Raffles Institution
Year 5 H2 Chemistry 2025
Tutorial 1 – Redox Reactions

Self-Check Questions

1 Determine the oxidation number of the underlined element in the following species:

(a)	$Ba\underline{S}O_4$	**(c)**	$\underline{Ti}O^{2+}$	**(e)**	$H_2\underline{O}_2$	**(g)**	$\underline{Br}F$
(b)	$Na_3\underline{V}O_4$	**(d)**	$\underline{C}_2O_4^{2-}$	**(f)**	$\underline{N}_2O_4$	**(h)**	$\underline{I}F_7$

2 Identify if the following equations represent a redox or non-redox reaction. Determine the change in oxidation number for the relevant element to support your answer.

(a) $NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$

(b) $3Mg(s) + 2NH_3(g) \rightarrow Mg_3N_2(s) + 3H_2(g)$

3 A Level N2010/III/4(f)

Ozone is usually made by passing oxygen gas through a tube between two highly charged electrical plates.

$$3O_2(g) \rightarrow 2O_3(g)$$

The reaction does not go to completion, so a mixture of the two gases results.
The concentration of O_3 in the mixture can be determined by its reaction with aqueous KI.

$$O_3 + 2KI + H_2O \rightarrow I_2 + O_2 + 2KOH$$

The iodine formed can be estimated by its reaction with sodium thiosulfate.

$$2Na_2S_2O_3 + I_2 \rightarrow Na_2S_4O_6 + 2NaI$$

When 500 cm^3 of an oxygen/ozone gaseous mixture at s.t.p. was passed into an excess of aqueous KI, and iodine titrated, 15.0 cm^3 of 0.100 mol dm^{-3} $Na_2S_2O_3$ was required to discharge the iodine colour.

(a) Calculate the amount in moles of iodine produced.

(b) Hence calculate the percentage of O_3 in the gaseous mixture.

4 A Level N2009/III/3(c)

When sodium is burned in air, a mixture of sodium oxide, Na_2O, and sodium peroxide, Na_2O_2, is formed. The mixture reacts with water according to the following equations.

$$Na_2O + H_2O \rightarrow 2NaOH$$
$$Na_2O_2 + 2H_2O \rightarrow 2NaOH + H_2O_2$$

The following information will allow you to calculate the relative amounts of the two oxides produced when sodium is burned.

- The mixture obtained by burning a sample of sodium was dissolved in distilled water and made up to 100 cm^3 to give solution **H**.
- A 25.0 cm^3 portion of solution **H** was titrated with 0.100 mol dm^{-3} HCl. 22.50 cm^3 of acid was required to reach the end-point.

$$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$$

- The H_2O_2 content of solution **H** was found by titration of another 25.0 cm^3 portion with 0.0200 mol dm^{-3} $KMnO_4$ in acidic medium. 10.0 cm^3 of $KMnO_4$ solution was required to reach the end-point.

$$2MnO_4^-(aq) + 5H_2O_2(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 5O_2(g) + 8H_2O(l)$$

(a) Using the results of the HC*l* titration, calculate the total amount of NaOH in 100 cm^3 of solution **H**.

(b) Using the results of the $KMnO_4$ titration, calculate the amount of H_2O_2 in 100 cm^3 of solution **H**.

(c) Hence, calculate the amount of Na_2O and Na_2O_2 formed during the burning of the sodium sample.

Suggested solutions to the self-check questions are appended behind the practice questions. Please use these solutions to check through your working and your final answers. Consult your tutor if you have any questions.

Practice Questions

5 Identify if the following equations represent a redox or non-redox reaction. Determine the change in oxidation number for the relevant element to support your answer.

(a) $2KNO_3(s) \rightarrow 2KNO_2(s) + O_2(g)$

(b) $2CrO_4^{2-}(aq) + 2H^+(aq) \rightarrow Cr_2O_7^{2-}(aq) + H_2O(l)$

(c) $Cu_2O(s) + H_2SO_4(aq) \rightarrow Cu(s) + CuSO_4(aq) + H_2O(l)$

(d) $2CH_4(g) + 2NH_3(g) + 3O_2(g) \rightarrow 2HCN(g) + 6H_2O(g)$
[In (d), the oxidation numbers of hydrogen and nitrogen remain unchanged after reaction.]

6 Write balanced half-equations and the overall equation for each of the following reactions in **acidic** solution:

(a) $I^-(aq) + H_2SO_4(aq) \rightarrow I_2(g) + H_2S(g)$

(b) $MnO_4^{2-}(aq) \rightarrow MnO_2(s) + MnO_4^-(aq)$

(c) $FeC_2O_4(aq) + Ce^{3+}(aq) \rightarrow Ce^{2+}(aq) + Fe^{3+}(aq) + CO_2(g)$
[Note: FeC_2O_4 contains Fe^{2+} and $C_2O_4^{2-}$. Determine the oxidation number of each element and find out which element(s) underwent oxidation or reduction.]

7 Write balanced half-equations and the overall equation for each of the following reactions in **basic** solution:

(a) $ClO^-(aq) + Mn(OH)_2(s) \rightarrow Cl^-(aq) + MnO_2(s)$

(b) $MnO_4^-(aq) + C_2O_4^{2-}(aq) \rightarrow MnO_2(s) + CO_3^{2-}(aq)$

(c) $ClO^-(aq) \rightarrow Cl^-(aq) + ClO_3^-(aq)$

8 RI 2014 Y5 CT Qn B1(c)

Sodium metabisulfite, $Na_2S_2O_5$, is often used as a food preservative.

100 g of preserved meat was boiled with hydrochloric acid.

$$Na_2S_2O_5 + 2HCl \rightarrow 2NaCl + 2SO_2 + H_2O$$

The sulfur dioxide gas produced reacted completely with 14.20 cm^3 of 0.0100 mol dm^{-3} acidified potassium dichromate(VI).

(a) Chromium(III) sulfate was formed in the reaction between sulfur dioxide and acidified potassium dichromate(VI). Write a balanced ionic equation for this reaction.

(b) Calculate the concentration of sodium metabisulfite in the preserved meat in ppm (parts per million). [1 ppm = 1 g in 10^6 g of meat]

9 RI 2014 Y5 CT Qn A3

An aqueous solution containing 1 mole of Cl_2O_7 oxidises 4 moles of H_2O_2 to form O_2 and a chlorine–containing product.

What is the chlorine–containing product of this reaction?

A Cl^- **C** ClO_2^-

B ClO^- **D** ClO_3^-

10 RI 2014 Y5 Promo Qn A2

An aqueous solution containing 0.010 mol of $NaNO_2$ oxidises 0.005 mol of acidified $(NH_4)_2SO_4$ to form a single nitrogen-containing product.

What is the nitrogen-containing product?

A N_2 **C** N_2O

B NO **D** NH_2OH

11 Hydroxylamine, NH_2OH, can be oxidised to nitrogen, N_2, or nitrogen oxide, N_2O, depending on the oxidising agent.

(a) Write a half-equation for each of the oxidation reactions in an acidic medium.

(b) In an experiment, 50 cm^3 of 0.050 mol dm^{-3} NH_2OH was found to reduce 10 cm^3 of 0.50 mol dm^{-3} Fe^{3+} to Fe^{2+}. Determine whether the NH_2OH is oxidised to N_2 or N_2O by Fe^{3+} and write a balanced ionic equation for the reaction.

12 Solution **FA1** contains 12.1 g dm^{-3} of sodium thiosulfate(VI) pentahydrate, $Na_2S_2O_3.5H_2O$.

Solution **FA2** contains 7.95 x 10^{-3} mol dm^{-3} of a compound MXO_3. M is a univalent metal and X is the symbol of an unknown element.

25.0 cm^3 of **FA2** was mixed with about equal volumes of potassium iodide solution and dilute sulfuric acid. The iodine liberated required 24.40 cm^3 of **FA1** for reaction.

(a) Calculate the number of moles of iodine liberated by 1 mole of XO_3^- when iodide ions are oxidised by XO_3^-. M^+ does not react with iodide ions.

(b) Using the answer obtained in **(a)**, decide which of the following species could be the product obtained from the reduction of XO_3^-: XO_2^-, X^+, X^- or X_2.

(c) Hence, write a balanced equation for the reaction between XO_3^- ions and iodide ions using the half-equation method.

13 RI Prelim 2018/4/1 (modified)

Copper(II) ions react with iodide ions according to the following equation.

$$2Cu^{2+}(aq) + 4I^{-}(aq) \longrightarrow \underset{\text{cream ppt}}{2CuI(s)} + \underset{\text{brown solution}}{I_2(aq)}$$

The iodine produced in this reaction may be titrated against thiosulfate ions, $S_2O_3^{2-}$, using starch solution as indicator. Thiosulfate ions react with iodine according to the following equation:

$$2S_2O_3^{2-}(aq) + I_2(aq) \longrightarrow S_4O_6^{2-}(aq) + 2I^{-}(aq)$$

41.00 cm^3 of a solution containing $CuSO_4$ was placed in a 250 cm^3 volumetric flask. Deionised water was added to make a total volume of 250.0 cm^3 of the diluted solution. 25.0 cm^3 of this diluted solution was transferred to a conical flask. Excess KI was added, and the resultant solution titrated against 0.0500 mol dm^{-3} $Na_2S_2O_3$, using starch solution as an indicator. It was found that 24.80 cm^3 of $Na_2S_2O_3$ was required for the dark blue colour to decolourise.

Calculate the concentration of $CuSO_4$ in the initial undiluted solution.

14 Solution **X** contains a mixture of a dibasic acid, ethanedioic acid ($H_2C_2O_4$), and a salt, sodium ethanedioate ($Na_2C_2O_4$). A student performed two titrations to determine the concentrations of ethanedioic acid and sodium ethanedioate in solution **X**.

In the first titration, 25.0 cm^3 of solution **X** required 14.75 cm^3 of 0.100 mol dm^{-3} sodium hydroxide solution for neutralisation.

In the second titration, 25.0 cm^3 of solution **X** required 32.00 cm^3 of 0.0205 mol dm^{-3} potassium manganate(VII) solution for complete oxidation. In the oxidation reaction, all the $C_2O_4^{2-}$ ions are oxidised to CO_2 in acidic conditions.

(a) Write the equation for the reaction between ethanedioic acid, $H_2C_2O_4$, and sodium hydroxide solution to form sodium ethanedioate, $Na_2C_2O_4$, and water.

Use this equation and the results of the first titration to calculate the concentration of ethanedioic acid in solution **X**.

(b) **(i)** Construct a balanced ionic equation for the reaction between ethanedioate ions ($C_2O_4^{2-}$) and manganate(VII) ions (MnO_4^-).

(ii) Using the balanced equation in **(b)(i)** and the results of the second titration, calculate the total amount of $C_2O_4^{2-}$ ions present in 25 cm^3 of solution **X**.

(c) Hence, calculate the concentration of sodium ethanedioate in solution **X**.