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CHEMISTRY

Physical Chemistry

Level & Board	AQA (A-LEVEL)
TOPIC:	Oxidation Reducation & Redox
PAPER TYPE:	SOLUTION - 1
TOTAL QUESTIONS	10
TOTAL MARKS	38

Oxidation, Reduction and Redox Equations QP

1.

(a)

An oxidizing agent is a substance that can accept electrons from another substance during a chemical reaction. So, it itself undergoes reduction (gains electrons) and causes the other substance to be oxidized (lose electrons). E.g. Cl can act as oxidising agent.

(1)

(b)

Half-equation for Oxidation of SO_3^{2-} to SO_4^{2-}:

$SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2H^+ + 2e^-$

Half-equation for the reduction of $Cr_2O_7^{\ 2-}$ to Cr^{3+}:

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

Overall equation :

$3SO_3^{\ 2-} + Cr_2O_7^{\ 2-} + 8H^+ \rightarrow 3SO_4^{\ 2-} + 2Cr^{3+} + 4H_2O$

(3)

2. (A)

(Total 1 mark)

3. (D)

(Total 1 mark)

4. A student carried out an experiment to find the mass of $FeSO_4.7H_2O$ in an impure sample, X. The student recorded the mass of X.
This sample was dissolved in water and made up to 250 cm^3 of solution.
The student found that, after an excess of acid had been added, 25.0 cm^3 of this solution reacted with 21.3 cm^3 of a 0.0150 mol dm^{-3} solution of $K_2Cr_2O_7$

(a)

Moles of $K_2Cr_2O_7$ per titration
$=21.3\times0.0150/1000 = 3.195\times10^{-4}$
$=21.3\times0.0150/1000$
$=3.195\times10^{-4}$

$Cr_2O_7^{2-}+14H^++6Fe^{2+}\longrightarrow 2Cr^{3+}+7H_2O+6Fe^{3+}$

Ratio of $Cr_2O_7^{2-}$ to Fe^{2+} is 1:6

Moles of Fe^{2+}
$=6\times 3.195\times 10^{-4}$
$=1.917\times 10^{-3}$

The original moles in 250 cm^3
$=1.917\times 10^{-3}\times 10$
$=1.917\times 10^{-2}$
(considering the solution was made up to 250 cm^3)
Mass of $FeSO_4.7H_2O$
$=1.917\times 10^{-2}\times 277.9$
=5.33Grams
So, the correct mass of FeSO4.7H2O in the sample X is 5.33 grams.

(5)

(b)

The impurity being a reducing agent or a less hydrated form of $FeSO_4$ (with fewer than 7 water molecules) would cause the calculated mass of $FeSO_4.7H_2O$ in sample X to be higher than the actual mass. This is because the impurity would react more readily or completely with the titrant ($K_2Cr_2O_7$) than the fully hydrated $FeSO_4.7H_2O$, leading to an overestimation of the $FeSO_4.7H_2O$ content during the titration.

(2)

5. **(C)**

(Total 1 mark)

6.

(a)

The equilibrium between chlorine and water in the absence of sunlight can be represented by the following equation:

$Cl_2 + H_2O \rightleftharpoons HOCl + HCl$

Oxidation states:

- Cl_2 (chlorine gas) has an oxidation state of 0.

- *H_2O (water) has an oxidation state of -2 for oxygen and +1 for hydrogen.*
- *HOCl (hypochlorous acid) has an oxidation state of +1 for chlorine, -2 for oxygen, and +1 for hydrogen.*
- *HCl (hydrochloric acid) has an oxidation state of -1 for chlorine and +1 for hydrogen.*

(2)

(b)

When the water pH is slightly greater than 7.0, it indicates the presence of a higher concentration of hydroxide (OH^-) or alkali ions in the solution. So,

Reaction of Hydroxide Ions with Acids:

Hydroxide ions (OH^-) or alkali ions have the propensity to react with acids present in the solution.

The equilibrium between chlorine, water, hypochlorous acid, and hydrochloric acid, the increase in OH^- ions encourages them to react with the acids (HCl and HOCl) present in the system.

Equilibrium Shift to the Right:

The reaction between hydroxide ions and the acidic species (HCl and HOCl) leads to the consumption of OH^- ions.

According to Le Chatelier's principle, to counteract this decrease in OH^- concentration, the equilibrium shifts to the right.

(2)

(c)

Chlorine, despite its toxicity, is used in swimming pools in small amounts due to several reasons:

***Effective Disinfection in Small Concentrations**:*

Even in small amounts, chlorine has disinfectant properties, effectively killing bacteria, viruses, and other microorganisms present in the water. So, only trace amounts are needed to maintain a sanitized pool environment.

***Balancing Risks and Benefits**: The health benefits of using chlorine to prevent waterborne illnesses and maintain a safe swimming environment are considered to outweigh the potential risks associated with its toxicity. The controlled and regulated application of chlorine allows for the reduction of health risks while still effectively disinfecting the pool.*

(2)

7. (D)

(Total 1 mark)

8.

(a)

i. The half-equation for the oxidation of chloride ions to chlorine is :
$2Cl^- \rightarrow Cl_2 + 2e^-$

(1)

ii.

Let x be the oxidation state of manganese:
Oxidation state of Mn+Oxidation states of O=Charge of ion
$x+(-8)=-1$
Solving for x:
$x=-1+8$
$=+7$

(1)

iii.

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

(1)

(b)

i.

$Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$

(1)

ii.

One observation made during this reaction is the formation of a reddish-brown color due to the production of elemental bromine (Br2). Bromine is a volatile liquid at room temperature, and its characteristic reddish-brown color is easily observable when formed in the reaction between chlorine and bromide ions.

(1)

iv.

An oxidizing agent is a substance that can accept electrons from another substance during a chemical reaction. So, it itself undergoes reduction (gains electrons) and causes the other substance to be oxidized (lose electrons). E.g. Br can act as oxidising agent.

(1)

(c)

$2Cl_2 + 2H_2O \rightarrow 4HCl + O$

Oxidation state −1

(2)

(d)

Chlorine has a lower boiling point than bromine due to the relative size of the chlorine molecules compared to bromine and the resultant strength of their intermolecular forces.

Relative Size of Atoms/Molecules:

Chlorine atoms/molecules are smaller than bromine atoms/molecules. Chlorine has a smaller atomic radius or is a smaller molecule compared to bromine.

This difference in size results in variations in the strength of intermolecular forces between the chlorine or bromine molecules.

Effect of Intermolecular Forces on Boiling Point:

The forces between chlorine molecules (Cl_2) are weaker than the forces between bromine molecules (Br_2). Due to the smaller size of chlorine molecules, they have weaker van der Waals forces. These weaker forces in chlorine require less energy to overcome, resulting in a lower boiling point for chlorine compared to bromine.

(2)

9.

(a)

Correct, when titanium (IV) oxide (TiO_2) is reduced using carbon, titanium carbide (TiC) is formed instead of pure titanium metal. This occurs due to the high stability of titanium carbide, preventing the production of titanium metal directly from the reduction process.

Titanium carbide is a brittle compound and not an ideal engineering material, further complicating the direct extraction of titanium using carbon as a reducing agent.

(1)

(b)

i.

$FeTiO_3 + 3\frac{1}{2}Cl_2 + 3C \rightarrow FeCl_3 + TiCl_4 + 3CO$

(1)

ii.

$FeCl_3 + TiCl_4 + 7Na \rightarrow 7NaCl + Fe + Ti$

(1)

(c)

The iron in the scrap metal undergoes oxidation:

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

Simultaneously, the copper(II) ions in the aqueous solution gain electrons from the iron and get reduced to elemental copper:

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

(2)

(d)

$2O^{2-} \rightarrow O_2 + 4e^-$

(1)

10. (A)

(Total 1 mark)

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