Quiz (Redox Titration)

1. Acidified potassium dichromate solution oxidizes sulphite to sulphate according to the following ionic equation:

$$Cr_2O_7^{2-}(aq) + 3SO_3^{2-}(aq) + 8H^+(aq) \longrightarrow 2Cr^{3+}(aq) + 3SO_4^{2-}(aq) + 4H_2O(l)$$

25.0 cm^3 of a sulphite salt solution was titrated with a 0.0200 M potassium dichromate solution. It requires 24.00 cm^3 of the dichromate solution for complete reaction. Calculate the molarity of SO_3^{2-} ions in the sulphite salt solution.

2. In an experiment to determine the concentration of a sodium sulphite solution, 25.0 cm^3 of the sodium sulphite solution with a little dilute sulphuric acid added were titrated with a 0.0100 M potassium permanganate solution. The results of the titrations were recorded in the table.

Titration / **Volume (in cm^3)**	**1**	**2**	**3**	**4**
Final burette reading	46.80	45.60	47.65	43.50
Initial burette reading	22.80	22.60	24.80	20.65
Volume of potassium permanganate solution used	24.00	23.00	22.85	22.85

(a) Describe the colour change of the solution at the end point.

(b) Calculate a reasonable average for the volume of 0.0100 M potassium permanganate solution required to completely react with 25.0 cm^3 of the sodium sulphite solution.

(c) Write down the equation for the reaction.

(d) Calculate the concentration of the sodium sulphite solution.

(e) What should be used to rinse the following pieces of apparatus used for the titration experiment?
(i) Pipette
(ii) Conical flask
Explain your answer.

(f) State THREE other precautions that should be taken to minimize experimental errors.

3. An experiment is carried out to determine the concentration of hydrochloric acid. It involves the following steps:

    (1) Prepare 0.010 M standard sodium hydroxide solution by diluting 25.0 cm^3 of a 0.10 M sodium hydroxide solution in distilled water and making it up to 250.0 cm^3.

    (2) Transfer 25.0 cm^3 of the acid to a conical flask with a dry and clean pipette. Methyl orange is used as the indicator.

    (3) Rinse a burette with distilled water and then fill it with the standard sodium hydroxide solution prepared. 25.50 cm^3 of sodium hydroxide solution is required to reach the end point.

    (4) Using this titration result, the concentration of hydrochloric acid can be determined.

    (a) What is the colour change of the indicator at the end point of titration?

    (b) Point out TWO inappropriate practices in the experiment and correct them.

    (c) If the titration result in step (3) were used for calculation, what would the concentration of hydrochloric acid be?

4. To determine the amount of hypochlorite ions in a sample of chlorine bleach, 25.0 cm^3 of the sample was made up to 250.0 cm^3. Excess potassium iodide solution and dilute sulphuric acid were added to 25.0 cm^3 of this solution. The solution required 20.50 cm^3 of 0.100 M sodium thiosulphate solution to reach the end point of the titration. Starch solution was used as indicator in the titration.

    (a) Explain why potassium iodide solution and dilute sulphuric acid added to the 25.0 cm^3 bleach solution should be in excess.

    (b) State the colour change at the end point.

    (c) Calculate the molarity of hypochlorite ions in the chlorine bleach.

    (d) State ONE possible source of error in the experiment.

5. You are provided with two brands of chlorine bleaches. For each brand of chlorine bleach, 25.0 cm^3 of the bleach is made up to 250.0 cm^3. Excess dilute hydrochloric acid and excess potassium iodide solution are added to 25.0 cm^3 of the solution. The solution is then titrated with 0.100 M sodium thiosulphate solution. The volume of sodium thiosulphate solution used in the titration experiment to reach the end point is recorded. The following table shows the experimental results and information about the two bleaches.

Brand	**Volume of bleach (cm^3)**	**Price ($)**	**Volume of 0.100 M sodium thiosulphate solution used in the titration experiment (cm^3)**
A	1000	15.8	22.50
B	2000	26.2	28.00

(a) Calculate the cost per mole of sodium hypochlorite for each brand of bleach.

(b) Which brand of chlorine bleach is more economical to buy?

6. The label on a bottle of commercial iron tablets indicates that every tablet (325 mg) contains 120 mg of iron.
In order to determine the iron content, 2.1850 g of iron tablets were dissolved in excess dilute sulphuric acid and the solution was made up to 100.0 cm^3 by adding distilled water. 25.0 cm^3 of this iron tablet solution required 15.60 cm^3 of 0.0460 M potassium permanganate solution for complete reaction.
(a) Calculate the molarity of iron(II) ions in the iron tablet solution.

(b) Does the iron content agree with that stated on the label?

(c) State ONE possible source of error in the experiment.
(Relative atomic mass: Fe = 55.8)

7. You are provided with two brands of iron tablets. For each brand of iron tablet, 5.00 g iron tablets are dissolved in excess dilute sulphuric acid and the solution is made up to 250.0 cm^3. 25.0 cm^3 of the solution is then titrated with 0.0500 M potassium permanganate solution until the end point is reached. The following table shows the results of the experiments:

Brand	**Price ($) per bottle (100 g)**	**Volume of potassium permanganate solution used (cm^3)**
A	320.5	15.70
B	280.6	14.80

(a) What is the percentage composition of iron in each brand of iron tablet?

(b) Calculate the cost per gram of iron for each brand of iron tablet.

(c) Which brand of iron tablet is more economical to buy?
(Relative atomic mass: Fe = 55.8)

Suggested Answer

1. $Cr_2O_7^{2-}(aq) + 3SO_3^{2-}(aq) + 8H^+(aq) \longrightarrow 2Cr^{3+}(aq) + 3SO_4^{2-}(aq) + 4H_2O(l)$

   No. of moles of $Cr_2O_7^{2-}$ in 24.00 cm^3 of 0.0200 M potassium dichromate solution
   $= 0.0200 \times 0.024$
   $= 4.8 \times 10^{-4}$

   From the equation, mole ratio of $SO_3^{2-} : Cr_2O_7^{2-} = 3 : 1$

   $\therefore$ No. of moles of SO_3^{2-} in 25.0 cm^3 of solution
   $= 4.8 \times 10^{-4} \times 3$
   $= 1.44 \times 10^{-3}$

   Molarity of SO_3^{2-} ions in the sulphite salt solution
   $= 1.44 \times 10^{-3} / 0.025$
   $= 0.0576$ M

2. (a) A permanent light purple colour appears.

   (b) The data from the first titration should not be taken into calculations.

   Average volume of the potassium permanganate solution used
   $= (23.00 + 22.85 + 22.85) / 3$
   $= 22.90$ cm^3

   (c) $2MnO_4^-(aq) + 6H^+(aq) + 5SO_3^{2-}(aq) \longrightarrow 2Mn^{2+}(aq) + 5SO_4^{2-}(aq) + 3H_2O(l)$

   (d) Number of moles of MnO_4^- used for titration
   $= 0.0100 \times 0.0229$
   $= 2.29 \times 10^{-4}$

   From the equation, mole ratio of $MnO_4^- : SO_3^{2-} = 2 : 5$

   $\therefore$ number of moles of SO_3^{2-} in 25.0 cm^3 solution
   $= 2.29 \times 10^{-4} \times 5 / 2$
   $= 5.73 \times 10^{-4}$

   Molarity of SO_3^{2-} solution
   $= 5.73 \times 10^{-4} / 0.025$
   $= 0.0229$ M

   (e) (i) It should be rinsed with distilled water first, then followed by the sodium sulphite solution (analyte). If we only rinse the pipette with distilled water, the solution delivered by the pipette would be diluted.

   (ii) The conical flask should be rinsed with distilled water but not with the sodium sulphite solution. Otherwise, the amount of sodium sulphite in the flask would be greater than expected.

(f) 1. In preparing the standard potassium permanganate solution, highly pure potassium permanganate should be used.

2. The standard potassium permanganate solution should also be freshly prepared for use. Otherwise, it may be contaminated after prolonged exposure to air.

3. When we transfer the sodium sulphite solution (analyte) to a conical flask with a pipette, allow time for drainage and then touch the tip of the pipette against the inner wall of the conical flask. Otherwise, the amount of analyte used would be smaller than expected.

4. When we run the potassium permanganate solution (titrant) to the conical flask, ensure that no air is trapped in the burette jet. Otherwise, the amount of titrant used would be smaller than expected.

(Any THREE)

3. (a) From red to orange

(b) Inappropriate practice: in step (3), the burette should not be rinsed with distilled water only.

Correct practice: the burette should be rinsed with distilled water, and then with the standard sodium hydroxide solution prepared in step (1).

In appropriate practice: in step (4), the calculation of concentration of hydrochloric acid should not be based on only one titration result.

Correct practice: the student should repeat the titration several times in order to get the reasonable average for the volume of the standard sodium hydroxide solution used. Then he should use this average value to calculate the concentration of hydrochloric acid.

(c) Number of moles of NaOH required
$= 0.010 \times 0.0255$
$= 2.55 \times 10^{-4}$

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

From the equation, mole ratio of NaOH to HCl = 1 : 1.

$\therefore$ number of moles of HCl that reacted with NaOH
$= 2.55 \times 10^{-4}$

Concentration of HCl(aq)
$= 2.55 \times 10^{-4} / 0.025$
$= 0.0102 \text{ mol dm}^{-3}$

4. (a) To ensure that all the hypochlorite ions have reacted.

(b) The solution changes from dark blue to colourless at the end point.

(c) From the titration results, number of moles of $S_2O_3^{2-}$ reacted with I_2
= 0.100 × 0.0205
= 2.05×10^{-3}

$I_2(aq) + 2S_2O_3^{2-}(aq) \longrightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$ .... (1)

From Equation (1), mole ratio of $S_2O_3^{2-} : I_2 = 2 : 1$.

∴ number of moles of I_2 produced from the reaction between OCl^- and I^- (in the presence of dilute acid)
= ½ × 2.05×10^{-3}
= 1.025×10^{-3}

$OCl^-(aq) + 2I^-(aq) + 2H^+(aq) \longrightarrow I_2(aq) + Cl^-(aq) + H_2O(l)$ .... (2)

From Equation (2), mole ratio of $I_2 : OCl^- = 1 : 1$.

∴ number of moles of OCl^- in 25.0 cm^3 diluted bleach solution
= 1.025×10^{-3}

Molarity of OCl^- in 25.0 cm^3 diluted bleach solution
= 1.025×10^{-3} / 0.025
= 0.041 M

∴ molarity of hypochlorite ions in the original chlorine bleach
= 0.041 × 250.0 / 25.0
= 0.41 M

(d) If starch is added too early, iodine will react with starch to form a water-insoluble complex. This may reduce the amount of iodine in the reaction mixture.

5. (a) For Brand A bleach, number of moles of $S_2O_3^{2-}$ reacted with I_2
= 0.100 × 0.0225
= 2.25×10^{-3}

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

From the equation, mole ratio of $S_2O_3^{2-}$ to $I_2 = 2 : 1$.

∴ number of moles of I_2 liberated from the reaction between $OCl^-(aq)$ and $I^-(aq)$.
= ½ × 2.25×10^{-3}
= 1.125×10^{-3}

$OCl^-(aq) + 2I^-(aq) + 2H^+(aq) \longrightarrow I_2(aq) + Cl^-(aq) + H_2O(l)$

From the equation, mole ratio of I_2 to OCl^- = 1 : 1.

∴ number of moles of OCl^- in 25.0 cm^3 diluted bleach solution
= 1.125×10^{-3}

Number of moles of OCl^- in 250.0 cm^3 diluted bleach solution
= $1.125 \times 10^{-3} \times 250.0 / 25.0$
= 0.01125

Number of moles of OCl^- in 1000 cm^3 Brand *A* bleach solution
= 0.01125 x 1000 / 25.0
= 0.450

The cost per mole of NaOCl for Brand *A* bleach
= \$ 15.8 / 0.450
= \$ 35.1

For Brand *B* bleach, number of moles of $S_2O_3^{2-}$ reacted with I_2
= 0.100×0.028
= 2.8×10^{-3}

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

From the equation, mole ratio of $S_2O_3^{2-}$ to I_2 = 2 : 1.

∴ number of moles of I_2 liberated from the reaction between $OCl^-(aq)$ and $I^-(aq)$.
= $\frac{1}{2} \times 2.8 \times 10^{-3}$
= 1.4×10^{-3}

$OCl^-(aq) + 2I^-(aq) + 2H^+(aq) \longrightarrow I_2(aq) + Cl^-(aq) + H_2O(l)$

From the equation, mole ratio of I_2 to OCl^- = 1 : 1.

∴ number of moles of OCl^- in 25.0 cm^3 diluted bleach solution
= 1.4×10^{-3}

Number of moles of OCl^- in 250.0 cm^3 diluted bleach solution
= $1.4 \times 10^{-3} \times 250.0 / 25.0$
= 0.014

Number of moles of OCl^- in 2000 cm^3 Brand *B* bleach solution
= $0.014 \times 2000 / 25.0$
= 1.12

The cost per mole of NaOCl for Brand *B* bleach
= \$ 26.2 / 1.12
= \$ 23.4

(b) Brand *B* chlorine bleach is more economical to buy.

6. (a) $MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \longrightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$

Number of moles of MnO_4^- used for titration
= 0.0460 M × 0.0156
= 7.18×10^{-4}

From the equation, mole ratio of MnO_4^- : Fe^{2+} = 1 : 5.

∴ number of moles of Fe^{2+} in 25.0 cm^3 iron tablet solution
= $7.18 \times 10^{-4} \times 5$
= 3.59×10^{-3}

Molarity of Fe^{2+} in the 25.0 cm^3 iron tablet solution
= 3.59×10^{-3} / 0.025
= 0.144 M

(b) Number of moles of Fe^{2+} in 100.0 cm^3 iron tablet solution
= $3.59 \times 10^{-3} \times 100.0 / 25.0$
= 0.0144

Mass of Fe in the tablets
= 0.0144 × 55.8
= 0.8035 g

% composition of Fe in a tablet found in the experiment
= (0.8035 / 2.1850) × 100%
= 36.77%

% composition of Fe in a tablet stated on the label
= $(120 \times 10^{-3} / 325 \times 10^{-3}) \times 100\%$
= 36.92%

∴ the iron content determined in the experiment agrees with that stated on the label.

(c) 1. Other ingredients present in the tablets may react with permanganate ions.

2. Some iron(II) ions in the iron tablet solution are oxidized by air.

(Any ONE)

7. (a) For Brand *A* iron tablet,

$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \longrightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$

Number of moles of MnO_4^- used for titration
= 0.0500 × 0.0157
= 7.85×10^{-4}

From the equation, mole ratio of MnO_4^- to Fe^{2+} = 1 : 5.

∴ number of moles of Fe^{2+} in 25.0 cm^3 iron tablet solution
= $7.85 \times 10^{-4} \times 5$
= 3.93×10^{-3}

Number of moles of Fe^{2+} in 250.0 cm^3 iron tablet solution
= $3.93 \times 10^{-3} \times 250.0 / 25.0$
= 0.0393

Mass of Fe in the iron tablet = 0.0393 × 55.8 = 2.19 g

Percentage composition of Fe in Brand *A* iron tablet
= (2.19 / 5.00) × 100%
= 43.8%

For Brand *B* iron tablet,

Number of moles of MnO_4^- used for titration
= 0.0500 × 0.0148
= 7.4×10^{-4}

From the equation, mole ratio of MnO_4^- to Fe^{2+} = 1 : 5.

∴ number of moles of Fe^{2+} in 25.0 cm^3 iron tablet solution
= $7.4 \times 10^{-4} \times 5$
= 3.7×10^{-3}

Number of moles of Fe^{2+} in 250.0 cm^3 iron tablet solution
= $3.7 \times 10^{-3} \times 250.0 / 25.0$
= 0.037

Mass of Fe in the iron tablet
= 0.037 × 55.8
= 2.06 g

Percentage composition of Fe in Brand *B* iron tablet
= (2.06 / 5.00) × 100%
= 41.2%

(b) The cost per gram of iron for Brand *A* iron tablet
= \$ 320.5 / 2.19
= \$146.3

The cost per gram of iron for Brand *B* iron tablet
= \$ 280.6 / 2.06
= \$136.2

(c) Brand *B* iron tablet is more economical to buy.