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CHEMISTRY

Physical Chemistry

Level & Board	AQA (A-LEVEL)
TOPIC:	Oxidation Reducation & Redox
PAPER TYPE:	SOLUTION - 4
TOTAL QUESTIONS	10
TOTAL MARKS	48

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Oxidation, Reduction and Redox Equations - 4

1.

(a)

i.

Amonia is Oxidised in the forward reaction.

(1)

ii.

The catalyst must be hot to provide/overcome activation energy.

(1)

iii.

The catalyst remains hot during the reaction is exothermic.

(1)

iv.

A catalyst increases the rate of a reaction because catalysts provide an alternative route to reaction and surface adsorption also occurs so it lowers the activation energy.

(2)

(b)

At lower temperatures:

The equilibrium favors the exothermic forward reaction

($2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$).

The equilibrium will shift to the right, favoring the formation of more NO_2.

The yield of NO_2 will be greater in the equilibrium mixture.

Lower temperatures cause the system to favor the formation of nitrogen dioxide (NO_2).

This shift occurs because the forward reaction is exothermic (releases heat), and to counter act the decrease in temperature, the equilibrium shifts toward the formation of more NO_2, ultimately leading to a higher concentration of NO_2 in the equilibrium mixture.

(2)

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(c)

NO_2 (Nitrogen Dioxide):
Let x be the oxidation state of nitrogen.
$2(-2) + x = 0$
$-4 + x = 0$
$x = +4$
Therefore, the oxidation state of nitrogen in NO_2 is +4.

NO_3^- (Nitrate ion):
Let x be the oxidation state of nitrogen.
$3(-2) + x = -1$
$-6 + x = -1$
$x = +5$
Therefore, the oxidation state of nitrogen in NO_3^- is +5.

HNO_2 (Nitrous acid):
Let x be the oxidation state of nitrogen.
$+1 + x - 2(-2) = 0$
$x - 3 = 0$
$x = +3$
Therefore, the oxidation state of nitrogen in HNO_2 is +3.

(3)

2. (B)

(Total 1 mark)

3.

Given:

- Mass of $FeSO_4.7H_2O$ = 10.00 g
- Molar mass of $FeSO_4.7H_2O$ (Mr) = 277.9 g/mol
- Volume of solution prepared = 250 cm^3
- Volume of solution used for titration = 25.0 cm^3
- Volume of potassium dichromate(VI) used = 23.70 cm^3
- Concentration of potassium dichromate(VI) solution = 0.0100 mol/dm^3

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The number of moles of potassium dichromate(VI) used in the titration:
Moles of potassium dichromate(VI) = concentration × volume (in dm^3)
Moles = 0.0100 mol/dm^3 × (23.70 cm^3 ÷ 1000)

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Moles = 0.0100 mol/dm³ × 0.02370 dm³
Moles = 2.37 × 10^{-4} mol
The balanced equation:

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

1 mol $Cr_2O_7^{2-}$ reacts with 6 mol Fe^{2+} so
moles Fe^{2+} in 25 cm^3
= 6 × 2.37 × 10^{-4}
= 1.422 × 10^{-3}
Moles Fe^{2+} in 250 cm^3
= 1.422 × 10^{-2}
=0.01422

Original moles Fe^{2+} = 10.00/277.9 = 0.0360

Moles Fe^{2+} oxidised = 0.0360 – 0.0142 = 0.0218
% oxidised
= (0.0218 × 100)/0.0360
= 60.5%

(6)

4. (D)

(Total 1 mark)

5.

(a)

Half-equation for the conversion of MnO_2 in acid solution into Mn^{2+} ions and water.

$$MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$$

*An **oxidizing agent** is a substance that accepts electrons from another substance, causing the latter to undergo oxidation by losing electrons.*

In the given reaction, MnO_2 gets reduced, meaning it loses oxygen and accepts electrons.

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(3)

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(b)

Extraction Process 2:

$2KBr + 3H_2SO_4 \rightarrow 2KHSO_4 + Br_2 + SO_2 + 2H_2O$

For the ionic equation without K^+:

$2Br^- + 6H^+ + 3SO_4^{2-} \rightarrow Br_2 + 2HSO_4^- + SO_2 + 2H_2O$

Extraction Process 3:

$2KBr + Cl_2 \rightarrow 2KCl + Br_2$

For the ionic equation without K^+:

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

The atom economy

It's calculated using the following formula:

$$\text{Atom economy} = \frac{\text{Molecular mass of desired product}}{\text{Sum of molecular masses of all reactants}} \times 100$$

For Extraction Process 3:

- Desired product: Bromine (Br_2)
- Molecular mass of Br_2 = 2 × atomic mass of Br = 2 × 79.904 g/mol = 159.808 g/mol
- Reactants: 2 moles of KBr (2 × 119.002 g/mol) + 1 mole of Cl_2 (2 × 35.453 g/mol)

Sum of molecular masses of all reactants =

=2×119.002 g/mol+2×35.453 g/mol

=238.004 g/mol+70.906 g/mol

=308.91 g/mol

$$= \frac{159.808\ \text{g/mol}}{308.91\ \text{g/mol}} \times 100$$

Atom economy= 51.8%

Extraction Process 3 is the method in large-scale use today due to high atom economy and less waste products.

(5)

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(c)

In HBr (hydrogen bromide), the oxidation state of bromine is -1.
In HBrO (hypobromous acid), the oxidation state of bromine is +1.

As hypobromous acid (HBrO) reacts with microorganisms in the swimming pool water, it acts as a disinfectant by oxidizing and neutralizing them. This consumption of HBrO disrupts the equilibrium:

$Br_2 + H_2O \rightleftharpoons HBrO + HBr$

The equilibrium will shift to the right (or from left to right) to replenish the reduced concentration of HBrO due to its consumption. This shift favors the forward reaction to replace the used-up HBrO, producing more hypobromous acid (HBrO) and hydrogen bromide (HBr) from bromine (Br_2) and water (H_2O). The purpose is to oppose or counteract the loss of HBrO and maintain the equilibrium balance.

(4)

6. **(D)**

(Total 1 mark)

7.

(a)

$Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$

(1)

(b)

HNO_3 (Nitric Acid):
Using the overall charge and summing the oxidation states:
$1+x+(-6)=0$
$x-5=0$
$x=+5$
Therefore, in nitric acid (HNO_3), the oxidation state of nitrogen is +5.

NO_2 (Nitrogen Dioxide):
$x+2(-2)=$
$x-4=0$
$x=+4$
Therefore, in nitrogen dioxide (NO_2), the oxidation state of nitrogen is +4.

(2)

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(c)

$HNO_3 + H^+ + e^- \rightarrow NO_2 + H_2O$

(1)

8. (C)

(Total 1 mark)

9.

(a)

An oxidizing agent is a substance that gains electrons from another substance, causing the latter to lose electrons and undergo oxidation. e.g Chlorine

(1)

(b)

i.

In SO_2 (sulfur dioxide):
Let x be the oxidation state of sulfur.
$x + 2(-2) = 0$
$x - 4 = 0$
$x = +4$

Let x be the oxidation state of sulfur.
In SO_4^{2-}, the sum of oxidation states equals the charge of the ion, which is -2:

$x + 4(-2) = -2$
$x - 8 = -2$
$x = +6$

(1)

ii.

$Br_2 + 2e^- \rightarrow 2Br^-$

(1)

iii.

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$SO_2 + 2H_2O \rightarrow 4H^+ + SO_4^{2-} + 2e^-$

(1)

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iv.

$Br_2 + SO_2 + 2H_2O \rightarrow 2Br^- + 4H^+ + SO_4^{2-}$

(2)

(c)

$Cl_2 + H_2O \rightarrow H^+ + Cl^- + HOCl$

Chloride: −1
Chlorate(I): +1

(3)

(d)

Chlorine is not formed when solid potassium chloride reacts with concentrated sulphuric acid because chloride ions cannot reduce sulphuric acid as chloride ions are weak reducing agents.

(1)

(e)

$KCl + H_2SO_4 \rightarrow HCl + KHSO_4$

(1)

(f)

i.

Bromine is oxidation product formed from potassium bromide.

(1)

ii.

Sulphur dioxide is reduction product formed from sulphuric acid.

(1)

10. **(B)**

(Total 1 mark)

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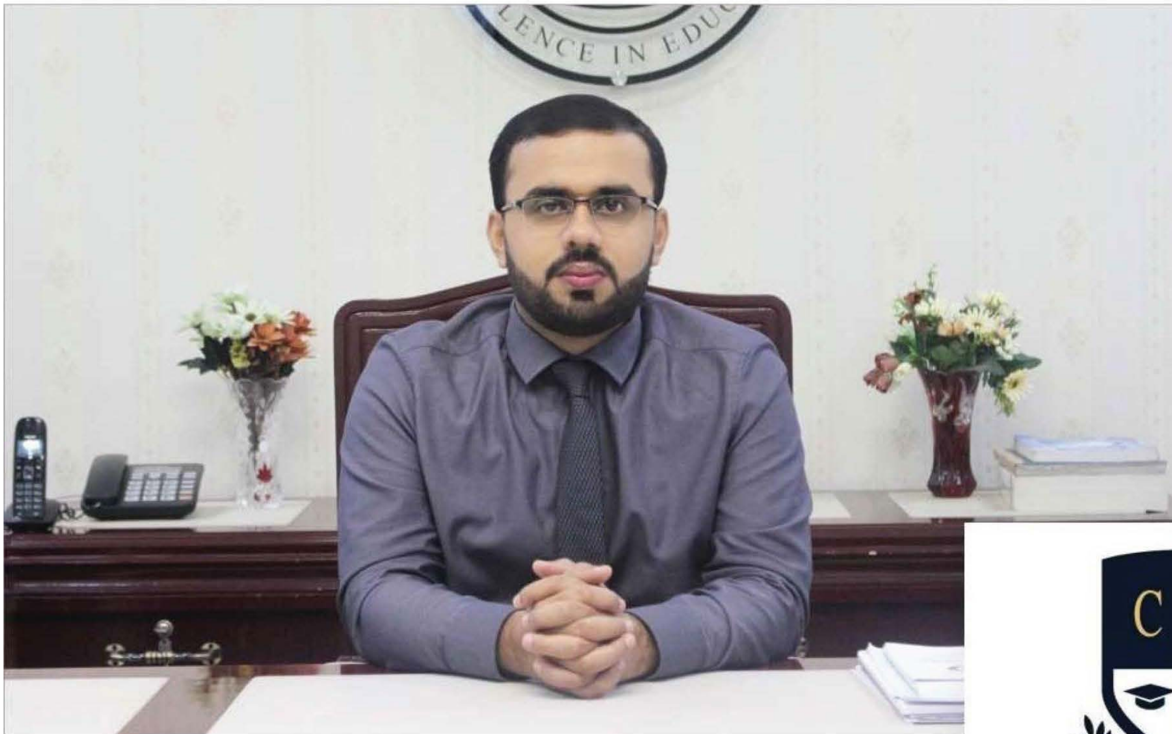

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