Group	1	2	13	14	15	16	17
Element	Na	Mg	Al	Si	P	S	Cl
Compound	NaCl	$MgSO_4$	AlF_3	$SiCl_4$	P_4O_{10}	SF_6	$HClO_4$
Highest oxidation number state of the group element	+1	+2	+3	+4	+5	+6	+7

The oxidation number/state of a metal in a compound is sometimes presented according to the notation given by German chemist, Alfred Stock. It is popularly known as **Stock notation.** According to this, the oxidation number is expressed by putting a Roman numeral representing the oxidation number in parenthesis after the symbol of the metal in the molecular formula. Thus aurous chloride and auric chloride are written as Au(I)Cl and Au(III)Cl_3. Similarly, stannous chloride and stannic chloride are written as Sn(II)Cl_2 and Sn(IV)Cl_4. This change in oxidation number implies change in oxidation state, which in turn helps to identify whether the species is present in oxidised form or reduced form. Thus, Hg_2(I)Cl_2 is the reduced form of Hg(II) Cl_2.

Problem 8.3

Using Stock notation, represent the following compounds :$HAuCl_4$, Tl_2O, FeO, Fe_2O_3, CuI, CuO, MnO and MnO_2.

Solution

By applying various rules of calculating the oxidation number of the desired element in a compound, the oxidation number of each metallic element in its compound is as follows:

$HAuCl_4$ → Au has 3
Tl_2O → Tl has 1
FeO → Fe has 2
Fe_2O_3 → Fe has 3
CuI → Cu has 1
CuO → Cu has 2
MnO → Mn has 2
MnO_2 → Mn has 4

Therefore, these compounds may be represented as:

HAu(III)Cl_4, Tl_2(I)O, Fe(II)O, Fe_2(III)O_3, Cu(I)I, Cu(II)O, Mn(II)O, Mn(IV)O_2.

The idea of oxidation number has been invariably applied to define oxidation, reduction, oxidising agent (oxidant), reducing agent (reductant) and the redox reaction. To summarise, we may say that:

Oxidation: An increase in the oxidation number of the element in the given substance.

Reduction: A decrease in the oxidation number of the element in the given substance.

Oxidising agent: A reagent which can increase the oxidation number of an element in a given substance. These reagents are called as **oxidants** also.

Reducing agent: A reagent which lowers the oxidation number of an element in a given substance. These reagents are also called as **reductants**.

Redox reactions: Reactions which involve change in oxidation number of the interacting species.

Problem 8.4

Justify that the reaction:

$$2Cu_2O(s) + Cu_2S(s) \rightarrow 6Cu(s) + SO_2(g)$$

is a redox reaction. Identify the species oxidised/reduced, which acts as an oxidant and which acts as a reductant.

Solution

Let us assign oxidation number to each of the species in the reaction under examination. This results into:

$$2\overset{+1}{Cu_2}\overset{-2}{O}(s) + \overset{+1}{Cu_2}\overset{-2}{S}(s) \rightarrow 6\overset{0}{Cu}(s) + \overset{+4}{S}\overset{-2}{O_2}$$

We therefore, conclude that in this reaction *copper is reduced* from +1 state to zero oxidation state and *sulphur is oxidised* from –2 state to +4 state. The above reaction is thus a *redox reaction*.

Further, Cu_2O helps sulphur in Cu_2S to increase its oxidation number, therefore, Cu(I) is an oxidant; and sulphur of Cu_2S helps copper both in Cu_2S itself and Cu_2O to decrease its oxidation number; therefore, sulphur of Cu_2S is reductant.

8.3.1 Types of Redox Reactions

1. Combination reactions

A combination reaction may be denoted in the manner:

$$A + B \rightarrow C$$

Either A and B or both A and B must be in the elemental form for such a reaction to be a redox reaction. All combustion reactions, which make use of elemental dioxygen, as well as other reactions involving elements other than dioxygen, are redox reactions. Some important examples of this category are:

0 0 +4 –2

$$C(s) + O_2(g) \xrightarrow{\Delta} CO_2(g) \quad (8.24)$$

0 0 +2 –3

$$3Mg(s) + N_2(g) \xrightarrow{\Delta} Mg_3N_2(s) \quad (8.25)$$

–4+1 0 +4 –2 +1 –2

$$CH_4(g) + 2O_2(g) \xrightarrow{\Delta} CO_2(g) + 2H_2O(l)$$

2. Decomposition reactions

Decomposition reactions are the opposite of combination reactions. Precisely, a decomposition reaction leads to the breakdown of a compound into two or more components at least one of which must be in the elemental state. Examples of this class of reactions are:

+1 –2 0 0

$$2H_2O(l) \xrightarrow{\Delta} 2H_2(g) + O_2(g) \quad (8.26)$$

+1 –1 0 0

$$2NaH(s) \xrightarrow{\Delta} 2Na(s) + H_2(g) \quad (8.27)$$

+1 +5 –2 +1 –1 0

$$2KClO_3(s) \xrightarrow{\Delta} 2KCl(s) + 3O_2(g) \quad (8.28)$$

It may carefully be noted that there is no change in the oxidation number of hydrogen in methane under combination reactions and that of potassium in potassium chlorate in reaction (8.28). This may also be noted here that all decomposition reactions are not redox reactions. For example, decomposition of calcium carbonate is not a redox reaction.

+2 +4 –2 +2 –2 +4 –2

$$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$$

3. Displacement reactions

In a displacement reaction, an ion (or an atom) in a compound is replaced by an ion (or an atom) of another element. It may be denoted as:

$$X + YZ \rightarrow XZ + Y$$

Displacement reactions fit into two categories: metal displacement and non-metal displacement.

(a) Metal displacement: A metal in a compound can be displaced by another metal in the uncombined state. We have already discussed about this class of the reactions under section 8.2.1. Metal displacement reactions find many applications in metallurgical processes in which pure metals are obtained from their compounds in ores. A few such examples are:

+2 +6 –2 0 0 +2 +6 –2

$$CuSO_4(aq) + Zn(s) \rightarrow Cu(s) + ZnSO_4(aq) \quad (8.29)$$

+5 –2 0 0 +2 –2

$$V_2O_5(s) + 5Ca(s) \xrightarrow{\Delta} 2V(s) + 5CaO(s) \quad (8.30)$$

+4 –1 0 0 +2 –1

$$TiCl_4(l) + 2Mg(s) \xrightarrow{\Delta} Ti(s) + 2MgCl_2(s) \quad (8.31)$$

+3 –2 0 +3 –2 0

$$Cr_2O_3(s) + 2Al(s) \xrightarrow{\Delta} Al_2O_3(s) + 2Cr(s) \quad (8.32)$$

In each case, the reducing metal is a better reducing agent than the one that is being reduced which evidently shows more capability to lose electrons as compared to the one that is reduced.

(b) Non-metal displacement: The non-metal displacement redox reactions include hydrogen displacement and a rarely occurring reaction involving oxygen displacement.