Oxidation Numbers

To follow the loss and gain of electrons in complicated reactions, we utilize the concept of **oxidation numbers** (or **oxidation state**). It is similar to valence, a term you learned in Grade 10. A method of expressing the valence or the combining power of elements is the idea of **oxidation number** or **oxidation state**. An oxidation number is assigned to an atom or ion to describe its relative state of oxidation or reduction.
Each atom is given a signed number (plus, minus or zero) according to the following rules:

Rules for assigning oxidation numbers

1. All elements have an oxidation number of zero. e.g. O_2 , Ca, Al, Na, S_8 , I_2 all have an O.N of Zero.

2. All monatomic ions have an oxidation number equal to their charge. e.g. Cl^- has an O.N. of –1, Mg^{2+} has an O.N. of +2 etc.

3. The sum of the oxidation numbers in a molecule is zero. e.g. CO_2 has a sum of zero, with C being +4 and O being –2; the algebraic sum of the oxidation numbers is 0.

4. The sum of the oxidation numbers in a polyatomic ion is the charge of that ion. e.g. in CO_3^{-2}, the carbonate ion, Carbon is +4 and Oxygen is –2; the algebraic sum of the oxidation numbers equals the overall charge on the ion.

5. Generally, the oxidation number of oxygen in compounds is –2. (The exceptions are peroxides where it is -1, and in combination with fluorine it is +2)

6. Generally, the oxidation number of hydrogen in compounds is +1. (The exception is the hydride ion, where H is –1)

7. Generally, the ions of the alkali metals (group I) have an oxidation number of +1, while the ions of the alkaline-earth metals (group II) have an oxidation number of +2. {Al3+}

8. The oxidation number of fluorine is always – 1.

9. In any substance the more electronegative element has the negative oxidation number whilst the less electronegative element has the positive oxidation number, e.g. OF_2

The non-metals can have a variety of oxidation numbers. e.g. Chlorine has the oxidation numbers –1,0,+1,+3,+5,+7

Assignment

1. What is the oxidation number of **N** in the following:
a) N_2 B) NO_2 c) N_2O_4 d) HNO_2 e) HNO_3 f) NO^+ g) N^{-3} h) NO_3^- I) NO_2^- J) NH_3 k) $Cu(NO_3)_2$ (l) $Fe(NO_2)$

2. What is the oxidation number of **S** in the following:
a. SO_2 b. SO_3 c. $H_2S_2O_8$ d. $NaHSO_3$ e. SO_4^{-2} f. $CuSO_3$
g. $S_2O_3^{-2}$ h. H_2S i. $CaSO_4$ j. SO_3^{-2}

3. What is the oxidation number of:
a) Cr in $Cr_2O_7^{-2}$ b) Mn in MnO_4^- c) Au in Au_2O_3 d) Ce in $Ce(SO_4)_2$ e) Bi in Bi_2O_5 f) N in NH_4^+
g) Mn in MnF_3 h) U in U_3O_8 (i) P in H_3PO_4 (j) Cl in Ca $(ClO_4)_2$ (k) Mn in $KMnO_4$
(l) Fe in $Fe_2(SO_4)_3$ (m) Cr in Cr $(CN)_6^{-3}$ (n) As in As_2O_3 , AsO_2^{-1}, AsO_4^{-3} , AsH_3
(o) I in I^{-1} , IO^{-1} , IO_3^{-1} , I_2 , ICl_3 , ICl_2^{-1}

Oxidation number and naming compounds

The use of oxidation number is often useful in the systematic naming of compounds and ions that contain elements which have variable oxidation states.

For example, in the case of the oxides of iron:

FeO	iron (II) oxide
Fe_2O_3	iron (III) oxide

or the chlorides of copper:

CuCl	copper (I) chloride
$CuCl_2$	copper (II) chloride

Roman numerals (I, II, III, IV, V, VI, VII) are used in writing the oxidation number of an element, and this number is placed after the element that it refers to.

For example, the oxides of sulphur:

SO_2	sulphur (IV) oxide
SO_3	sulphur (VI) oxide

The use of oxidation numbers for the naming of **oxyanions** has become a much simplified task! Oxyanions are negatively charged ions whose names end in — ate, which shows that they contain oxygen, for example the sulphate ion, SO_4^{-2}. The first part of the name refers to the element that is combined with the oxygen, i.e. the sulphur. However, there is another sulphate ion with a different formula, SO_3^{-2}, thus the oxidation number of the sulphur is used in each case to distinguish between them. Hence the names of these ion are:

SO_4^{-2}	sulphate (VI)	(previously known as sulphate)
SO_3^{-2}	sulphate (IV)	(previously known as sulphite)

Hence the correct name for $FeSO_4$ is iron (II) sulphate (VI), and for $FeSO_3$ iron (II) sulphate (IV)

Assignment

1. Name the following compounds:

a. $CoCl_3$ b. CuI c. MnO_2 d. Cr_2O_3 e. Sb_2O_5 f. $SnCl_4$

g. MnO_4^{-1} h. $Cr_2O_7^{-2}$ i. PO_4^{-3} j. NO_3^{-1} k. NO_2^{-1}

2. Write the formulae of the following compounds:

a. Carbon (IV) oxide b. Phosphorus (V) chloride c. lead (II) oxide d. Lead (IV) oxide

e. Manganese (II) chloride f. Silicon (IV) bromide

3. Name the following compounds:

a. $NaClO_4$ b. $Ni(NO_3)_2$ c. $CuSO_4$ d. $KMnO_4$ e. K_2CrO_4

f. $Fe_2(SO_4)_3$ g. $NaBrO_3$ h. $Ca_3(PO_4)_2$ i. $Sn(ClO_2)_4$