# Chapter 8 Redox Reactions

Topics →
- Oxidation and Reduction: Classical & Modern Concepts
- Oxidation Number or Oxidation State
- Balancing of Redox reactions in acidic as well as basic medium
- Types of Redox reactions

## (A) Oxidation And Reduction: Classical Concept

◉ Oxidation → It is the addition of oxygen

Example · $C + O_2 \longrightarrow CO_2$ · $S + O_2 \longrightarrow SO_2$

→ It is the removal of hydrogen

Example · $H_2S + Cl_2 \longrightarrow 2HCl + S$

→ It is the addition of an electronegative element

[Electronegative Element → elements which gain electron]

Example · $H_2 + Cl_2 \longrightarrow 2HCl$

→ It is the removal of an electropositive element

Example · $2KI + H_2O_2 \longrightarrow I_2 + 2KOH$

◉ Reduction → It is the removal of oxygen

Example · $CuO + C \longrightarrow Cu + CO$

→ It is the addition of hydrogen

Example · $H_2 + S \longrightarrow H_2S$

→ It is the removal of an electronegative element

Example · $2FeCl_3 + H_2 \longrightarrow 2HCl + 2FeCl_2$

→ It is the addition of an electropositive element

Example • $CuCl_2 + Cu \longrightarrow Cu_2Cl_2$

25/6/19 • **Oxidising Agent** - A substance which is a supplier of oxygen and undergoes reduction is called an Oxidising Agent.

Example • $KMnO_4$, • $HNO_3$

• **Reducing Agent** - A substance which is a supplier of hydrogen and undergoes oxidation is called a Reducing Agent.

Example • $LiAlH_4$, • $NaBH_4$

**Oxidation And Reduction : Modern Concept**

⊙ Electronic Concept

→ Oxidation [Loss electron Oxidation (LeO)] (R.A.)

$Al \rightarrow Al^{+3} + 3e^-$

$Na \rightarrow Na^{+1} + 1e^-$

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

$Ca \rightarrow Ca^{+2} + 2e^-$

$K \rightarrow K^+ + 1e^-$

$MnO_4^{-2} \longrightarrow MnO_4^- + 1e^-$

→ Reduction [Grain electron Reduction (GrER)] (O.A.)

$Cl_2 + 2e^- \longrightarrow 2Cl^-$

$Fe^{3+} + 1e^- \longrightarrow Fe^{2+}$

$Cu^{2+} + 1e^- \longrightarrow Cu^{1+}$

26/6/19 **Redox Reaction Examples**

• Redox Reaction involves two half reactions - one involving the loss of ~~electron~~ electron, and other involving the gain of electron.

Example 1 $Hg^{+2} + Sn^{+2} \longrightarrow Hg_2^{+2} + Sn^{+4}$

The equation can be splitted into two halves - reduction part and oxidation part.

$2Hg^{+2} + 2e^- \longrightarrow Hg_2^{+2}$ (Reduction)
$Sn^{+2} \longrightarrow Sn^{+4} + 2e^-$ (Oxidation)

Example 2 $SnCl_2 + FeCl_3 \longrightarrow FeCl_2 + SnCl_4$
$Sn^{+2} \longrightarrow Sn^{+4} + 2e^-$ (Oxidation)
$Fe^{+3} + 1e^- \longrightarrow Fe^{+2}$ (Reduction)

Example 3 $K + Cl_2 \longrightarrow KCl$
$K \longrightarrow K^+ + 1e^-$ (Oxidation)
$Cl_2 + 2e^- \longrightarrow 2Cl^-$ (Reduction)

Example 4 $FeCl_3 + KI \longrightarrow FeCl_2 + I_2$
$Fe^{+3} + 1e^- \longrightarrow Fe^{+2}$ (Reduction)
$2I^- \longrightarrow I_2 + 2e^-$ (Oxidation)

27/6/19 Example 5 $Na_2S_2O_3 + I_2 \longrightarrow Na_2S_4O_6 + NaI$
(Sodium Thiosulphate)
$I_2 + 2e^- \longrightarrow 2I^-$ (Reduction)
$2S_2O_3^{-2} \longrightarrow S_4O_6^{-2} + 2e^-$ (Oxidation)

Example 6 $Al + Cu(SO_4) \longrightarrow Al_2(SO_4)_3 + Cu$
$2Al \longrightarrow Al_2^{+3} + 3e^-$ (Oxidation)
$3SO_4^- + 3e^- \longrightarrow (SO_4)_3^{-2}$ (Reduction)

1/7/19 ⟨B⟩ OXIDATION STATE / OXIDATION NUMBER

Oxidation number is defined as "the charge (real or imaginary) which an atom appears to have when it is in a combination."

RULES TO DETERMINE THE OXIDATION NUMBER:

1. The O.N. of an atom in free elements is zero and also

when it is in its molecular state.
Example - $K, Na, H_2, N_2, O_2, P_4, S_8, O_3$ etc.
Covalently Bonded

2. The alkali metals in periodic table (group 1) always have +1 oxidation no. and also alkaline earth metals (group 2) will have +2 O.N.

3. The Fluorine being the most electronegative element in the periodic table has always $-1$ O.N.

4. O.N. of oxygen is always $-2$ except in peroxides its O.N. is $-1$, in superoxide it is $-\frac{1}{2}$ and in $OF_2$ (+2), $O_2F_2$

Example $KO_2, CaO_2$

5. The O.N. of hydrogen is +1 in all its compounds except metallic hydrides, like $NaH, BaH_2$ etc, where it has $-1$ oxidation state.

6. (a) When we calculate O.N. of a neutral molecule, for example $HCl, HNO_3$, then the sum of all individual O.N. is equal to O.

(b) When O.N. for an ion is calculated, the sum of O.N. of each atom of an element, will always be equal to the charge present on molecule.

Example • $KMnO_4$ O.N. for Mn=?

$1 + x + (-2)4 = 0$

$x - 7 = 0 \Rightarrow x = +7$

• $K_2Cr_2O_7$ O.N. for Cr = ?

(1) $2+(x)2+(-2)7=0$

$2+2x-14=0 \Rightarrow 2x=12$

$\therefore x=+6$

3/7/19 Q. Calculate the O.N. of underlined elements:

• $\underline{K}Al(SO_4)_2 \cdot 12H_2O$ $\quad 1+x+(-2)2=0$

$\Rightarrow x=+3$

• $\underline{H_2}SO_4$ $\quad 2(1)+x+(-2)4=0$

$2+x-8=0$

$\Rightarrow x=+6$

cyanide → -1

like OH → -1

• $MnO_2$ $\quad x+(-2)2=0$

$\Rightarrow x=+4$

• $K_4[Fe(CN)_6]$ $\quad (1)4+x+(-1)6=0$

$4+x-6=0 \Rightarrow x=+2$

• $\underline{S}O_4^{-2}$ $\quad x+(-2)4=-2$

$\Rightarrow x=+6$

• $\underline{Mn}O_4^-$ $\quad x+(-2)4=-1$

$\Rightarrow x=+7$

• $Cr_2O_7^{-2}$ $\quad (x)2+(-2)7=-2$

$2x=12 \Rightarrow x=+6$

7. OXIDATION NO. OF PEROXI COMPOUNDS:

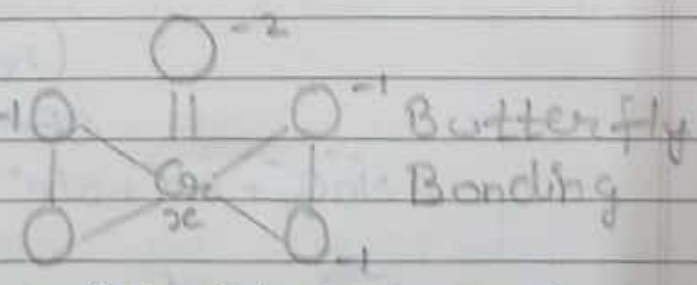
Some compounds like $H_2O_2$, $H_2SO_5$ [peroxisulphuric acid or Caro's Acid], $CrO_5$ [peroxichromium] have a special bonding where oxygen is making a bond with another oxygen. In order to calculate the O.N. of these compounds the chemical bonding method is used.

9/7/19 Example • $CrO_5$

$x+(-2)5=0$

$x=+10$ ✗

No element can donate more than 8 $e^-$.




Butterfly Bonding

$x+(-1)4+(-2)=0 \Rightarrow x=+6$

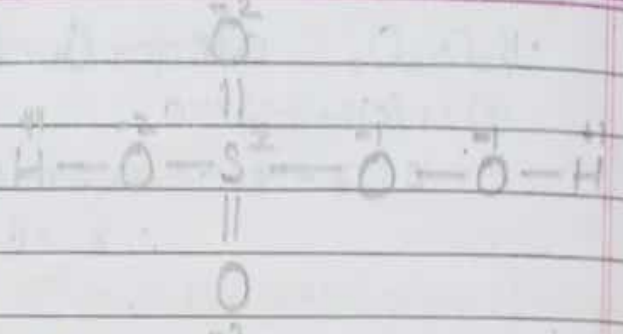
• $H_2SO_5$

$(+1)2 + x + (-2)5 = 0$

$2 + x - 10 = 0$

$x = +8$ ✗

Only Mn can donate $8e^-$



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

$2 - 6 - 2 + x = 0 \Rightarrow x = +6$

• In $H_2SO_4$, coordinate bond is formed between S and O.

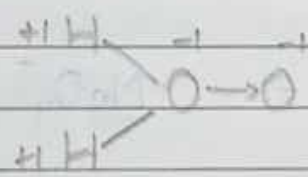
• In $HNO_3$, coordinate bond is formed between N and O.

34 [total no. of $e^-$ each element should have]

$-10$ [actual no. of $e^-$ present in outer shells of elements]

$= 24$ [shared $e^-$]

• $H_2O_2$



## ⟨C⟩ Balancing Of Redox Reactions

### (a) In Acidic Medium

$$MnO_4^- + Fe^{+2} \longrightarrow Fe^{+3} + Mn^{+2}$$

1 (Split into 2 halves) $8H^+ + \overset{+7}{M_nO_4^-} + 5e^- \longrightarrow Mn^{+2} + 4H_2O$ (Reduction)

2 (Assign O.N. to element undergoing change) $Fe^{+2} \longrightarrow Fe^{+3} + 1e^-$ (Oxidation)

3 (Balance the elements)

11/7/19 4 (Loss-gain of $e^-$ is shown) $\Rightarrow 8H^+ + \overset{+7}{Mn}O_4^- + 5e^- \longrightarrow Mn^{+2} + 4H_2O$

$(Fe^{+2} \longrightarrow Fe^{+3} + 1e^-) \times 5$

$5Fe^{+2} \longrightarrow 5Fe^{+3} + 5e^-$

$= \overset{+7}{Mn}O_4^- + 8H^+ + 5Fe^{+2} \longrightarrow Mn^{+2} + 4H_2O + 5Fe^{+3}$

Ques. $Cr_2O_7^{-2} + Fe^{+2} \longrightarrow Fe^{+3} + Cr^{+3}$

$14H^+ + Cr_2O_7^{+6,-2} + 6e^- \longrightarrow 2Cr^{+3} + 7H_2O$ (Reduction)

$6Fe^{+2} \longrightarrow 6Fe^{+3} + 6e^-$ (Oxidation)

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

Ques. $MnO_4^- + I^- \longrightarrow I_2 + Mn^{+2}$

$(8H^+ + MnO_4^{+7,-} + 5e^- \longrightarrow Mn^{+2} + 4H_2O)2$ (Reduction)

$(2I^- \longrightarrow I_2 + 2e^-)5$ (Oxidation)

$16H^+ + 2MnO_4^{+7,-} + 10e^- \longrightarrow 2Mn^{+2} + 8H_2O$

$10I^- \longrightarrow 5I_2 + 10e^-$

$= 16H^+ + 2MnO_4^- + 10I^- \longrightarrow 2Mn^{+2} + 8H_2O + 5I_2$

Ques. $Cr_2O_7^{-2} + SO_2 \longrightarrow Cr^{+3} + HSO_4^-$

$14H^+ + Cr_2O_7^{+6,-2} + 6e^- \longrightarrow 2Cr^{+3} + 7H_2O$ (Reduction)

$(2H_2O + SO_2^{+4} \longrightarrow HSO_4^{+6,-} + 3H^+ + 2e^-)3$

$6H_2O + 3SO_2 \longrightarrow 3HSO_4^- + 9H^+ + 6e^-$ (Oxidation)

$14H^+ + Cr_2O_7^{-2} + 6H_2O + 3SO_2 \longrightarrow 2Cr^{+3} + 7H_2O + 3HSO_4^- + 9H^+$

$Cr_2O_7^{-2} + 5H^+ + 3SO_2 \longrightarrow 2Cr^{+3} + H_2O + 3HSO_4^-$

15/7/19 Ques. $H_2O_2 + Fe^{+2} \longrightarrow Fe^{+3} + H_2O$

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

$2H^+ + H_2O_2^{-1} \longrightarrow H_2O^{-2} + H_2O$ (Reduction)

$2H^+ + H_2O_2 + 2Fe^{2+} \longrightarrow 2H_2O + 2Fe^{+3}$

Ques. $MnO_4^- + H_2O_2 \longrightarrow Mn^{+2} + O_2$

$(8H^+ + MnO_4^- + 5e^- \longrightarrow Mn^{+2} + 4H_2O)2$ (Reduction)

$(H_2O_2 \longrightarrow O_2 + 2H^+ + 2e^-)5$ (Oxidation)

$2MnO_4^- + 16H^+ + 5H_2O_2 \longrightarrow 2Mn^{+2} + 8H_2O + 5O_2 + 10H^+$

$\therefore 2MnO_4^- + 6H^+ + 5H_2O_2 \longrightarrow 2Mn^{+2} + 8H_2O + 5O_2$

17/7/19 (b) In Basic Medium

1→ Divide/split the equation into 2 halves.
2→ Assign the Oxidation Number
3→ Balance the elements
4→ Balance the loss and gain of electrons
5→ Write the added equation
*6→ Observe both the sides of the equation. Wherever you have more $H^+$ ions, add same no. of $OH^-$ ions on both the sides of equation.

Ques. $MnO_4^- + Br^- \longrightarrow MnO_2 + BrO_3^-$

$(3e^- + \overset{+7}{Mn}O_4^- + 4H^+ \longrightarrow \overset{+5}{Mn}O_2 + 2H_2O)2$ (Reduction)

$\overset{-1}{Br}^- + 3H_2O \longrightarrow \overset{+5}{Br}O_3^- + 6H^+ + 6e^-$ (Oxidation)

$6e^- + 2MnO_4^- + 8H^+ \longrightarrow 2MnO_2 + 4H_2O$

$Br^- + 3H_2O \longrightarrow BrO_3^- + 6H^+ + 6e^-$

$\therefore 2MnO_4^- + 8H^+ + Br^- + 3H_2O \longrightarrow 2MnO_2 + 4H_2O + BrO_3^- + 6H^+$

$2MnO_4^- + 2H^+ + Br^- \longrightarrow 2MnO_2 + H_2O + BrO_3^-$

$2MnO_4^- + 2H^+ + Br^- + 2OH^- \longrightarrow 2MnO_2 + H_2O + BrO_3^- + 2OH^-$

$2MnO_4^- + H_2O + Br^- \longrightarrow 2MnO_2 + BrO_3^- + 2OH^-$

Ques. $MnO_4^- + I^- \longrightarrow MnO_2 + I_2$

$(Mn^{+7}O_4^- + 3e^- + 4H^+ \longrightarrow Mn^{+4}O_2 + 2H_2O) 2$ (Reduction)

$(2I^- \longrightarrow I_2 + 2e^-) 3$ (Oxidation)

$= 2MnO_4^- + 6e^- + 8H^+ \longrightarrow 2MnO_2 + 4H_2O$

$6I^- \longrightarrow 3I_2 + 6e^-$

$2MnO_4^- + 8H^+ + 6I^- \longrightarrow 2MnO_2 + 4H_2O + 3I_2$

$= 2MnO_4^- + 8H^+ + 8OH^- + 6I^- \longrightarrow 2MnO_2 + 4H_2O + 3I_2 + 8OH^-$

$= 2MnO_4^- + 8H_2O + 6I^- \longrightarrow 2MnO_2 + 4H_2O + 3I_2 + 8OH^-$

$= 2MnO_4^- + 4H_2O + 6I^- \longrightarrow 2MnO_2 + 3I_2 + 8OH^-$

## (D) Types of Redox Reactions

22/7/19

- Combination Reactions

$\overset{0}{C} + \overset{0}{O_2} \longrightarrow \overset{+4\ -2}{CO_2}$ (Reduction; Oxidation)

All combination reactions are redox reactions.

- Decomposition Reactions

All decomposition reactions are redox reactions.

$2H_2O \xrightarrow{EC} \overset{0}{H_2} + \overset{0}{O_2}$

- Displacement Reactions

All displacement reactions are redox reactions

$$Fe + CuSO_4 \longrightarrow FeSO_4 + Cu$$

(Oxidation, Reduction)

• Double Displacement Reactions

All double displacement reactions are not redox reactions

$$BaCl_2 + Na_2SO_4 \longrightarrow 2NaCl + BaSO_4$$

★ • Disproportionation Reaction

In this reaction, same element undergoes both reduction and oxidation simultaneously.

$Mn^{+3}$ is unstable and it stabalizes itself when added to water and forms $Mn^{+2}$ and $MnO_2$.

$$\cdot\ Mn^{+3} \longrightarrow Mn^{+2} + MnO_2$$

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

$$Mn^{+3} + 2H_2O \longrightarrow MnO_2 + 4H^+ + e^-$$

$$2Mn^{+3} + 2H_2O \longrightarrow Mn^{+2} + MnO_2 + 4H^+ \rightarrow \text{acidic}$$

$$\cdot\ P_4 \longrightarrow PH_3 + H_2PO_2^-$$

$$12H^+ + P_4 \longrightarrow 4PH_3 + 12e^-$$

$$(8H_2O \rightleftharpoons 8H^+ + P_4 \longrightarrow 4H_2\overset{+4}{P}O_2^- + 4e^-)3$$

$$24H_2O \rightleftharpoons 24H^+ + 3P_4 \longrightarrow 12H_2PO_2^- + 12e^-$$

$$24H_2O \rightleftharpoons 12H^+ + 4P_4 \longrightarrow 4PH_3 + 12H_2PO_2^-$$

$$12H_2O + P_4 \longrightarrow PH_3 + 3H_2PO_2^- + 3H^+$$

$N_2H_4 + ClO_3^- \longrightarrow NO + Cl^-$

$(2H_2O + \overset{-2}{N_2}H_4 \longrightarrow 2\overset{+2}{N}O + 6H^+ + 4e^-)\ 3$

$(6H^+ + 6e^- + \overset{+5}{Cl}O_3^- \longrightarrow Cl^- + 6e^- + 3H_2O)\ 2$

$6H_2O + 3N_2H_4 \longrightarrow 6NO + 24H^+ + 12e^-$

$12H^+ + 12e^- + 2ClO_3^- \longrightarrow 2Cl^- + 6H_2O$

$3N_2H_4 + 2ClO_3^- \rightarrow 6NO + 2Cl^- + 12H^+$