration of 0.1048 mol L^{-1}, using a starch indicator. The appearance of a blue colour in the solution indicates the end-point of the reaction. After repeated titrations, the average titre using concordant results was 11.96 mL.

Calculate the concentration of the OCl^- in the original bleach solution.

5. To determine the concentration of copper(II) in solution, the Cu^{2+} ions are first reduced to Cu^+ ions by reacting with I^- ions and then the I_2 produced in the reaction is titrated against sodium thiosulfate solution.

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The equations for the reactions occurring at each step are:

$$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$$

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

The overall equation is:

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

In a reaction, 20.00 mL of a solution known to contain Cu^{2+} ions is reacted with 10 mL of potassium iodide solution and the resulting mixture titrated with standardised thiosulfate solution. The average titre value was 17.92 mL using sodium thiosulfate with a concentration of 0.228 mol L^{-1}.

Calculate the concentration of the copper(II) in the solution.

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Activity 5B: Redox titrations (page 24)

1. $n(H_2C_2O_4) = c(H_2C_2O_4) \times V(H_2C_2O_4) = 0.0524 \text{ mol dm}^{-3} \times 0.02000 \text{ dm}^3 = 1.048 \times 10^{-3} \text{ mol}$

From the equation: $\frac{n(MnO_4^-)}{2} = \frac{n(H_2C_2O_4)}{5}$

So, $n(MnO_4^-) = \frac{2 \times n(H_2C_2O_4)}{5} = \frac{2 \times 1.0478 \times 10^{-3}}{5} = 4.192 \times 10^{-4} \text{ mol}$

$V(MnO_4^-) = \frac{18.54 + 18.68 + 18.72}{3} = 18.65 \text{ mL}$

$c(MnO_4^-) = \frac{n(MnO_4^-)}{V(MnO_4^-)} = \frac{4.192 \times 10^{-4} \text{ mol}}{0.01865 \text{ L}} = 0.0225 \text{ mol L}^{-1}$

2. $n(Cr_2O_7^{2-}) = c(Cr_2O_7^{2-}) \times V(Cr_2O_7^{2-}) = 0.0596 \text{ mol L}^{-1} \times 0.02546 \text{ L} = 1.517 \times 10^{-3} \text{ mol}$

From the equation: $n(CH_3CH_2OH) = \frac{1}{2}n(Cr_2O_7^{2-}) = 7.588 \times 10^{-4} \text{ mol}$

$c(CH_3CH_2OH) = \frac{n(CH_3CH_2OH)}{V(CH_3CH_2OH)} = \frac{7.588 \times 10^{-4} \text{ mol}}{0.02800 \text{ L}} = 0.0271 \text{ mol L}^{-1}$

3. $n(MnO_4^-) = c(MnO_4^-) \times V(MnO_4^-) = 0.0200 \text{ mol L}^{-1} \times 0.02236 \text{ L} = 4.472 \times 10^{-4} \text{ mol}$

From the equation: $\frac{n(MnO_4^-)}{2} = \frac{n(SO_3^{2-})}{5}$

So, $n(SO_3^{2-}) = \frac{5}{2} \times n(MnO_4^-) = \frac{5}{2} \times 4.472 \times 10^{-4} = 1.118 \times 10^{-3} \text{ mol}$

$c(SO_3^{2-}) = \frac{n(SO_3^{2-})}{V(SO_3^{2-})} = \frac{1.118 \times 10^{-3} \text{ mol}}{0.02500 \text{ L}} = 0.0447 \text{ mol L}^{-1}$

4. Using diluted solution:

$n(S_2O_3^{2-}) = c(S_2O_3^{2-}) \times V(S_2O_3^{2-}) = 0.1048 \text{ mol L}^{-1} \times 0.01196 \text{ L} = 1.25 \times 10^{-3} \text{ mol}$

From the equation:

$n(OCl^-) = \frac{1}{2}n(S_2O_3^{2-}) = \frac{1}{2} \times 1.25 \times 10^{-3} \text{ mol} = 6.27 \times 10^{-4} \text{ mol}$

$c(OCl^-) = \frac{n(OCl^-)}{V(OCl^-)} = \frac{6.27 \times 10^{-4} \text{ mol}}{0.02000 \text{ L}} = 0.0313 \text{ mol L}^{-1}$

Original solution was diluted by a factor of $\frac{25}{250} = \frac{1}{10}$

So, concentration of original solution = $10 \times 0.0313 \text{ mol L}^{-1} = 0.313 \text{ mol L}^{-1}$

5. $n(S_2O_3^{2-}) = c(S_2O_3^{2-}) \times V(S_2O_3^{2-}) = 0.228 \text{ mol L}^{-1} \times 0.01792 \text{ L} = 4.09 \times 10^{-3} \text{ mol}$

From the equation:

$n(Cu^{2+}) = n(S_2O_3^{2-}) = 4.09 \times 10^{-3} \text{ mol}$

$c(Cu^{2+}) = \frac{n(Cu^{2+})}{V(Cu^{2+})} = \frac{4.09 \times 10^{-3} \text{ mol}}{0.02000 \text{ L}} = 0.204 \text{ mol L}^{-1}$

$c(Cu^{2+}) = 0.0204 \text{ mol L}^{-1}$

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