MANIDHANAEYAM FREE IAS ACADEMY – TNPSC GROUP II & IIA

UNIT - I

Chemistry - Oxidation and Reduction

1. OXIDATION, REDUCTION AND REDOX REACTIONS (6 Marks)

When an apple is cut and left for sometimes, its surface turns brown. Similarly, iron bolts and nuts in metallic structures get rusted. Do you know why these are happening? It is because of a reaction called oxidation.

Oxidation: The chemical reaction which involves addition of oxygen or removal of hydrogen or loss of electrons is called oxidation.

$2\,Mg + O_2 \rightarrow 2\,MgO$ (addition of oxygen)
$CaH_2 \rightarrow Ca + H_2$ (removal of hydrogen)
$Fe^{2+} \rightarrow Fe^{3+} + e^-$ (loss of electron)

Reduction: The chemical reaction which involves addition of hydrogen or removal of oxygen or gain of electrons is called reduction.

$2\,Na + H_2 \rightarrow 2\,NaH$ (addition of hydrogen)
$CuO + H_2 \rightarrow Cu + H_2O$ (removal of oxygen)
$Fe^{3+} + e^- \rightarrow Fe^{2+}$ (gain of electron)

Redox reactions: Generally, the oxidation and reduction occurs in the same reaction (simultaneously). If one reactant gets oxidised, the other gets reduced. Such reactions are called oxidation-reduction reactions or Redox reactions.

$$2\,PbO + C \rightarrow 2\,Pb + CO_2$$
$$Zn + CuSO_4 \rightarrow Cu + ZnSO_4$$

Oxidation	Addition of oxygen
	Removal of hydrogen
	Loss of electron
Reduction	Removal of oxygen
	Addition of hydrogen
	Gain of electron

OXIDISING AGENTS AND REDUCING AGENTS

Substances which have the ability to oxidise other substances are called oxidising agents. These are also called as electron acceptors because they remove electrons from other substances.

Example: H_2O_2, MnO_4^-, CrO_3, $Cr_2O_7^{2-}$

Substances which have the ability to reduce other substances are called Reducing agents. These are also called as electron donors because they donate electrons to other substances.

Example: $NaBH_4$, $LiAlH_4$ and metals like Palladium, Platinum.

2. OXIDATION REACTIONS IN DAILY LIFE: (6 Marks)

In nature, the oxygen present in atmospheric air oxidises many things, starting from metals to living tissues.

- The shining surface of metals tarnishes due to the formation of respective metal oxides on their surfaces. This is called corrosion.
- The freshly cut surfaces of vegetables and fruits turn brown after some time because of the oxidation of compounds present in them.
- The oxidation reaction in food materials that were left open for a long period is responsible for spoiling of food. This is called Rancidity.

3. OXIDATION NUMBER (12 Marks)

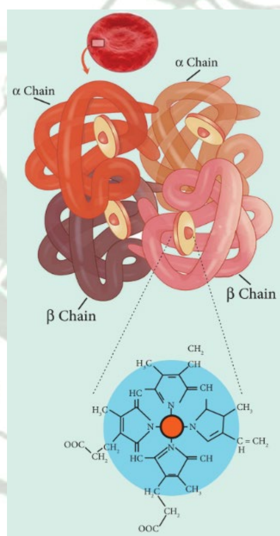
Oxidation number of an element is defined as the total number of electrons that an atom either gains or loses in order to form a chemical bond with another atom. Oxidation number is also called oxidation state. If the oxidation number is positive then it means that the atom loses electron, and if it is negative it means that the atom gains electrons. If it is zero then the atom neither gains nor loses electrons. The sum of oxidation numbers of all the atoms in the formula for a neutral compound is ZERO. The sum of oxidation numbers of an ion is the same as the charge on that ion. Negative oxidation number in a compound of two unlike atoms is assigned to the more electronegative atom.

Example:

- Oxidation number of K and Br in KBr molecule is +1 and –1 respectively.
- Oxidation number of N in NH3 molecule is –3.
- Oxidation number of H is +1 (except hydrides).
- Oxidation number of oxygen in most cases is –2.

4. HAEMOGLOBIN AND OXYGEN TRANSPORT

- ✓ Even a small amount of oxygen present in air leads to the rusting of iron, i.e. iron is oxidised to Fe3+. But the Fe2+ present in haemoglobin which binds oxygen during transport of oxygen from lungs to tissues never gets oxidised. Do you know why?
- ✓ The answer lies in the structural features of haemoglobin. Haemoglobin contains four sub units each with a porphyrin ring (heme) attached to the protein (globin) molecule. In this structure, the iron (Fe^{2+}) forms a co-ordination complex with an octahedral geometry. The four positions of the octahedron are occupied by porphyrin rings, fifth position is filled by imidazole ring of a histidine residue and the sixth position is utilized for binding the oxygen molecule. Generally the Fe^{2+} in heme is susceptible to oxidation. Since the Fe^{2+} ion in haemoglobin is surrounded by the globin protein chain that provides a hydrophobic environment, the oxidation of Fe^{2+} becomes difficult. However, 3% of haemoglobin is oxidised to methemoglobin (haemoglobin where the iron is present in Fe^{3+} state and oxygen does not bind to this) daily. The enzyme methemoglobin reductase reduces it back to haemoglobin.



Cyanide poisoning: While oxygen binds reversibly to haemoglobin, cyanide binds irreversibly to haemoglobin and blocks oxygen binding. As a result the transport of oxygen from the lungs to tissues is stopped. It leads to the quick death of the person.

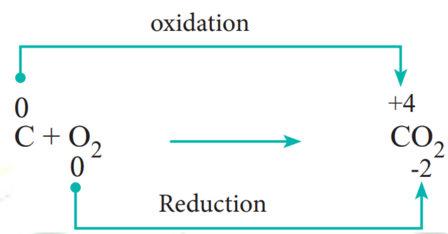
5. TYPES OF REDOX REACTIONS (15 Marks)

Redox reactions are classified into the following types.

1. Combination reactions:

Redox reactions in which two substances combine to form a single compound are called combination reaction.

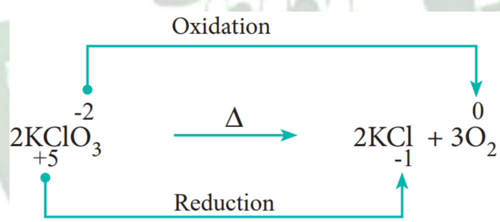
Example:



2. Decomposition reactions:

Redox reactions in which a compound breaks down into two or more components are called decomposition reactions. These reactions are opposite to combination reactions. In these reactions, the oxidation number of the different elements in the same substance is changed.

Example:



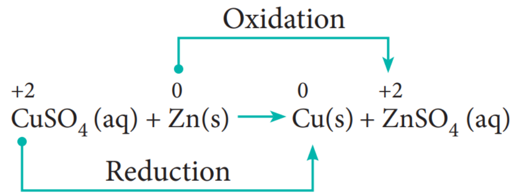
3. Displacement reactions:

Redox reactions in which an ion (or an atom) in a compound is replaced by an ion (or atom) of another element are called displacement reactions. They are further classified into (i) metal displacement reactions (ii) non-metal displacement reactions.

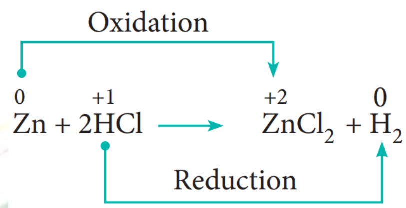
(i) Metal displacement reactions:

Place a zinc metal strip in an aqueous copper sulphate solution taken in a beaker. Observe the solution, the intensity of blue colour of the solution slowly reduced and finally disappeared.

The zinc metal strip became coated with brownish metallic copper. This is due to the following metal displacement reaction.



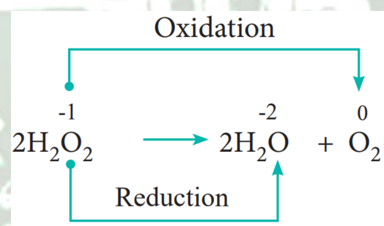
ii) Non-metal displacement

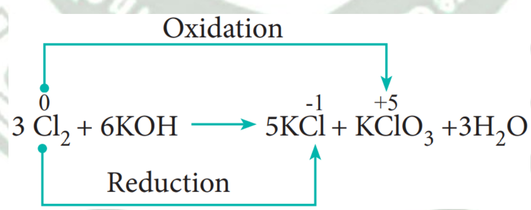


4. Disproportionation reaction (Auto redox reactions)

In some redox reactions, the same compound can undergo both oxidation and reduction. In such reactions, the oxidation state of one and the same element is both increased and decreased. These reactions are called disproportionation reactions.

Examples:

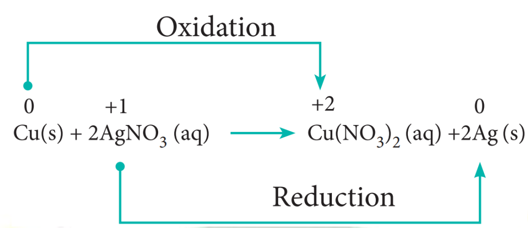




5. Competitive electron transfer reaction

In metal displacement reactions, we learnt that zinc replaces copper from copper sulphate solution. Let us examine whether the reverse reaction takes place or not. As discussed earlier, place a metallic copper strip in zinc sulphate solution. If copper replaces zinc from zinc sulphate solution, Cu^{2+} ions would be released into the solution and the colour of the solution would change to blue. But no such change is observed. Therefore, we conclude that among zinc and copper, zinc has more tendency to release electrons and copper to accept the electrons.

Let us extend the reaction to copper metal and silver nitrate solution. Place a strip of metallic copper in sliver nitrate solution taken in a beaker. After some time, the solution slowly turns blue. This is due to the formation of Cu^{2+} ions, i.e. copper replaces silver from silver nitrate. The reaction is,



It indicates that between copper and silver, copper has the tendency to release electrons and silver to accept electrons.

From the above experimental observations, we can conclude that among the three metals, namely, zinc, copper and silver, the electron releasing tendency is in the following order.

Zinc > Copper > Silver

This kind of competition for electrons among various metals helps us to design (galvanic) cells. In XII standard we will study the galvanic cell in detail.

6. GASTRIC ACID AND ANTACIDS

Antacids are commonly used medicines for treating heartburn and acidity. Do you know the chemistry behind it?

Gastric acid is a digestive fluid formed in the stomach and it contains hydrochloric acid. The typical concentration of the acid in gastric acid is 0.082 M. When the concentration exceeds 0.1 M it causes the heartburn and acidity.

Antacids used to treat acidity contain mostly magnesium hydroxide or aluminium hydroxide that neutralises the excess acid. The chemical reactions are as follows.

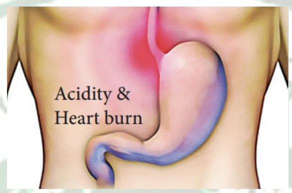
$$3\ HCl + Al(OH)_3 \rightarrow AlCl_3 + 3\ H_2O$$

$$2\ HCl + Mg(OH)_2 \rightarrow MgCl_2 + 2\ H_2O$$

From the above reactions we know that 1 mole of aluminium hydroxide neutralises 3 moles of HCl while 1 mole of magnesium hydroxide neutralises 2 moles of HCl.

Let us calculate the amount of acid neutralised by an antacid that contains 250 mg of aluminium hydroxide and 250 mg of magnesium hydroxide.

Active Compound	Mass in (mg)	Molecular mass (g mol-1)	No. of moles of active compound	No. of moles OH^-
$Al(OH)_3$	250	78	0.0032	0.0096
$Mg(OH)_2$	250	58	0.0043	0.0086
Total no. of moles of OH^- ion from one tablet				0.0182



One tablet of above composition will neutralise 0.0182 mole of HCl for a person with gastric acid content of 0.1 mole. One tablet can be used to neutralize the excess acid which will bring the concentration back to normal level. (0.1 – 0.018 = 0.082 M)

7. PROBLEMS ON DETERMINATION OF OXIDATION NUMBER (6 Marks)

ON (Oxidation Number) of neutral molecule is always zero

Illustration 1

Oxidation Number of H and O in H_2O

Let us take ON of H = +1 and ON of O = −2

$2 \times (+1) + 1 \times (-2) = 0$

$(+2) + (-2) = 0$

Thus, ON of H is +1 and ON of O is −2

Illustration 2

Oxidation Number of S in H_2SO_4

Let ON of S be x and we know ON of H = +1 and O = −2

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

$(+2) + x + (-8) = 0$

x = +6 Therefore, ON of S is +6

Illustration 3

Oxidation Number of Cr in $K_2 Cr_2 O_7$

Let ON of Cr be x and we know ON of K = +1 and O = –2

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

$(+2) + 2x + (-14) = 0$

$2x = +12$

$x = +6$ Therefore, ON of Cr in $K_2 Cr_2 O_7$ is +6

Illustration 4

Oxidation Number of Fe in $FeSO_4$

Let ON of Fe be x and we know ON of S = +6 and O = –2

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

$x + (+6) + (-8) = 0$

$x = +2$ Therefore, ON of Fe in $FeSO_4$ is +2

Problems:

1. Find the oxidation number of Mn in $KMnO_4$
2. Find the oxidation number of Cr in $Na_2 Cr_2 O_7$
3. Find the oxidation number of Cu in $CuSO_4$
4. Find the oxidation number of Fe in FeO