VNIT

06 Oxidation & Reduction:-

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Classical Concept of Oxidation:-

↳ The process that involves addition of oxygen or any other electronegative element or removal of Hydrogen or any other electropositive element is called Oxidation.

$Mg + O_2 \longrightarrow MgO$

$Na + Cl_2 \longrightarrow NaCl$

Classical concept of reduction:-

↳ The process that involves removal of oxygen or any other electronegative elements or addition of hydrogen or any other electropositive element is called reduction.

$CuO + H_2 \longrightarrow Cu + H_2O$

$ZnO + C \longrightarrow Zn + CO$

$Cr_2O_3 + Al \longrightarrow Al_2O_3 + 2Cr$

Imp # Modern Concept of oxidation:- [Electronic concept]:-

↳ According to electronic concept, the process of that involves loss of electron is called Oxidation. Simply loss of electron is called oxidation.

$Mg \longrightarrow Mg^{++} + 2e^-$

$Fe^{++} \longrightarrow Fe^{+++} + e^-$

In short Oxidation is,

i) Loss of electron
ii) Increase in positive charge
iii) decrease in negative charge

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Imp

Modern (electronic) concept of Reduction:-

↳ According to electronic concept the process that involves gain of electron is called reduction. simply, gain of electron is called reduction.

$$Mg^{++} + 2e^- \longrightarrow Mg$$
$$Fe^{++} + e^- \longrightarrow Fe^{+++}$$

In short Reduction is;

i) gain of electron
ii) decrease in positive charge
iii) increase in negative charge

Oxidising agent (Oxidant):-

↳ A substance that oxidises another substance but itself get reduced is known as oxidising agent. All non-metals are oxidising agent except C, H and P. Acid like H_2SO_4, HNO_3 are oxidising agent. Other substance like $KMnO_4$, $K_2Cr_2O_7$, O_3 etc.

Reducing agent (Reductant):-

↳ A substance that reduces another substance but itself get oxidied is known as reducing agent. All the metals are reducing agent. Non-metal like C, H, P are also reducing agent.

Oxidising agent according to electronic Concept:-

↳ A substance that accept electron is known as oxidising agent.

$$FeCl_3 + SnCl_2 \longrightarrow FeCl_2 + SnCl_4$$

Here $FeCl_3$ is oxidising agent and $SnCl_2$ is reducing agent.

A substance which donate electrons is known as reducing agent.

Oxidation Number:-

↳ The residual charge that an atom appears to have when all other atoms present in a molecule are removed in the form of ions is called Oxidation number.

Rules for remembering Oxidation Number:-

i) The Oxidation number of an element in its free state is taken as zero. For example, oxidation number of Na, Cu, Zn, Ca is zero. $H_2 = Cl_2 = O_2 = 0$

ii) The Oxidation number of element of group IA, IIA & IIIA are these compounds.

iii) The oxidation number of oxygen in its combined state is -2 except peroxide where it is -1. e.g. H_2O_2, Na_2O_2, K_2O_2, BaO_2 in these compounds Oxidation number of oxygen is -1.

iv) The Oxidation number of Hydrogen in its Combined state is +1 except metal hidrides where it is -1. e.g:- the Oxidation number of Hydrogen in NaH, KH, CaH_2, MgH_2 etc is -1.

v) The sum of positive oxidation number & negative Oxidation number in a neutral molecule is equal to Zero.

e.g $AlCl_3 = Al^{+++} + 3Cl^-$ $\quad$ $NaCl = Na^+ + Cl^-$

$= +3 + (-3) = 0$ $\quad$ $= +1 - 1 = 0$

vi) The sum of positive & negative oxidation number in a Charged ion is equal to its ionic charge.

Calculate the oxidation number of following underlined elements:-

a) $H\underline{N}O_3$

↳ Let the oxidation number of Nitrogen (N) be x.

Then, $1 + x + (-2) \times 3 = 0$

or, $x + 1 - 6 = 0$

$\therefore x = +5$

Hence, The oxidation number of Nitrogen in HNO_3 is +5. #

b) $\underline{N_2}O$

↳ Let the Oxidation number of Nitrogen (N) be x.

Then, $2x + (-2) = 0$

$\therefore x = +1$

Hence, The Oxidation number of N in N_2O is +1. #

g) Li_2^+

↳ Let the oxidation number of Li in Li_2^+ is x.

Then, $2x + 2(-2) = +1$

$\Rightarrow \boxed{x = +\frac{5}{2}}$

Hence, O.N. of Li in Li_2^+ is $+\frac{5}{2}$. Ans.

h) KCl_4

↳ Let the oxidation number of Cl is x.

Then, $+1 + 4x + [-2(+2)] = 0$

or, $5 - 4x = 0$

$\Rightarrow \boxed{x = \frac{5}{4}}$

Hence, O.N. of Cl in KCl_4 is $+\frac{5}{4}$. Ans.

i) HCl

↳ Let the oxidation number of Cl is x.

Then, $+1 + x = 0$

$\Rightarrow \boxed{x = -1}$

Hence, O.N. of Cl in HCl is -1. Ans.

j) $Na_2S_2O_3$

↳ Let the oxidation number of Sulphur be x;

According, $2(+1) + 2x + 3(-2) = 0$

or, $2 + 2x - 6 = 0$

$\Rightarrow \boxed{x = +2}$

Hence, O.N. of Sulphur in $Na_2S_2O_3$ is $+2$. Ans.

g) $K_2Cr_2O_7$

↳ Let the O.N. of Chromium is x;

Then, $+1\times2 + 2x + (-2)\times7 = 0$

or, $2 + 2x - 14 = 0$

$\Rightarrow \boxed{x = 6}$

Hence, O.N. of Chromium in $K_2Cr_2O_7$ is 6. #

h) S

↳ The oxidation Number of Sulphur in S is 0.

i) Cl_2

↳ The oxidation number of chlorine in Cl_2 is 0.

j) Na_2O_2

↳ Let the O.N. of Oxygen in Na_2O_2 be x;

Then, $+1(2) + 2x = 0$

or, $2x = -2$

$\Rightarrow \boxed{x = -1}$

Hence, The O.N. of Oxygen in Na_2O_2 is -1. #

k) NO_3^-

↳ Let the O.N. of Nitrogen in NO_3^- be x;

Then, $x + (-2)\times3 = -1$

or, $x - 6 = -1$

$\Rightarrow \boxed{x = +5}$

Hence, The O.N. of Nitrogen in NO_3^- is +5. #

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l) $\underline{Cr_2O_7^{--}}$

↳ Let the O.N. of chromium be x;

Then, $2x + (-2)\times 7 = -2$

$2x = 12$

$\Rightarrow \boxed{x = 6}$

Hence, the O.N. of chromium is 6. #

m) $\underline{C_6H_2O_6}$

↳ The the O.N. of Carbon be x;

Then, $6x + 1(12) + (-2)\times 6 = 0$

or, $6x = 0$

$\Rightarrow \boxed{x = 0}$

Hence, the O.N. of Carbon in $C_6H_2O_6$ is 0. #

n) $\underline{Fe_3O_4}$

↳ The O.N. of Iron be x. (Let).

Then, $3x + (-2)\times 4 = 0$

$\Rightarrow \boxed{x = 8/3}$

Hence, the oxidation numbers of Iron in Fe_3O_4 is $8/3$. #

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Balancing a redox reaction by oxidation number method:-

★ Rules for balancing redox reaction by oxidation number method:-

1) Write unbalanced chemical equation and assign the Oxidation number above the symbol of element.
2) Calculate the change in oxidation number of those elements which have undergone oxidation or reduction. When oxidation number of more than one atom changed in a molecule then total change in oxidation number is Calculated.
3) Write change in oxidation number below the formula of oxidising agent and reducing agent in bracket.
Note:- When both the changes are odd, double them
4) To balance, increase in oxidation number with decrease in oxidation number multiplying criss cross with change in oxidation number.
5) Balance the main elements on product side by hit & trial method.
6) Balance other elements first: metal then non-metal except Hydrogen and Oxygen.
7) Balance: hydrogen and finally oxygen.

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Balance the following redox reactions by oxidation number method:

1. $\overset{+5}{H}\overset{}{N}\overset{}{O_3} + \overset{-2}{H_2}\overset{}{S} \longrightarrow \overset{+4}{N}\overset{}{O_2} + \overset{0}{S} + H_2O$

Change in oxidation number of N = Final − initial
= +4 − (+5)
= −1

Change in oxidation number of (S) per atom = 0 − (−2)
= +2

$HNO_3 + H_2S \longrightarrow NO_2 + S + H_2O$

(1 ⟷ 2)

$2HNO_3 + H_2S \longrightarrow NO_2 + S + H_2O$

Then, balancing elements;

$2HNO_3 + H_2S \longrightarrow 2NO_2 + S + 2H_2O$ #

2. $\overset{0}{C} + \overset{+6}{H_2}\overset{}{S}\overset{}{O_4} \longrightarrow \overset{+4}{C}\overset{}{O_2} + \overset{+4}{S}\overset{}{O_2} + H_2O$

Change in O.N. of Carbon = 4 − 0 = +4
& Change in O.N. of Sulphur = 4 − 6 = −2

$C + H_2SO_4 \longrightarrow CO_2 + SO_2 + H_2O$

(4 ⟷ 2)

2 1 [∵ 2 is common]

$C + 2H_2SO_4 \longrightarrow CO_2 + SO_2 + H_2O$

Then, Balancing elements:-

$C + 2H_2SO_4 \longrightarrow CO_2 + 2SO_2 + 2H_2O$ #

3. ★ $\overset{+5}{HNO_3} + \overset{0}{I_2} \longrightarrow \overset{+5}{HIO_3} + \overset{+4}{NO_2} + H_2O$

Now,

Change in O.N. of N = 4 − 5 = −1

Change in O.N. of I_2 = (5−0)2 = 10 [∵ I have two atoms]

$HNO_3 + I_2 \longrightarrow HIO_3 + NO_2 + H_2O$

1 ✕ 10

$10HNO_3 + I_2 \longrightarrow 2HIO_3 + 10NO_2 + 4H_2O$

4. ★ $\overset{+5}{HNO_3} + \overset{-2}{H_2S} \longrightarrow \overset{+4}{SO_2} + \overset{+4}{NO_2} + H_2O$

Now,

Change in O.N. of N = 4 − 5 = −1

Change in O.N. of S = 4 + 2 = 6

$HNO_3 + H_2S \longrightarrow SO_2 + NO_2 + H_2O$

1 ✕ 6

$6HNO_3 + H_2S \longrightarrow SO_2 + 6NO_2 + 4H_2O$

5. ★ $\overset{0}{C_{12}H_{22}O_{11}} + \overset{+5}{HNO_3} \longrightarrow \overset{+4}{NO_2} + \overset{+3}{C_2H_2O_4} + H_2O$

Now;

Change in O.N. of C for 12 atom = (3−0)12 = +36

Change in O.N. of N per atom = +4−5 = −1

$C_{12}H_{22}O_{11} + HNO_3 \longrightarrow NO_2 + C_2H_2O_4 + H_2O$

36 ✕ 1

$C_{12}H_{22}O_{11} + 36HNO_3 \longrightarrow 36NO_2 + 6C_2H_2O_4 + 23H_2O$

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$\overset{+7}{KMnO_4} + \overset{+3}{C_2H_2O_4} + H_2SO_4 \longrightarrow K_2SO_4 + \overset{+2}{MnSO_4} + \overset{+4}{CO_2} + H_2O$

Now;

Change in O.N. of Mn = +2-7 = -5

Change in O.N. of C per two atom = (4-3)2 = +2

$KMnO_4 + C_2H_2O_4 + H_2SO_4 \longrightarrow K_2SO_4 + MnSO_4 + CO_2 + H_2O$

5 ⤫ 2

$2KMnO_4 + 5C_2H_2O_4 + 3H_2SO_4 \longrightarrow K_2SO_4 + 2MnSO_4 + 10CO_2 + 8H_2O$ [balancing]

#

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$\overset{+6}{K_2Cr_2O_7} + \overset{+2}{FeSO_4} + H_2SO_4 \longrightarrow \overset{+6}{K_2SO_4} + \overset{+3}{Cr_2(SO_4)_3} + \overset{+3}{Fe_2(SO_4)_3} + H_2O$

Now,

Change in O.N. of Cromium per two atom = (3-6)x2 = +6

Change in O.N of Iron per atom = 3-2 = 1

$K_2Cr_2O_7 + FeSO_4 + H_2SO_4 \longrightarrow K_2SO_4 + Cr_2(SO_4)_3 + Fe_2(SO_4)_3 + H_2O$

6 ⤫ 1

$K_2Cr_2O_7 + 6FeSO_4 + 7H_2SO_4 \longrightarrow K_2SO_4 + Cr_2(SO_4)_3 + 3Fe_2(SO_4)_3 + 7H_2O$

#

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$\overset{0}{Cu} + \overset{+5}{HNO_3} \longrightarrow \overset{+2}{Cu(NO_3)_2} + \overset{+4}{NO_2} + H_2O$

Now;

Change in O.N. of Cu = 2-0 = 2

Change in O.N of N = 4-5 = -1

$Cu + HNO_3 + HNO_3 \longrightarrow Cu(NO_3)_2 + NO_2 + H_2O$

2 ⤫ 1

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

#

[9] ☆ $\overset{0}{Cu} + HNO_3 \longrightarrow \overset{+2}{Cu}(NO_3)_2 + \overset{+2}{NO} + H_2O$

Now;

Change in O.N. of Cu = 2 - 0 = 2

Change in O.N. of N = 2 - 5 = -3

$Cu + HNO_3 + HNO_3 \longrightarrow Cu(NO_3)_2 + NO + H_2O$

2 ✕ 3

$3Cu + 2HNO_3 + 6HNO_3 \longrightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$

i.e, $3Cu + 8HNO_3 \longrightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$

[10] ☆ $\overset{0}{Cu} + \overset{+5}{HNO_3} \longrightarrow \overset{+2}{Cu(NO_3)_2} + \overset{+1}{N_2O} + H_2O$

i.e, $Cu + HNO_3 + HNO_3 \longrightarrow Cu(NO_3)_2 + N_2O + H_2O$

Now,

Change in O.N. of Cu = +2 - 0 = 2

Change in O.N. of N = +1 - 5 = -4

$Cu + HNO_3 + HNO_3 \longrightarrow Cu(NO_3)_2 + N_2O + H_2O$

2 ✕ 4

$4Cu + 2HNO_3 + 8HNO_3 \longrightarrow 4Cu(NO_3)_2 + N_2O + 5H_2O$

[11] ☆ $\overset{0}{Cu} + \overset{+5}{HNO_3} \longrightarrow \overset{+2}{Cu(NO_3)_2} + \overset{-3}{NH_4}\overset{+5}{NO_3} + H_2O$

☆ Change in O.N. of Copper = 2 - 0 = 2

Change in O.N. of Nitrogen = -3 - 5 = -8

$\Rightarrow 4Cu + 10HNO_3 \longrightarrow 4Cu(NO_3)_2 + NH_4NO_3 + 3H_2O$

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12. ☆ $\overset{+7}{KMnO_4} + \overset{-1}{HCl} \longrightarrow KCl + \overset{+2}{MnCl_2} + \overset{0}{Cl_2} + H_2O$

Now;
Change in O.N. of Mn = 2 − 7 = −5
Change in O.N. of Cl_2 = 2[0 − (−1)] = 1 × 5

⇒ $2KMnO_4 + 10HCl + 6HCl \longrightarrow 2KCl + 2MnCl_2 + 5Cl_2 + 8H_2O$

13. ☆ $\overset{+4}{MnO_2} + \overset{-1}{HCl} \longrightarrow \overset{+2}{MnCl_2} + \overset{0}{Cl_2} + H_2O$

Now;
Change in O.N. of Mn = 2 − 4 = −2
Change in O.N. of Cl = 0 + 1 = 1

⇒ $MnO_2 + 2HCl + 2HCl \longrightarrow MnCl_2 + Cl_2 + 2H_2O$

14. ☆ $\overset{0}{Zn} + \overset{+5}{NaNO_3} + NaOH \longrightarrow \overset{+2}{Na_2ZnO_2} + \overset{-3}{NH_3} + H_2O$

Now,
Change in O.N. of Zn = 2 − 0 = +2
Change in O.N. of N = −3 − 5 = −8

⇒ $4Zn + NaNO_3 + 7NaOH \longrightarrow 4Na_2ZnO_2 + NH_3 + 2H_2O$

15. ☆ $\overset{-1}{KI} + \overset{+6}{H_2SO_4} \longrightarrow K_2SO_4 + \overset{0}{I_2} + \overset{-2}{H_2S} + H_2O$

Now,
Change in O.N. of I = 0 + 1 = 1
Change in O.N. of S = −2 − 6 = −8

⇒ $8KI + 5H_2SO_4 \longrightarrow 4K_2SO_4 + 4I_2 + H_2S + 4H_2O$

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$\overset{+6}{K_2Cr_2O_7} + \overset{+2}{SnCl_2} + HCl \longrightarrow \overset{+3}{CrCl_3} + \overset{+4}{SnCl_4} + KCl + H_2O$

Now,
Change in O.N. of Cr = 3-6 = -3
Change in O.N. of Sn = 4-2 = 2

$\Rightarrow 2K_2Cr_2O_7 + 6SnCl_2 + 28HCl \longrightarrow 4CrCl_3 + 6SnCl_4 + 4KCl + 14H_2O$

i.e. $\Rightarrow K_2Cr_2O_7 + 3SnCl_2 + 14HCl \longrightarrow 2CrCl_3 + 3SnCl_4 + 2KCl + 7H_2O$ #

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$\overset{+3}{FeCl_3} + \overset{-2}{H_2S} \longrightarrow \overset{+2}{FeCl_2} + \overset{0}{S} + HCl$

Now,
Change in O.N. of Fe = 2-3 = -1
Change in O.N. of S = 0+2 = 2

$\Rightarrow 2FeCl_3 + H_2S \longrightarrow 2FeCl_2 + S + 2HCl$ #

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$\overset{0}{Zn} + \overset{+5}{HNO_3} \longrightarrow \overset{+2}{Zn(NO_3)_2} + \overset{-3}{NH_4NO_3} + H_2O$

Now, Change in O.N. of Zn = 2-0 = 2
Change in O.N. of N = -3-5 = -8

$\Rightarrow 4Zn + 10HNO_3 \longrightarrow 4Zn(NO_3)_2 + NH_4NO_3 + 3H_2O$

19 $\overset{+6}{Cr_2O_7^{--}} + \overset{+2}{Fe^{++}} + H^+ \longrightarrow \overset{+3}{Cr^{+++}} + \overset{+3}{Fe^{+++}} + H_2O$

Now,
Change in O.N. of Cr_2 = (3-6)×2 = -3×2 = -6
Change in O.N. of Fe = 3-2 = 1

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

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$\overset{+7}{MnO_4^-} + \overset{-2}{S^{--}} + H_2O \rightarrow \overset{+4}{MnO_2} + \overset{0}{S} + OH^-$

Now,

Change in O.N. of Mn = 4-7 = -3

Change in O.N. of S = 0+2 = 2

$\Rightarrow 2MnO_4^- + 3S^{--} + 4H_2O \rightarrow 2MnO_4 + 3S + 8OH^-$

Ion Electron Method:-

↳ The rules for balancing chemical reaction by ion electron method are:-

i) Split redox reaction into Oxidation half & reduction half.

ii) For each half reaction
   a) Balance all elements except H & O.
   b) Balance oxygen by using H_2O.
   c) Balance Hydrogen by using H^+ ions.
   d) Balance charges by using e^-.

iii) In order to equalize number of electron produced in Oxidation half & number of electron produced in Reduction half, multiplying one or both half reaction by suitable integers.

iv) Add both half reaction to get balanced redox reaction.

vi) Both the balanced half reactions are multiplied by suitable number to make equal no. of electrons in both half reactions. Both half reactions are added and common terms which appears on both sides are cancelled out.

① e.g:-

$$\overset{+6}{Cr_2}O_7^{--} + \overset{+2}{Fe^{++}} + H^+ \longrightarrow \overset{+3}{Cr^{+++}} + \overset{+3}{Fe^{+++}} + H_2O$$

(reduction, oxidation)

Oxidation half rxn:-

$$\overset{+2}{Fe^{++}} \longrightarrow \overset{+3}{Fe^{+++}}$$

$$Fe^{++} - e^- \longrightarrow Fe^{+++} \quad \text{---(i)}$$

Reduction half rxn:-

$$\overset{+6}{Cr_2O_7^{--}} \longrightarrow 2Cr^{+++}$$

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

$$+14H^+ \quad \text{---(ii)}$$

Multiplying eqn (i) by 6 & adding with (ii)

$$6Fe^{++} - 6e^- \longrightarrow 6Fe^{+++}$$

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

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

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② $\overset{+2}{Fe^{2+}} + H^+ + \overset{+5}{NO_3^-} \longrightarrow \overset{+3}{Fe^{3+}} + \overset{+2}{NO} + H_2O$

Oxidation

Reduction

Oxidation half rxn:

$Fe^{2+} \longrightarrow Fe^{3+}$

$Fe^{2+} - e^- \longrightarrow Fe^{3+}$ — (i)

Reduction half rxn

$NO_3^- \longrightarrow NO$

$NO_3^- + 3e^- \longrightarrow NO^{2+} + 2H_2O$

$+ 4H^+$ — (ii)

Multiplying (i) by 3 & adding with (ii)

$3Fe^{2+} - 3e^- \longrightarrow 3Fe^{3+}$

$4H^+ + NO_3^- + 3e^- \longrightarrow NO^{2+} + 2H_2O$

$\Rightarrow NO_3^- + 3Fe^{2+} + 4H^+ \longrightarrow 3Fe^{3+} + NO^{2+} + 2H_2O$ #