Balancing Oxidation-Reduction Equations

Balancing the redox equations requires a special technique known as *ion-electron method that* involves the following approach:

- The overall given equation is first divided into two half-reactions, one for oxidation and one for reduction.
- The equations for half-reactions are balanced separately; first balance atoms, then use H_2O to balance O atoms, and finally use H^+ ions to balance H atoms in the water.
- Next balance the charges.
- Make the number of electrons lost in oxidation half-reaction equal number of electrons gained in reduction reaction.
- Add both half-equations and cancel the electrons that appear on both sides of the equation.
- If balancing in basic medium is required, neutralize the H^+ ions using OH^- ions forming H_2O molecules.
- If the water molecules appear on both sides of the equations, move them to one side.

Example

Balance the following redox equation in **acidic medium**

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

Answer

Step 1. Separate the above equation into two half-equations.

$Fe^{+2} \rightarrow Fe^{+3}$ oxidation half-reaction
$Cr_2O_7^{-2} \rightarrow Cr^{+3}$ reduction half-reaction

Step 2. First balance oxidation half-reaction.

Since there are equal numbers of Fe atoms on both sides, there is no need to balance Fe atoms. Only charges have to be balanced. Since Fe^{+2} becomes F^{+3}, it is losing one electron. Add one electron on the product side.

$$Fe^{+2} \rightarrow Fe^{+3} + e^- \qquad (1)$$

This equation is balanced in terms of atoms as well as charges.

Step 3. Balance the reduction half-reaction.

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

There are unequal numbers of Cr as well as O atoms; they have to be balanced first. There are two Cr atoms on the left side, write 2 in front of Cr^{+3} on the right-side to make two Cr atoms.

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

There are seven O atoms on the left-side. Add seven H_2O molecules on the right-side to balance O atoms.

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

Balance 14 H atoms appearing in water molecules by adding 14 H^+ on left-side of the equation.

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

Now balance the charges. There are net 12 positive charges on the left-side and net 6 positive charges on the right-side. Add $6e^-$ on the left-side to balance charges.

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

Step 4. Make the number electrons lost equal to number of electrons gained.

Comparing balanced half-equations (1) and (2), it is clear one electron is lost in oxidation reaction (Equation(1)) and six electrons are gained in reduction reaction(Equation(2)). But in reality, **the number of electrons lost must be equal to number of electrons gained.** Therefore, multiply the entire equation (1) by 6.

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

$$6\ Fe^{+2} \rightarrow 6\ Fe^{+3} + 6e^- \qquad (3)$$

Step 5. Add equations (2) and (3).

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

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

NOTE: When you add two half-equations, make sure you add reactants together and products together as is done here.

Now cancel the electrons appearing on both sides yielding the final balanced equation in acidic medium.

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

IMPORTANT: This reaction is in acidic medium because free protons (H^+) appear as a part of the balanced equation.

Step 6. Verify that the balanced equation contains equal number of atoms of each type on both sides and also exactly the same charge on both sides.

Example

Balance the following equation in **basic medium**.

$$MnO_4^- + I^- \rightarrow MnO_2 + I_2$$

Answer

Step 1. Break the above given equation into two half-equations.

$$\overset{-1}{I^-} \longrightarrow \overset{0}{I_2} \qquad \text{oidation half-reaction}$$

$$\overset{+7}{Mn}O_4^- \longrightarrow \overset{+4}{Mn}O_2 \qquad \text{reduction half-reaction}$$

Step 2. Balance both half-reactions.

Oxidation half-reaction: There is one I atom on the left-side and two I atoms on the right-side. Hence, I atoms have to be balanced by writing 2 front of I^- on the left-side.

$$2\ I^- \rightarrow I_2$$

Now balance the charges by adding two electrons on the right-side.

$$2\ I^- \rightarrow I_2 + 2e^- \qquad (1)$$

Reduction half-reaction: There are four O atoms on the left-side and two O atoms on the right-side. So, add $2H_2O$ molecules on the right-side to balance O atoms.

$$MnO_4^- \rightarrow MnO_2 + 2H_2O$$

Now balance H atoms in H_2O molecules by adding $4H^+$ on the left-side.

$$MnO_4^- + 4H^+ \rightarrow MnO_2 + 2H_2O$$

Balance the charges by adding 3 electrons on the left-side.

$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$ (2)

Step 3. Make number electrons lost equal to number of electrons gained by multiplying equation (1) by 3 and equation (2) by 2. And add them up.

$3(2\ I^- \rightarrow I_2 + 2e^-)$
$2(MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O)$

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

Step 4. Cancel electrons and rewrite the equation as the final balanced equation.

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

Step 5. This balanced equation is in acidic medium as it contains H^+ ions. However, the problem calls for balancing in basic medium. To do that, every H^+ ion must be neutralized by OH^- ion by adding eight OH^- on both sides.

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

Finally, combining the H^+ and OH^- ions to form eight water molecules (one H^+ and one OH^- gives one water molecule).

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

Water molecules appear on both sides of the equation. As a further simplification, move the water molecules to one side. Thus, the final equation takes the following form.

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

Since this equation contains free OH^- ions, it can be considered as the reaction in basic medium.

Things to Remember: If the problem calls for balancing in basic medium, first you balance the equation as if you are balancing in acidic medium and then cancel every H^+ ion by using equal number of OH^- ions.