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VCE Chemistry ¾
Introduction to Redox [1.6]
Homework Solutions

Homework Outline:

Compulsory Questions	Pg 2 – Pg 11
Supplementary Questions	Pg 12 – Pg 21

Section A: Compulsory Questions (47 Marks)

Sub-Section [1.6.1]: Apply Oxidation Numbers to Find Oxidant & Reductant

Question 1 (4 marks)

Find the oxidation number for all elements in each of the following molecules:

a. C_2H_5COOH. (1 mark)

$C\ (\text{in } CH_3) = -3$ $\quad$ $C\ (\text{in } COOH) = +3$
$C\ (\text{in } CH_2) = -2$ $\quad$ $O = -2, H = +1$

b. H_2O. (1 mark)

$H = +1, O = -2$

c. O_2. (1 mark)

$O = 0$

d. CH_4. (1 mark)

$C = -4, H = +1$

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Question 2 (4 marks)

Preesha is investigating the following chemical reaction:

$$CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(g)$$

a. Find the oxidation numbers for all atoms in the following molecules:

i. CuO. (1 mark)

$Cu = +2$
$O = -2$

ii. Cu. (1 mark)

$Cu = 0$

b. Hence, determine and justify whether CuO is an oxidant or a reductant. (2 marks)

CuO is an oxidant (1). This is because the oxidation number of Copper in CuO to Cu decreases from $+2$ to 0, meaning CuO has undergone reduction (2).

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Question 3 (4 marks)

Micah is observing the following reaction occurring at school.

$$2MnO_4^-(aq) + 16H^+(aq) + 10I^-(aq) \rightarrow 2Mn^{2+}(aq) + 5I_2(s) + 8H_2O(l)$$

His friend explains that the oxidising agent in this reaction is MnO_4^-. Evaluate Micah's friend's statement, using calculations as justification.

Oxidation numbers:

Let the oxidation number of Mn^{2+} ions be represented by "x"

$MnO_4^- \rightarrow x + (-2 \times 4) = -1$

$x = +7$

$Mn^{2+} \rightarrow x = +2$

Micah's friend is correct (1). The manganese ions from MnO_4^- to Mn^{2+} have an oxidation number decrease from $+7$ to $+2$ (2). This means that the MnO_4^- has reduced and is the oxidising agent (3).

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Sub-Section [1.6.2]: Apply KOHES to Write Balanced Half-Equations in Acidic & Basic Conditions

Question 4 (2 marks)

Nitrate ions (NO_3^-) turn into nitrogen gas (N_2) in a laboratory.

a. Write the half-equation in acidic conditions. (1 mark)

$2NO_3^-(aq) + 12H^+(aq) + 10e^- \rightarrow N_2(g) + 6H_2O(l)$

b. Write the half-equation in alkaline conditions. (1 mark)

$10e^- + 6H_2O(l) + 2NO_3^-(aq) \rightarrow N_2(g) + 12OH^-(aq)$

Question 5 (4 marks)

Complete the balanced half-equation for each of the following, and state whether it is a reduction or oxidation reaction.

a. Iron (II) ions turning into iron solid. (1 mark)

$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$, reduction

b. $AgNO_3$ turning into silver solid. (1 mark)

$Ag^+(aq) + e^- \rightarrow Ag(s)$, reduction

c. Ethanol (CH_3CH_2OH) turning into ethanoic acid (CH_3COOH). (1 mark)

$H_2O(l) + C_2H_5OH(l) \rightarrow CH_3COOH(l) + 4H^+(aq) + 4e^-$, oxidation

d. Nitrogen dioxide (NO_2) turning into nitrogen gas (N_2). (1 mark)

$8e^- + 8H^+(aq) + 2NO_2(aq) \rightarrow N_2(g) + 4H_2O(l)$

Question 6 (4 marks)

In acidic conditions, dichromate ($Cr_2O_7^{2-}$) can react and turn into chromium ions (Cr^{3+}).

a. Write a balanced half-equation for this process. (1 mark)

$6e^- + 14H^+(aq) + Cr_2O_7^{2-}(aq) \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$

b. State whether this is an oxidation or reduction reaction and justify why. (2 marks)

Reduction reaction as there is a gain of electrons. Additionally the oxidation number of chromium goes from +6 to +3, indicating reduction has occurred.

c. Hence or otherwise, is Cr^{3+} an oxidant or reductant? (1 mark)

Since Cr^{3+} was produced in a reduction reaction, this means when Cr^{3+} reacts, it must undergo oxidation. Therefore it is a reductant.

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Sub-Section [1.6.3]: Apply KOHES to Write Balanced Half-Equations and Overall Equations in Acidic & Basic Conditions

Question 7 (6 marks)

Express the overall equation using the half equations provided.

a. Oxidation half-equation: (2 marks)

$$2I^-(aq) \rightarrow I_2(s) + 2e^-$$

Reduction half-equation:

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

$$5\left(2I^-(aq) \rightarrow I_2(s) + 2e^-\right)$$

$$2\left(MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)\right)$$

Now combine them:

$$10I^-(aq) + 2MnO_4^-(aq) + 16H^+(aq) \rightarrow I_2(g) + 2Mn^{2+}(aq) + 8H_2O(l)$$

b. Oxidation half-equation: (2 marks)

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$$

Reduction half-equation:

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$$

- Oxidation:

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$$

- Reduction:

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$$

Both have the same number of electrons (2), so just add them directly:

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

c. Oxidation half-equation: (2 marks)

$$H_2O_2(aq) \rightarrow O_2(g) + 2e^-$$

Reduction half-equation:

$$H_2O_2(aq) + 2e^- + 2H^+(aq) \rightarrow H_2O(l)$$

- Oxidation:

$$H_2O_2(aq) \rightarrow O_2(g) + 2e^-$$

- Reduction:

$$H_2O_2(aq) + 2e^- + 2H^+(aq) \rightarrow H_2O(l)$$

Both have the same number of electrons (2), so just add them directly:

$$H_2O_2(aq) \rightarrow O_2(g) + 2e^-$$

$$H_2O_2(aq) + 2e^- + 2H^+(aq) \rightarrow H_2O(l)$$

Resulting in:

2 $H_2O_2(aq) \rightarrow O_2(g) + 2H_2O(l)$

Question 8 (3 marks)

Lead (II) Pb^{2+} can be formed from Lead solid, Pb, when reacted with permanganate ions (MnO_4^-). Mn^{2+} ions are formed in the process.

Write the balanced equation for:

a. The oxidation reaction. (1 mark)

$Pb(s) \rightarrow Pb^{2+}(aq) + 2e^-$

b. The reduction reaction. (1 mark)

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

c. The overall reaction. (1 mark)

$5Pb(s) + 16H^+(aq) + 2MnO_4^-(aq) \rightarrow 5Pb^{2+}(aq) + 2Mn^{2+}(aq) + 8H_2O(l)$

Question 9 (4 marks)

Magnesium (Mg) can react with water (H_2O) in an alkaline environment to form magnesium hydroxide ($Mg(OH)_2$) and hydrogen gas (H_2).

Write the balanced equation for:

a. The oxidation reaction. (1 mark)

$$Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$$

b. The reduction reaction. (1 mark)

$$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$$

c. The overall reaction. (2 marks)

- **Oxidation reaction:**

$$Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$$

- **Reduction reaction:**

$$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$$

Now, combine the two reactions by canceling out the electrons:

$$Mg(s) + 2H_2O(l) \rightarrow Mg(OH)_2(aq) + H_2(g)$$

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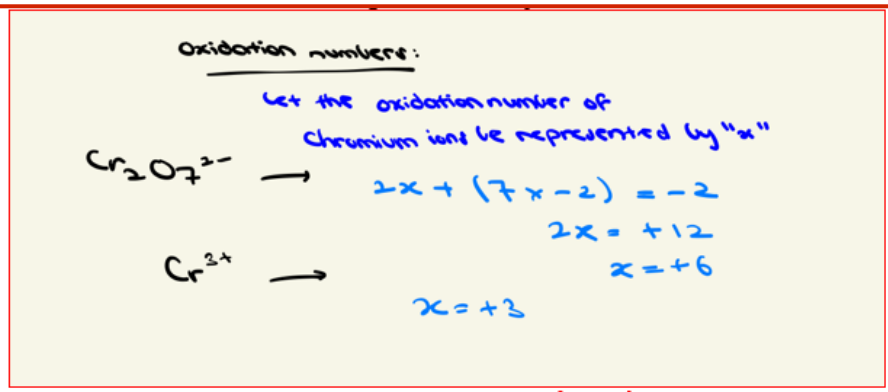
Sub-Section: The 'Final Boss'

Question 10 (12 marks)

Liam is experimenting with Potassium dichromate ($K_2Cr_2O_7$) reacting with ethanol (C_2H_5OH), forming chromium (III) ions and acetic acid (CH_3COOH) in a reaction vessel with a pH of 8.2.

a. His friend explains that the reducing agent in this reaction is $K_2Cr_2O_7$. Evaluate Liam's friend's statement, using calculations as justification. (4 marks)



Liam's friend is incorrect (1). The chromium ions of $Cr_2O_7^{2-}$ to Cr^{3+} have an oxidation number decrease from +6 to +3 (2). This means that the $Cr_2O_7^{2-}$ has reduced and is the oxidising agent (3).

b. Express the half-equations involving the following and state the type of reaction occurring.

i. Oxidant. (2 marks)

$$Cr_2O_7^{2-}(aq) + 7H_2O(l) + 6e^- \rightarrow 2Cr^{3+}(aq) + 14OH^-(aq)$$

ii. Reductant. (2 marks)

$$C_2H_5OH(aq) + 4OH^-(aq) \rightarrow CH_3COOH(aq) + 4e^- + 3H_2O(aq)$$

c. Write the complete reaction that Liam is observing. (2 marks)

- **Oxidation half-equation (multiplied by 3):**

$$3C_2H_5OH(aq) + 12OH^-(aq) \rightarrow 3CH_3COOH(aq) + 12e^- + 9H_2O(l)$$

- Reduction half equation (multiplied by 2)

$$2Cr_2O_7{}^{2-}(aq) + 14H_2O(l) + 12e^- \rightarrow 4Cr^{3+}(aq) + 28OH^-(aq)$$

Now, we can add the two half-equations together:

$$2Cr_2O_7{}^{2-}(aq) + 3C_2H_5OH(aq) + 5H_2O(l) \rightarrow 3CH_3COOH(aq) + 4Cr^{3+}(aq) + 16OH^-(aq)$$

d. Liam is also curious about the following reaction:

$$HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(l)$$

State and explain whether the above reaction is a redox reaction. (2 marks)

No, there is no change of oxidation numbers across any of the species. This reaction rather is an acid-base reaction.

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Section B: Supplementary Questions (43 Marks)

Sub-Section [1.6.1]: Apply Oxidation Numbers to Find Oxidant & Reductant

Question 11 (4 marks)

State the oxidation number for the element specified in the molecule/ion provided.

a. Oxidation number of Chromium in CrO_4^{2-}. (1 mark)

$Cr = +6, O = -2$

b. Oxidation number of Sulphur in SO_3^{2-}. (1 mark)

$S = +4, O = -2$

c. Oxidation number of Phosphorus in $H_2PO_4^-$. (1 mark)

$P = +5, H = +1, O = -2$

d. Oxidation number of Nitrogen in NO_3^-. (1 mark)

$N = +5, O = -2$

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Question 12 (4 marks)

Natalie is investigating the following chemical reaction:

$$ZnO(s) + C(s) \rightarrow Zn(s) + CO_2(g)$$

a. Find the oxidation numbers for all atoms in the following molecules:

i. C. (1 mark)

$C = 0$

ii. CO_2. (1 mark)

$C = +4, O = -2$

b. Hence, determine and justify whether C (carbon) is a reductant or an oxidant. (2 marks)

C is a reductant (1). This is because the oxidation number of Carbon in C to CO_2 increases from 0 to +4, meaning C has undergone oxidation (2).

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Question 13 (4 marks)

Kanta is observing the following reaction occurring at school:

$$2Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6I^-(aq) \rightarrow 2Cr^{3+}(aq) + 3I_2(g) + 7H_2O(l)$$

His friend explains that the reducing agent in this reaction is $Cr_2O_7^{2-}$. Evaluate Kanta's friend's statement, using calculations as justification.

Oxidation numbers:

Let the oxidation number of Cr ions be represented by "x"

$Cr_2O_7^{2-} \rightarrow$ $2x + (7 \times -2) = -2$

$2x = +12$

$x = +6$

$Cr^{3+} \rightarrow$ $x = +3$

Micah's friend is incorrect (1). The chromium ions from $Cr_2O_7^{2-}$ to Cr^{3+} have an oxidation number decrease from +6 to +3 (2). This means that the $Cr_2O_7^{2-}$ has reduced and is the oxidising agent (3).

Question 14

In an acidic solution, ascorbic acid ($C_6H_8O_6$) reacts with dichromate ions ($Cr_2O_7^{2-}$), resulting in the formation of chromium(III) ions (Cr^{3+}) and dehydroascorbic acid ($C_6H_6O_6$).

$$C_6H_8O_6(aq) + Cr_2O_7^{2-}(aq) + 8H^+(aq) \rightarrow C_6H_6O_6(aq) + 2Cr^{3+}(aq) + 4H_2O(l)$$

A friend claims that $\mathbf{C_6H_8O_6}$ is the reducing agent in this reaction. Evaluate this claim, justify your response with the relevant calculations.

Oxidation numbers:

Let the oxidation number of carbon be represented by "x"

$C_6H_8O_6 \rightarrow$ $6x + 8 + (6x - 2) = 0$

$x = +2$

$C_6H_6O_6 \rightarrow$ $6x + 6 + (6x - 2) = 0$

$x = +3$

The friend is correct (1). The carbon oxidation number in $C_6H_8O_6$ to $C_6H_6O_6$ has an oxidation number increase from +2 to +3 (2). This means that the $C_6H_8O_6$ has oxidised and is the reducing agent (3).

Sub-Section [1.6.2]: Apply KOHES to Write Balanced Half-Equations in Acidic & Basic Conditions

Question 15 (2 marks)

Perchlorate ions (ClO_4^-) turn into chlorine gas (Cl_2) in a laboratory.

a. Write the half-equation in acidic conditions. (1 mark)

$2ClO_4^{2-}(aq) + 16H^+ + 14e^- \rightarrow Cl_2(g) + 8H_2O(l)$

b. Write the half-equation in alkaline conditions. (1 mark)

$2ClO_4^{2-}(aq) + 8H_2O(l) + 14e^- \rightarrow Cl_2(g) + 16OH^-(aq)$

Question 16 (4 marks)

Complete the balanced half-equation for each of the following, and state whether it is a reduction or oxidation reaction.

a. Copper (II) ions turning into copper solid. (1 mark)

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ (Reduction, Cu goes from +2 to 0.)

b. Silver oxide (Ag_2O) turning into silver solid. (1 mark)

$Ag_2O(s) + 2e^- \rightarrow 2Ag(s) + O^{2-}(aq)$ (Reduction, Ag goes from +1 to 0.)

c. Butanol (C_4H_9OH) turning into butanoic acid ($C_4H_8O_2$). (1 mark)

$C_4H_9OH \rightarrow C_4H_8O_2 + 2e^-$ (Oxidation, C goes from -1 to $+3$.)

d. Nitrous oxide (N_2O) turning into nitrogen gas (N_2). (1 mark)

$N_2O \rightarrow N_2 + O$ (Reduction, N goes from $+1$ to 0.)

Question 17 (4 marks)

In acidic conditions, potassium permanganate ($KMnO_4$) can react and turn into manganese ions (Mn^{2+}).

a. Write a balanced half-equation for this process. (1 mark)

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

b. State whether this is an oxidation or reduction reaction and justify why. (2 marks)

- This is a **reduction reaction** because the oxidation number of manganese decreases.
- In **MnO_4^-**, the oxidation number of manganese is **$+7$**, but in **Mn^{2+}**, it is **$+2$**. Since the oxidation number of manganese decreases, it means that **MnO_4^-** is gaining electrons (reduction).

c. Hence or otherwise, is Mn^{2+} an oxidant or reductant? (1 mark)

Mn^{2+} is a **reductant (reducing agent)** because it has a low oxidation state of **$+2$** and can easily donate electrons to other species (undergoing oxidation itself).

Question 18 (4 marks)

In acidic conditions, potassium dichromate ($K_2Cr_2O_7$) reacts and turns into chromium(III) ions (Cr^{3+}).

a. Write a balanced half-equation for the reduction of potassium dichromate to chromium(III) ions in acidic conditions. (1 mark)

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$

b. State whether this is an oxidation or reduction reaction and justify why. (2 marks)

The oxidation number of chromium in **dichromate** ($Cr_2O_7^{2-}$) is **+6**, while in **chromium(III)** ions (Cr^{3+}), the oxidation number is **+3**.

Since the oxidation number of chromium decreases, it indicates that the **chromium has gained electrons** in the reaction (reduction).

This is further evidenced by the presence of **electrons** on the left-hand side of the half-equation, indicating a gain of electrons.

c. Hence or otherwise, is Cr^{3+} an oxidant or reductant? (1 mark)

Chromium(III) ions (Cr^{3+}) have an oxidation state of **+3**, which is relatively low. Therefore, they can easily **lose electrons** to be oxidized to a higher oxidation state (e.g., Cr^{6+} or $Cr_2O_7^{2-}$).

A species with a low oxidation state (like Cr^{3+}) is a good **reducing agent** because it can donate electrons to other species and undergo **oxidation** itself.

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Sub-Section [1.6.3]: Apply KOHES to Write Balanced Half-Equations and Overall Equations in Acidic & Basic Conditions

Question 19 (4 marks)

Express the overall equation using the half-equations provided.

a. Oxidation half-equation: (2 marks)

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^{-}$$

Reduction half-equation:

$$Cr_2O_7{}^{2-}(aq) + 14H^{+}(aq) + 6e^{-} \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$

- Oxidation:

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^{-}$$

- Reduction:

$$Cr_2O_7^{2-}(aq) + 14H^{+}(aq) + 6e^{-} \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$

Multiply the oxidation half-equation by **6** and the reduction half-equation by **1** to balance electrons:

$$6Fe^{2+}(aq) \rightarrow 6Fe^{3+}(aq) + 6e^{-}$$

Now combine:

$$6Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14H^{+}(aq) \rightarrow 6Fe^{3+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$$

b. Oxidation half-equation: (2 marks)

$$2Cl^{-}(aq) \rightarrow Cl_2(g) + 2e^{-}$$

Reduction half-equation:

$$2H^{+}(aq) + 2e^{-} \rightarrow H_2(g)$$

$2Cl^-(aq) + 2H^+(aq) \rightarrow Cl_2(g) + H_2(g)$

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Question 20 (4 marks)

Zinc(II) Zn^{2+} can be formed from Zinc solid, Zn, when reacted with dichromate ions ($Cr_2O_7^{2-}$). Cr^{3+} ions are formed in the process.

Write the balanced equation for:

a. The oxidation reaction. (1 mark)

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$$

b. The reduction reaction. (1 mark)

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$

c. The overall reaction. (2 marks)

Oxidation reaction (multiplied by 3):

$$3Zn(s) \rightarrow 3Zn^{2+}(aq) + 6e^-$$

Reduction reaction (no change):

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$

Now, combine the two reactions:

$$3Zn(s) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \rightarrow 3Zn^{2+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$$

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Question 21 (4 marks)

Sodium (Na) reacts with water in an alkaline environment to form sodium hydroxide and hydrogen gas.

Write the balanced equation for:

a. The oxidation reaction. (1 mark)

$$\mathrm{Na}(s) \rightarrow \mathrm{Na}^{+}(aq) + e^{-}$$

b. The reduction reaction. (1 mark)

$$2\mathrm{H_2O}(l) + 2e^{-} \rightarrow \mathrm{H_2}(g) + 2\mathrm{OH}^{-}(aq)$$

c. The overall reaction. (2 marks)

- **Oxidation reaction:**

$$\mathrm{Na}(s) \rightarrow \mathrm{Na}^{+}(aq) + e^{-}$$

- **Reduction reaction:**

$$2\mathrm{H_2O}(l) + 2e^{-} \rightarrow \mathrm{H_2}(g) + 2\mathrm{OH}^{-}(aq)$$

Now, combine them:

$$2\mathrm{Na}(s) + 2\mathrm{H_2O}(l) \rightarrow 2\mathrm{NaOH}(aq) + \mathrm{H_2}(g)$$

Explanation:

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Question 22 (5 marks)

In the paper industry, bleaching is a crucial process to eliminate colour from pulp, ensuring the production of high-quality paper. Chlorine or chlorine compounds are commonly used in redox reactions to oxidise and remove impurities, enhancing the paper's brightness and quality.

a. Chlorine gas is used in a reaction with water. This purifies pulp and produces oxygen gas (O_2) and hypochlorous acid (HOCl).

Write a balanced equation for the:

i. Oxidation reaction. (1 mark)

$2H_2O(l) + Cl_2(g) \rightarrow 2HOCl(aq) + 2H^+(aq) + 2e^-$

ii. Reduction reaction. (1 mark)

$H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

iii. Overall reaction. (1 mark)

$5H_2O(l) + 2Cl_2(g) \rightarrow 4HOCl(aq) + 8H^+ + O_2(g)$

b. Hydrochloric acid (HCl) is also often used as an alternative to using chlorine gas. HCl can undergo the following reaction:

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

State and explain whether the above reaction is a redox reaction. (2 marks)

No, there is no change of oxidation numbers across any of the species. This reaction rather is an acid-base reaction.

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