# BALANCING OF REDOX REACTIONS

(a) Oxidation number change method
(b) Ion electron method

## (a) Oxidation number change method:

This approach was introduced by Johnson. In a well-balanced redox reaction, the overall increases in oxidation numbers should be equivalent to the overall decreases in oxidation numbers. This equivalence serves as the foundation for the balancing of redox reactions.

(i) Choose the atom within the oxidizing agent whose oxidation number diminishes, and specify the acquisition of electrons.
(ii) Select the atom in the reducing agent where the oxidation number rises, and signify the loss of electrons.
(iii) Then, perform a cross-multiplication. In other words, multiply the oxidizing agent by the number of electrons lost and the reducing agent by the number of electrons gained.
(iv) Achieve balance by adjusting the quantity of atoms on both sides that experience alterations in their oxidation numbers during the reaction.
(v) In order to balance oxygen atoms, and $H_2O$ molecules to the side deficient in oxygen.
(vi) Then balance the number of H atoms by adding $H^+$ ions to the side deficient in hydrogen.

**Example:** Balance the following reaction by oxidation number method?

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

**Solution:** Writer the oxidation number of all the atoms

$$0 + 1 + 5 + 2 + 2 + 5 - 2 + 4 - 2 + 1 - 2$$

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

There is change in oxidation number of Cu and N.

$$0 + 2\ Cu \rightarrow Cu(NO_3)_2 \quad .....(1)$$

(Oxidation no. is increased by 2)

$$+ 5 + 4\ HNO_3 \rightarrow NO_2 \quad .....(2)$$

(Oxidation no. is decreased by 1)

To make increases and decrease equal, eq. (2) is multiplied by 2.

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

Balancing nitrates ions, hydrogen and oxygen, the following equation is obtained.

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

This is the balanced equation

**Example:** Balance the following reaction by the oxidation number method

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

**Solution:** Write the oxidation number of all the atoms.

$$+ 7 - 2\ MnO_4^- + Fe^{+2} \longrightarrow Mn^{+2} + Fe^{+3}$$

Change in oxidation number has occurred in Mn and Fe

$$+ 7\ MnO_4^- \rightarrow \quad .....(1)$$

(Decrement in oxidation no. by 5)

$$Fe^{+2} \rightarrow Fe^{+3} \quad .....(2)$$

(Increment in oxidation no. by 1)

To make increase and decrease equal, eq. (2) is multiplied by 5.

$$MnO_4^- + 5Fe^{+2} \rightarrow Mn^{+2} + 5Fe^{+3}$$

To balance oxygen, $4H_2O$ are added to R.H.S. and to balance hydrogen, $8H^+$ are added to L.H.S.

$$MnO_4^- + 5Fe^{+2} + 8H^+ \rightarrow Mn^{+2} + 5Fe^{+3} + 4H_2O$$

This is the balanced equation

## (b) Ion-Electron method:

This technique was introduced by Jette and La Mew in the year 1972.

The following steps are followed while balancing redox reaction (equations) by this method.

(i) Express the equation in its ionic form.

(ii) Divide the redox equation into two separate half-reactions, one illustrating the process of oxidation and the other depicting reduction.

(iii) Balance these individual half-reactions independently, and subsequently combine them by applying appropriate coefficients to ensure the cancellation of electrons.

Balancing is done using following sub steps.

(a) Achieve balance for all atoms other than hydrogen (H) and oxygen (O).

(b) Afterward, balance the oxygen atoms by introducing $H_2O$ molecules to the side that lacks oxygen. The quantity of $H_2O$ molecules added should correspond to the deficit in the number of oxygen atoms.

(c) Next, balance the hydrogen atoms by incorporating $H^+$ ions in an amount equivalent to the deficit on the side that lacks hydrogen atoms.

(d) Balance the overall charge by including electrons on the side that possesses a positive charge, i.e., the side deficient in electrons. The number of electrons added should match the deficit.

(e) Finally, modify the half-equations as needed by applying appropriate coefficients, ensuring that the equations are balanced.

(iv) Combine these half-equations to produce an equation that is balanced in terms of both charge and atoms.

(v) In cases where the reaction medium is basic, introduce $OH^-$ ions to both sides of the balanced equation. The quantity of $OH^-$ ions added should be equal to the number of H+ ions in the balanced equation.

### Example:

### (A) Acidic Medium

(a) $$Cr_2O_7^{2-} + C_2O_4^{2-} \longrightarrow Cr^{3+} + CO_2$$

(b) Write both the half reaction

$$Cr_2O_7^{2-} \rightarrow Cr^{3+} \quad \text{[Reduction half reaction]}$$

$$C_2O_4^{2-} \rightarrow CO_2 \quad \text{[Oxidation half reaction]}$$

(c) Atoms other than H and O are balanced.

$$Cr_2O_7^{2-} \rightarrow 2Cr^{3+}$$

$$C_2O_4^{2-} \rightarrow 2CO_2$$

(d) Balance O-atoms by the addition of $H_2O$ to another side

$$Cr_2O_7^{2-} \rightarrow 2Cr^{3+} + 7H_2O$$

$$C_2O_4^{2-} \rightarrow CO_2$$

(e) Balance H-atoms by the addition of $H^+$ to another side

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

$$C_2O_4^{2-} \rightarrow 2CO_2$$

(f) Now balance the charge by the addition of electron ($e^-$)

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O \quad ..(1)$$

$$C_2O_4^{2-} \rightarrow 2CO_2 + 2e^- \quad ..(2)$$

(g) Multiply the equations by a suitable constant factor to ensure an equal number of electrons on both sides. In the given scenario, the second equation is multiplied by a factor of 3 and subsequently added to the first equation.

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O \quad ..(1)$$

$$3C_2O_4^{2-} \rightarrow 6CO_2 + 6e^-$$

$$Cr_2O_7^{2-} + 3C_2O_4^{2-} + 14\,H^+ \rightarrow 2Cr^{3+} + 6CO_2 + 7H_2O$$

## (B) Alkaline Medium

(a) Consider the reaction

$$Cr(OH)_3 + IO_3^- \xrightarrow{OH^-} I^- + CrO_4^{2-}$$

(b) Separate the two half reactions

$Cr(OH)_3 \rightarrow CrO_4^{2-}$ (Oxidation half reaction )

$IO_3^- \rightarrow I^-$ (Reduction half reaction)

(c) Balance O-atoms by adding $H_2O$.

$$H_2O + Cr\,(OH)_3 \rightarrow CrO_4^{2-}$$

$$IO_3^- \rightarrow I^- + 3H_2O$$

(d) Balance H-atoms by adding $H^+$ to side having deficiency and add equal no. of $OH^-$ ions to the side ($\because$ medium is known)

$$H_2O + Cr\,(OH)_3 \rightarrow CrO_4^{-2} + 5H^+$$

$$5OH^- + H_2O + Cr(OH)_3 \rightarrow CrO_4^{2-} + 5H^+ + 5OH^-$$

or $5OH^- + Cr(OH)_3 \rightarrow CrO_4^{2-} + 4H_2O$

$$IO_3^- + 6H^+ \longrightarrow I^- + 3H_2O$$

$$IO_3^- + 6H^+ + 6OH^- \longrightarrow I^- + 3H_2O + 6OH^-$$

$$IO_3^- + 3H_2O \longrightarrow I^- + 6OH^-$$

(e) Balance the charges by adding electrons

$$5OH^- + Cr(OH)_3 \longrightarrow CrO_4^{2-} + 4H_2O + 3e^-$$

$$IO_3^- + 6H_2O + 6e^- \longrightarrow I^- + 3H_2O + 6OH^-$$

(f) Multiply first equation by 2 and add to second to give

$$10OH^- + 2Cr(OH)_3 \longrightarrow 2CrO_4^{2-} + 8H_2O + 6e^-$$

$$IO_3^- + 6H_2O + 6e^- \longrightarrow I^- + 3H_2O + 6OH^-$$

Add their balanced half reaction to give complete balanced reaction.

$$4OH^- + 2Cr(OH)_3 + IO_3^- \rightarrow 5H_2O + 2CrO_4^{2-} + I^-$$