Redox Reactions

Oxidation → It is defined as addition of oxygen, electronegative element to substance or removal of hydrogen / electropositive element from a substance.

For eg →

$2Mg + O_2 \longrightarrow 2MgO$

$2H_2S + O_2 \longrightarrow 2S + 2H_2O$

Reduction → It is defined as the removal of oxygen / electronegative element from a substance or addition of hydrogen / electropositive element to a substance

For eg →

$2HgO \xrightarrow{\Delta} 2Hg + O_2$

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

Redox Reactions → The reaction that involve oxidation & reduction as its two half reactions are called Redox reaction.

For eg →

Oxidation

$2HgCl_2 + SnCl_2 \longrightarrow Hg_2Cl_2 + SnCl_4$

Reduction

#	Reduction	Oxidation
→	Gain of Hydrogen	→ Loss of Hydrogen
→	Loss of Oxygen	→ Gain of Oxygen
→	Loss of any electronegative atom	→ Gain of any electronegative atom
→	Gain of any electropositive atom.	→ Loss of any electropositive atom
→	It is gain of electrons	→ It is loss of electrons
Eg →	$CuO_{(s)} \longrightarrow Cu_{(s)} + \frac{1}{2}O_{2(g)}$	Eg → $Zn_{(s)} + \frac{1}{2}O_{2(g)} \longrightarrow ZnO_{(aq)}$

Oxidation Number or Oxidation state :-

Charge carried by any atom or group of atoms in its free state is called "Oxidation state" or combining

Radicle	Oxidation number
Na	0
Na^+	+1
Cl_2	0
Cl^-	-1
CH_4	-1
H_2	0
H^+	+1
NH_4^+	+1
NO_3^-	-1
CO_3^{--}	-2
SO_4^{--}	-2
O_2	0
O^{--}	-2
Al^{+++}	+3
BO_3^{---}	-2
BH_3	0
Br^-	-1
Fe^{++}	+2
I_2	0

Important points of oxidation state :-

→ Oxidation number of group-1 metals is +1.

→ Oxidation number of group-2 metals is +2

→ Oxidation number of halogens is -1.

→ Oxidation number of inert gases is 0.

→ Oxidation number of all molecules is 0.

* Calculation of Oxidation number

① NaH_2PO_4

$\Rightarrow 1+2+n-8=0$

$\Rightarrow -5+n=0$

$\Rightarrow n=+5$

So, Oxidation number of P is +5

(2) $NaHSO_4$

$\Rightarrow 1+1+x-8=0$
$\Rightarrow -6+x=0$
$\Rightarrow x=+6$

So, oxidation number of 'S' is +6

(3) $H_4P_2O_7$

$\Rightarrow 4+2x-14=0$
$\Rightarrow -10+2x=0$
$\Rightarrow 2x=+10$
$\Rightarrow x=+5$

So, oxidation state of 'P' is +5

(4) K_2MnO_4

$\Rightarrow 2+x-8=0$
$\Rightarrow x-6=0$
$\Rightarrow x=+6$

So, oxidation state of Mn is +6

(5) $NaBH_4$

$\Rightarrow 1+x+4=0$
$\Rightarrow x+5=0$
$\Rightarrow x=-5$

So, oxidation state of 'B' is -5

Types of Redox Reactions →

(1) Combination Reaction → A combination reaction may be denoted in the manner:

$$A+B \longrightarrow C$$

Either A or B or both A & B is must of elemental form to be a redox reaction

Eg → $\overset{0}{C}_{(s)} + \overset{0}{O}_{2(g)} \longrightarrow \overset{+4\ -2}{CO_2}_{(g)}$

$3\,\overset{0}{Mg}_{(s)} + \overset{0}{N}_{2(g)} \longrightarrow \overset{+2\ \ -3}{Mg_3N_2}$

(2) Decomposition Reaction → Decomposition reactions are the opposite of combination reactions. It leads to the breakdown of compound in two or more components.

Eg → $2\,\overset{+1\ -2}{H_2O}_{(l)} \xrightarrow{\Delta} 2\,\overset{0}{H}_{2(g)} + \overset{0}{O}_{2(g)}$

③ Displacement reaction → In a displacement reaction, an ion (or an atom) in a compound is replaced by an ion (or an atom). It may be denoted as :

$$X + YZ \longrightarrow XZ + Y$$

$$\overset{+2\ +6\ -2}{CuSO_4} + \overset{0}{Zn} \longrightarrow \overset{+2\ +6\ -2}{ZnSO_4} + \overset{0}{Cu}$$

$$\overset{0}{2Na} + \overset{+1\ -2}{2H_2O} \longrightarrow \overset{+1\ -2\ +1}{2NaOH} + \overset{0}{H_2}$$

④ Disproportionation reaction → Such reactions in which same object is oxidized & reduced both simultaneously is called Disproportionation reaction.

$$\overset{+1\ -1}{2H_2O_2} \longrightarrow \overset{+1\ -2}{2H_2O} + \overset{0}{O_2}$$

Balancing of Redox Reactions :-

There are two methods of balancing the chemical equation

① Oxidation number method (for all type of reaction.)

② Ion-electron method. (only for ionic reactions)

☆ Oxidation Number Method ⇒

Following are main steps →

ⓐ Write down the oxidation no. of all the elements present in given reaction per atom.

ⓑ Identify whose oxidation no. is changing & break the given reaction in two half reactions — Oxidation half reaction (OHR) & Reduction Half reaction.

ⓒ Balance the atom whose oxidation no. is changing.

ⓓ Calculate net change in oxidation state in both half reactions individually.

ⓔ Balance the net change in oxidation state b/w both half reactions.

(f) Add the two half reactions

(g) Balance oxygen according to medium. Method of balancing is same in acidic & neutral

For eg → Balance the reactions

(1) $Cr_2O_{7(aq.)}^{2-} + SO_{3(aq.)}^{2-} \longrightarrow Cr_{(aq.)}^{3+} + SO_{4(aq.)}^{2-}$

$\Rightarrow$ $\overset{+6\ -2}{Cr_2O_7^{2-}} + \overset{+4\ -2}{SO_3^{2-}} \longrightarrow \overset{+3}{Cr^{3+}} + \overset{+6\ -2}{SO_4^{2-}}$

→ O·H·R. | R·H·R

$\overset{+4}{SO_3^{2-}} \longrightarrow \overset{+6}{SO_4^{2-}}$ | $\overset{+6}{Cr_2O_7^{2-}} \longrightarrow \overset{+3}{Cr^{3+}}$

→ O·H·R. | R·H·R.

$\overset{+4}{SO_3^{2-}} \longrightarrow \overset{+6}{SO_4^{2-}}$ | $\overset{+6}{Cr_2O_7^{2-}} \longrightarrow \overset{+6}{2Cr^{3+}}$

→ O·H·R. | R·H·R.

$3\,SO_3^{2-} \longrightarrow 3\,SO_4^{2-}$ | $Cr_2O_7^{2-} \longrightarrow 2Cr^{3+}$

$+4 \longrightarrow +6$ | $+12 \longrightarrow +6$

→ $Cr_2O_7^{2-} + 3SO_3^{2-} \longrightarrow 3SO_4^{2-} + 2Cr^{3+}$

→ $Cr_2O_7^{2-} + 3SO_3^{2-} + 12H^+ \longrightarrow 3SO_4^{2-} + 2Cr^{3+} + 6H_2O$

(2) $Cl_2O_7 + H_2O_2 \longrightarrow ClO_2^- + O_2$

→ $\overset{+7\ -2}{Cl_2O_{7(aq.)}} + \overset{+1\ -1}{H_2O_{2(aq.)}} \longrightarrow \overset{+3\ -2}{ClO_{2(aq.)}^-} + \overset{0}{O_2}$

→ O·H·R. | R·H·R.

$\overset{-1}{H_2O_2} \longrightarrow \overset{0}{O_2}$ | $\overset{+7}{Cl_2O_7} \longrightarrow \overset{+3}{ClO_2^-}$

→ O·H·R. | R·H·R.

$\overset{-1}{H_2O_2} \longrightarrow \overset{0}{O_2}$ | $\overset{+7}{Cl_2O_7} \longrightarrow \overset{+6}{2ClO_2^-}$

HW O·H·R. | R·H·R.

→ $H_2O_2 + Cl_2O_7 \longrightarrow O_2 + 2ClO_2^-$

→ $H_2O_2 + Cl_2O_7 + 3H_2O \longrightarrow O_2 + 2ClO_2^- + 6OH^-$

→ $H_2O_2 + Cl_2O_7 + 3H_2O + 2OH^- \rightarrow O_2 + 2ClO_2^- + 6OH^- + 2H$

→ $H_2O_2 + Cl_2O_7 + H_2O \longrightarrow O_2 + 2ClO_2^- + 4OH^-$

☆ Ion-electron method →

Following are main steps →

(a) Write down oxidation no. of all elements of given reaction per atom.

(b) Identify the change in oxidation no. & break the reaction in Oxidation half reaction (O.H.R) & Reduction half reaction (R.H.R).

(c) Balance the atom whose oxidation no. is changing.

(d) Balance oxygen according to medium.

(e) Balance hydrogen according to medium.

(f) Balance charge. Charge will be balanced with no. of electrons only.

(g) Balance electron of both half reactions.

(h) Add the two half reactions.

For eg → Balance the reactions :-

(1) $NO_{3(aq)}^- + Bi_{(s)} \longrightarrow Bi^{3+}_{(aq)} + NO_{2(g)}$

⇒ $\overset{+5\ -2}{NO_3^-} + \overset{0}{Bi} \longrightarrow \overset{+3}{Bi^{3+}} + \overset{+4\ -2}{NO_2}$

→

O.H.R.	R.H.R.
$\overset{0}{Bi} \longrightarrow \overset{+3}{Bi^{3+}}$	$\overset{+5}{NO_3^-} \longrightarrow \overset{+4}{NO_2}$

→

O.H.R.	R.H.R.
$\overset{0}{Bi} \longrightarrow \overset{+3}{Bi^{3+}}$	$2H^+ + NO_3^- \rightarrow NO_2 + H_2O$

→

O.H.R.	R.H.R.
$Bi \longrightarrow Bi^{3+} + 3e^-$ $0 \quad = \quad 0$	$2H^+ + NO_3^- + e^- \rightarrow NO_2 + H_2O$ $0 = 0$

→ O·H·R. | R·H·R.

$Bi \longrightarrow Bi^{3+} + 3e^-$ | $3e^- + 6H^+ + 3NO_3^- \longrightarrow 3NO_2 + 3H_2O$

O = O

→ $Bi + 3e^- + 6H^+ + 3NO_3^- \longrightarrow Bi^{3+} + 3e^- + 3NO_2 + 3H_2O$

→ $Bi + 6H^+ + 3NO_3^- \longrightarrow Bi^{3+} + 3NO_2 + 3H_2O$

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

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

+6 −2 +2 +3 +3

→ O·H·R. | R·H·R.

~~$Fe^{2+}/O_2^{2-}/H^+/H_2O$~~

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

+2 +3 | +6 −2 +3

→ O·H·R. | R·H·R.

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

+2 +3 | +6 +3

→ O·H·R. | R·H·R.

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

+2 +3

→ O·H·R. | R·H·R

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

+2 = +2

→ O·H·R. | R·H·R.

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

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

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