

Oxidation – Reduction and Electrochemistry

Definitions

Oxidation and Reduction

Oxidation: Oxidation is the **loss of electrons** by an atom or ion.

Reduction: Reduction is the **gain of electrons** by an atom or ion.

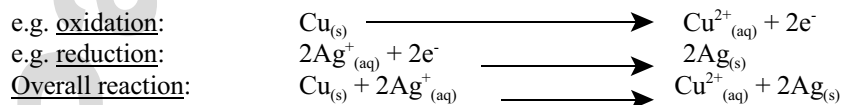
Oxidizing agent (oxidant): This substance, (atom, molecule or ion), causes oxidation. i.e. causes the loss of electrons from the substance being oxidized. (Thus the oxidizing agent gains electrons in the process and is itself reduced.)

Reducing agent (reductant): This substance, (atom, molecule or ion), causes reduction. i.e. causes the gain of electrons to the substance being reduced. (Thus the reducing agent loses electrons in the process and is itself oxidized.)

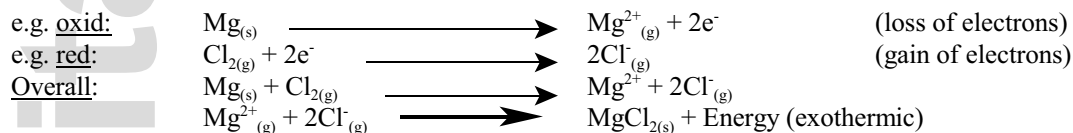
Oxidation and reduction occur together. In an **oxidation – reduction** reaction or **redox** reaction, electrons pass from the reducing agent to the oxidising agent.

See p.148 in Harwood & Petrucci

Redox reactions consist of two **half reactions** which must occur together, the oxidation half-reaction and the reduction half-reaction. *See p.142/3 in Harwood & Petrucci for an example.*



In this reaction, a piece of copper wire will “grow” silver metal crystals from a solution of silver nitrate while the blue copper ions dissolve in solution as they are produced. Copper metal is **oxidized** (and is the **reducing agent**). Silver ions (aq) are **reduced** (and is the **oxidizing agent**).



Heated magnesium metal will readily combine with chlorine to form the salt magnesium chloride. The reaction is self-sustaining once started. ((Magnesium, a Group II metal tends to lose $2e^{-}$ to acquire noble gas configuration, while Chlorine, a Group VII non-metal tends to gain $1e^{-}$ to reach noble gas configuration.)

OIL RIG

Oxidation Is Loss

Reduction Is Gain

LEO GER

Lose Electrons – Oxidation

Gain Electrons – Reduction

Reduction and **Oxidation** reactions always occur concurrently – you can't have one without the other, ∴ they are often called **REDOX** reactions.

Oxidation Numbers

To follow the loss and gain of electrons in complicated reactions, we utilize the concept of **oxidation numbers**. It is similar to valence, a term you learned in Grade 11. A method of expressing the valence or the combining power of elements is the idea of **oxidation number** or **oxidation state**. 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 .
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 .
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 $+2$. {Al $^{3+}$ }

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

In a chemical reaction, the net change in oxidation numbers must be zero.

Oxidation is an increase in oxidation number while reduction is a decrease in oxidation number.

Oxidation

_____ \
/
-5 -4 -3 -2 -1 0 + 1 +2 +3 +4 +5

/
_____ \
Reduction

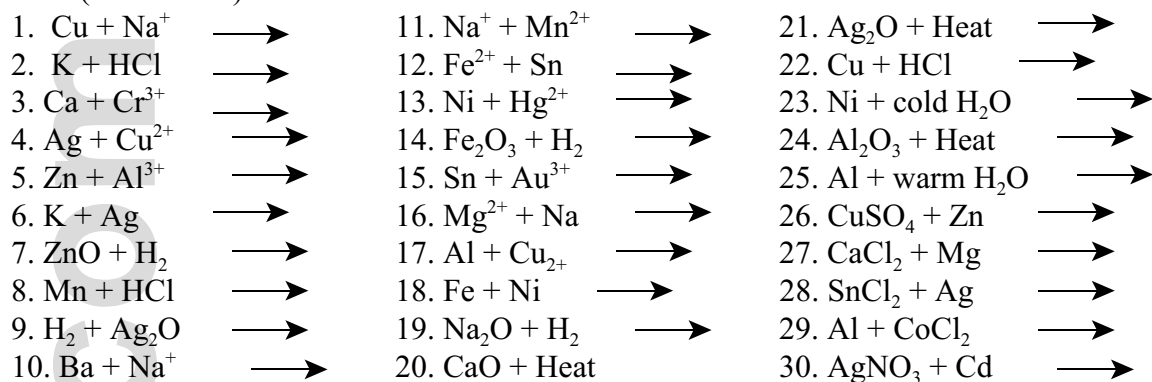
1. What is the oxidation number of N in the following:
a) N_2 B) NO_2 c) N_2O_4 d) HNO_2 e) HNO_3 f) NO^+ g) N^{3-} h) NO_3^- I) NO_2^- J) NH_3 k) $Cu(NO_3)_2$
(l) $Fe(NO_2)$
2. What is the oxidation number of:
a) Cr in $Cr_2O_7^{2-}$ b) Mn in MnO_4^- c) Au in Au_2O_3
d) Ce in $Ce(SO_4)_2$ e) Bi in Bi_2O_5 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^- , AsO_4^{3-} , AsH_3 (o) I in I^- , IO^- , IO_3^- , I_2 , ICl_3 , ICl_2^-

The Electrochemical Series of Metals

K		Potassium		K	
Ba		Barium		Ba	
Sr		Strontium	soluble	Sr	liberate H ₂ from
Ca		Calcium		Ca	cold water
Na	extremely	Sodium	never	Na	
Mg	difficult	Magnesium		Mg	liberate H ₂
Al		Aluminum		Al	from steam
Mn		Manganese		Mn	
Zn		Zinc		Zn	liberate H ₂
Cr		Chromium		Cr	from acids
Fe	oxides	Iron		Fe	
Cd	stable	Cadmium		Cd	
Co		Cobalt	rarely	Co	
Ni	difficult	Nickel		Ni	
Sn		Tin		Sn	
Pb		Lead	insoluble	Pb	
H		Hydrogen		H	
Cu		Copper		Cu	attacked by
As		Arsenic		As	oxidizing acids
Bi		Bismuth		Bi	
Sb	easy	Antimony	frequently	Sb	do not liberate
Hg		Mercury		Hg	H ₂ from acids
Ag	oxides	Silver		Ag	
Pt	decompose	Platinum	usually	Pt	not attacked by
Au		Gold		Au	common acids
reduction	effect of		solubility	found	
of oxides	heat on		of oxides	free in	
by hydrogen	oxides		in water	nature	

Problem Assignment

Give products for the following reactions where a reaction occurs. If no reaction occurs, write N.R. (no reaction).



31. Place a check in the appropriate box below if:

- a. the metal reacts with cold water;
- b. the metal reacts with steam;
- c. the metal reacts with hydrochloric acid;
- d. the oxide of the metal decomposes when heated;
- e. the oxide of the metal is reduced by hydrogen;
- f. the metal displaces tin from a stannous chloride solution;
- g. the metal displaces copper from a cupric sulfate solution;

	aAaaa	B	C	D	E	F	G	
Mg								
Ag								
Hg								
Na								
Al								
Pb								
Fe								

32. Using the electrochemical series:

- a. Name 2 reducing agents better than Ni.
- b. Name 2 oxidizing agents better I_2 .
- c. Name 1 oxide that can be reduced by hydrogen.
- d. Name 1 oxide that cannot be reduced by hydrogen.
- e. Name 2 substances that can be oxidized by the O_2 of the air.
- f. Name 1 oxide that decomposes on heating.
- g. Name 2 oxides that do not decompose on heating.
- h. Name 2 substances that will oxidize I^- .
- i. Name 2 substances that will reduce I_2 .
- j. Name 2 substances that will reduce Pb^{+2} .
- k. Name 2 substances that will oxidize Pb.

Oxidizing and Reducing Agents

An oxidizing agent is something that causes oxidation, i.e. an increase in the oxidation state of another substance and is itself reduced. It is therefore a good electron acceptor. The cheapest oxidizing agent is: _____.

Most oxidizing agents are rich in oxygen. They accept electrons readily, therefore losing oxygen as oxide. Chlorine also works well producing chloride.

A reducing agent is something that causes reduction i.e. a decrease in the oxidation state of another substance and is itself oxidized. It must therefore be a good electron donor. The most common reducing agent is hydrogen, H_2 . Another good reducing agent is $LiAlH_4$ (releases H^-), useful in organic chemistry.

The activity series introduced earlier is a list of metals in the order of decreasing strength as reducing agents. Elemental metals are reducing agents in most of their reactions. The active metals of the sodium family and also calcium, barium and strontium are very good reducing agents. Other good reducing agents are Mg and Al.

How can an atom, molecule, or ion be recognized as a potential oxidizing agent or reducing agent? An oxidizing agent must contain an atom that can have a lower oxidation number, otherwise no reduction is possible. Similarly, a reducing agent must contain an atom that can have a higher oxidation number.

Here is a list of **oxidizing agents**:

Permanganates	MnO_4^-
dichromates	$Cr_2O_7^{2-}$
chlorates	ClO_3^-
perchlorates	ClO_4^-
bromates	BrO_3^-
iodates	IO_3^-
hypochlorites	ClO^-
Halogens	F, Cl, Br, I
nitrates	NO_3^-
Hydrogen peroxide	H_2O_2
Oxygen / Ozone	O_2, O_3
Metal dioxides (Pb, Mn)	

Reducing Agents

H_2	metal hydrides	metals	carbon	sulphites	iron (II) salts
SO_2	$SnCl_2$	H_2S	NO_2^-	CO	