

Guessing Reaction Products

This handout presents some guidelines on how to predict reactions. The products one gets by using these rules are those normally expected. Exceptions to these are the difficult part of chemistry, and one spends a much more time on learning the exceptions than those expected.

In order to understand and utilize this handout, you must be able to:

- 1) determine oxidation numbers
- 2) identify, recall and write the common polyions and
- 3) construct Lewis dot structures.

If you are weak in these areas, review until you are competent.

There are two general classes of reactions, redox (oxidation-reduction) and non-redox. Redox reactions are those where there is a change in oxidation number during the reaction. The following are special definitions used here.

"expected" and "normal" - These are those products of redox reactions that one would obtain by the rules presented here.

"acceptable Lewis dot structure" - These are those structure which are possible by the rules given in the Laboratory Manual*.

WARNING - Never balance a reaction before you are certain of the reaction products. Never distort the answer for the product merely to balance a reaction. Any reaction can be balanced, regardless of the complexity of the reactants or products.

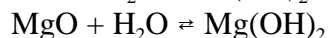
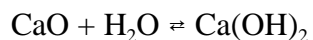
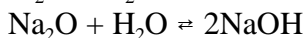
Non-redox Reactions

I. Production of bases or acids by reaction with water

A. Reaction of water with normal metal oxides:

Examples:

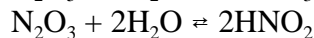
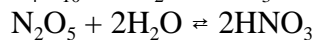
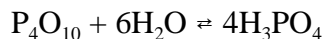
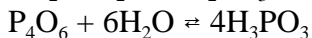
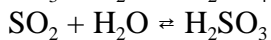
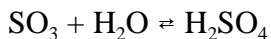
normal oxide + water \rightleftharpoons base



* General Chemistry Laboratory Manual by Dr. James B. Condon, 2nd Edition.

B. Reaction water with non-metal oxides for which there is an acceptable Lewis dot structure:

Examples:



C. Exceptions involving redox violate the caveats given, but yield bases or acids expected by the rules:

$\text{Na}_2\text{O}_2 + \text{H}_2\text{O} \rightarrow \text{NaOH} + \text{H}_2\text{O}_2$ - a reaction of a peroxide (not normal) to give hydrogen peroxide.

$4\text{KO}_2 + \text{H}_2\text{O} \rightarrow 4\text{KOH} + \text{O}_2$ - a reaction of a superoxide (not normal) to give oxygen gas

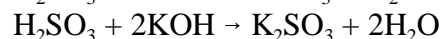
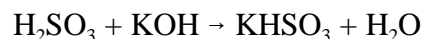
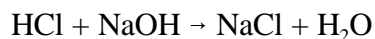
$3\text{NO}_2 + \text{H}_2\text{O} \rightarrow 2\text{HNO}_3 + \text{NO}$ - a reaction of an oxide that does not have an acceptable Lewis dot structure. I. E. NO_2 has a Lewis dot structure with an odd number of electrons or one unpaired e^- .

II. Acid-base reactions, by any of the definitions: Arrhenius, Brønsted-Lowry or Lewis.

Examples:

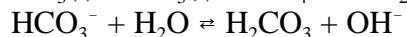
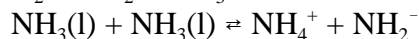
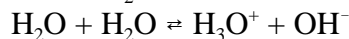
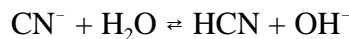
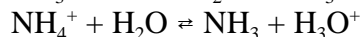
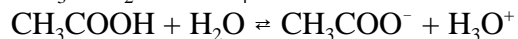
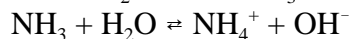
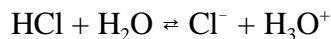
A. Arrhenius:

Acid + Base \rightarrow Salt + (water optional)



B. Brønsted-Lowry:

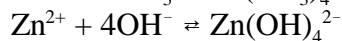
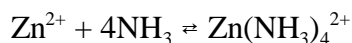
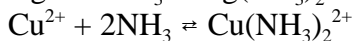
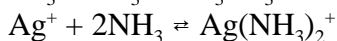
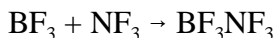
Acid 1 + Base 2 \rightleftharpoons Acid 2 + Base 1*



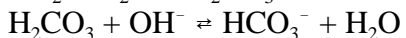
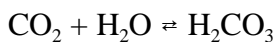
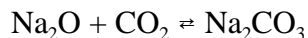
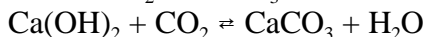
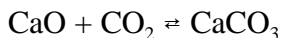
C. Lewis:

Acid + Base \rightarrow compound

or Acid + Base \rightleftharpoons complex ion



III. Reactions of hydroxides or normal oxides with CO_2 to yield carbonates, CO_3^{2-} or HCO_3^- and dissolution of CO_2 in H_2O and reaction to form HCO_3^-



(see above)

Redox Reactions

IV. Reactions of Metals with non-metals

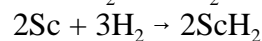
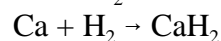
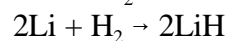
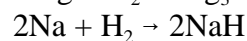
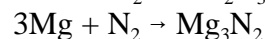
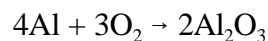
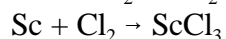
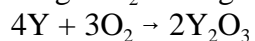
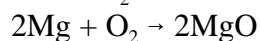
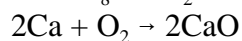
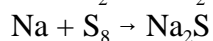
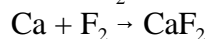
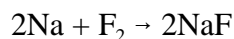
The oxidation number for **metals** will become the **principal oxidation number**.

The oxidation number for **non-metals** (including hydrogen) will become the **principal oxidation number**. (Recall that hydrogen as a non-metal is -1)

*

The reactions are written according to the standard that water is the second reactant given, thus the acid-base order may not be the same as this order.

Examples:

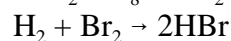
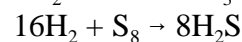
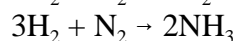
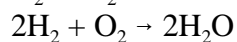
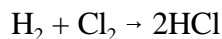


V. Reactions of hydrogen with non-metals

The oxidation number for **hydrogen** will become +1.

The oxidation number for **non-metals** will become the **principal oxidation number**.

Examples:



VI. Reactions of non-metals with non-metals

The oxidation number for the **most electronegative non-metal** will become the **principal oxidation number**.

The oxidation number for the **other non-metal** will become either

The **IUPAC group number** - 10 or
18 - the group number

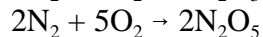
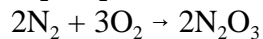
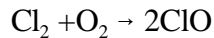
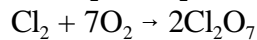
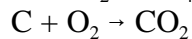
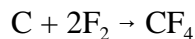
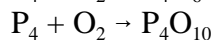
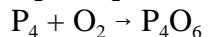
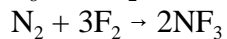
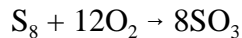
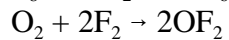
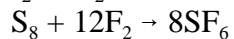
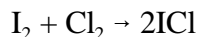
with the caveat that a **Lewis dot structure must be possible**.

Example:



$\text{Cl}_2 + 7\text{F}_2 \rightarrow 2\text{ClF}_7$ Cl has an oxidation number of the group number - **however, an allowed Lewis dot structure cannot be created. Therefore ClF₇ does is not formed.**

Examples: (Note that O is more electronegative than Cl.)



VII. Some important exceptions:

Note, there exists other possible compounds. This is especially true with oxygen. You must learn these compounds. Amongst these exceptions are:

Compounds of N and O:



NO_2 with an unpaired electron

NO with an unpaired electron

N_2O_4 the dimer of NO_2

Compounds of S and O:

SO_2 which has the same Lewis dot structure as ozone O_3

SO is not a common oxide of sulfur, i.e. expected but not formed.

Compounds of peroxides and superoxides:

In dry oxygen the following are common products of the reaction between O_2 and the metal given.

