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## Ions

Ions are charged species.
This is due to a gain or loss of electrons (almost never protons!)

Gain of electrons → negatively charged ion ≡ **anion**
Loss of electrons → positively charged ion ≡ **cation**

There are two types of ions: simple and complex

### Simple ions

Simple ions (monoatomic ions) are species with one nucleus that has gained or lost electrons

$F^-$ (anion) = $^{9}F^{9+}$ + 10 $e^-$
$Ca^{2+}$ (cation) = $^{20}Ca^{20+}$ + 18 $e^-$

## Complex ions

Complex ions are molecules, where the atoms are connected by covalent bonds, that have lost or gained electrons.
Those are also called polyatomic ions

Examples: $NH_4^+$ ammonium ion or $H_3O^+$ hydronium ion

Note that polyatomic ions themselves do not break apart

More examples can be found in **Table 2.2 of M & H p. 41**

Compounds can also be formed the interaction of anions and cations (species of opposite charge)

These are called ionic compounds even though they are electrically neutral (# of positive charges = # negative charges)

Such compounds are held together by an electrostatic attraction known as an ionic bond

Crystalline table salt (NaCl) is $Na^+$ and $Cl^-$ bonded together.
When dissolved, NaCl dissociates to form a solution of $Na^+$ and $Cl^-$

## Names of Compounds

A compound can be identified using its formula (NaCl) or its name (sodium chloride).
The following are conventions used in naming compounds:

1. **Ions**

Simple (monoatomic) cations of metals take the name of the metal

$Na^+$ = sodium $K^+$ = potassium

However, some metals, specially transition metals in the periodic table, exist in more than one cationic form.
To distinguish these, we note the charge as a Roman numeral

$Fe^{2+}$ = Fe(II) $Fe^{3+}$ = Fe(III)

Simple (monoatomic) anions are named by adding the suffix **ide** to the base name of the non-metal

$Cl^-$ = chloride $O^{2-}$ = oxide $H^-$ = hydride

Polyatomic ions are given special names (see **M&H Table 2.2**).
However, those containing oxygen (oxoanions) can be names using the base name and the following rules:

When the non-metal forms only two oxoanions, the suffix **ate** is used for the one with the more oxygens.
The suffix **ite** is used for the one with the least oxygens

$SO_4^{2-}$ = sulfate $SO_3^{2-}$ = sufite

When a non-metal forms more than two oxoanions, we use the prefixes, **per** and **hypo** for the **most** and least oxygens, respectively

$ClO_4^-$ = perchlorate     $ClO_3^-$ = chlorate

$ClO_2^-$ = chlorite     $ClO^-$ = hypochlorite

## 2. Ionic Compounds

Recall that ionic compounds consist of a cation and an anion.
It follows that they are named using the names of the cation and the anion (also the order which they are written)

NaI = sodium iodide     $NH_4Cl$ = ammonium chloride

$FeCl_2$ = iron(II) chloride     FeCl = iron(I) chloride

Note: the Roman numerals are used as appropriate

## 3. Binary Molecular Compounds

The combination of two non-metals usually forms a binary compound.
They usually contain two-worded names

The first word corresponds to the first element in the formula, with a Greek prefix to show the number of atoms of that element

| | | | | |
|---|---|---|---|---|
| 2 = di | 3 = tri | 4 = tetra | 5= penta | 6 = hexa |
| 7 = hepta | | 8 = octa | 9 = nona | 10 = deca |

The second word uses the stem name of the element, the Greek prefix, and the suffix **ide**

Examples: $N_2O_5$ = dinitrogen pentaoxide
$NO_2$ = nitrogen dioxide
$N_2O$ = dinitrogen oxide

Many binary compounds have accepted common names:

$H_2O$ = water     $NH_3$ = ammonia
$H_2O_2$ = hydrogen peroxide     $C_2H_2$ = acetylene

## 4. Acids

Some binary compounds ionize in water to form $H^+$ ions, and are called **acids**.
For example, when hydrogen chloride is dissolved in water it forms $H^+$ and $Cl^-$ ions.

$$HCl(g) \xrightarrow{H_2O} H^+(aq) + Cl^-(aq)$$

The water solution of HCl is called hydrochloric acid

Acids that also contain oxygen are oxoacids.
Two common ones are nitric acid ($HNO_3$) and sulfuric acid ($H_2SO_4$)

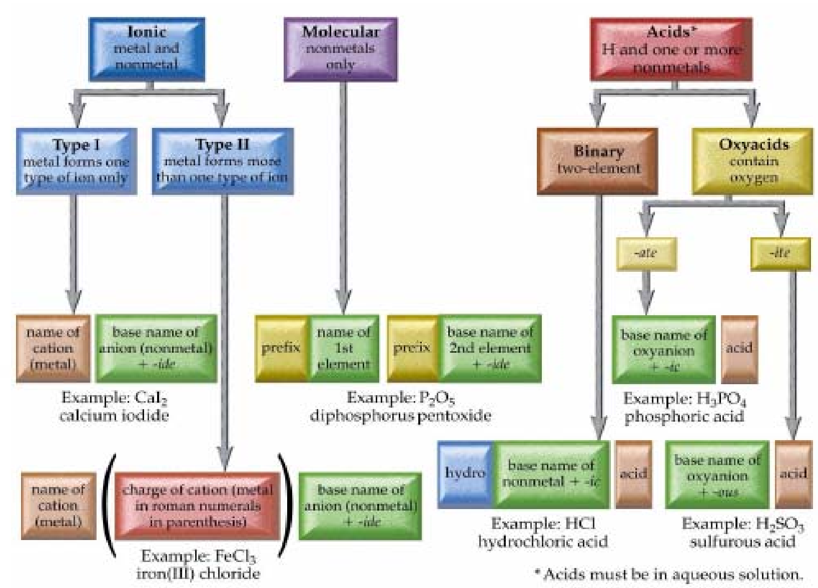
The names of oxoacids originate from the names of the corresponding oxoanions.
The suffix ***ate*** is replaced with **ic**, and ***ite*** is replaced with **ous**

**Examples:**

| | |
|---|---|
| $ClO_4^-$ = perchlorate ion | $HClO_4$ = perchloric acid |
| $ClO_3^-$ = chlorate ion | $HClO_3$ = chloric acid |
| $ClO_2^-$ = chlorite ion | $HClO_2$ = chlorous acid |
| $ClO^-$ = hypochlorite | HClO = hypochlorous acid |

Note: polyanions do not "break apart".
In the example below, sulfate stays as sulfate

$$H_2SO_4 \xrightarrow{H_2O} 2H^+(aq) + SO_4^{2-}(aq)$$




## The mole *(M&H Ch. 3)* (relevant problems found in tutorial manual section Stoichiometry Part 1, p. 17…)

The unit for chemical mass is the **mole**

≡ "the mass (in g) of an element or compound equal to its average atomic mass (in amu)"

▪usually denoted by symbol "n"

For example 1 atom of C weighs 12.01 amu while 1 mole of C weighs 12.01 g

That methane, $CH_4$: one molecule weighs [12.01 + 4(1.01)] = 16.05 amu while one mole weighs 16.05 g

> One mole of a substance always contains the same number of particles
> = $6.022 \times 10^{23}$
> ≡ Avogadro's number, $N_{AV}$

Compare 1 dozen = 12 units; 1 mole = $6.022 \times 10^{23}$ units

For example: 1 mole of $O_2$ = $6.022 \times 10^{23}$ $O_2$ molecules = 32.0 g

1 mole $CH_3CH_2OH$ contains $6.022 \times 10^{23}$ ethanol molecules = 46.0 g and contains $9xN_{AV}$ = $5.42 \times 10^{24}$atoms total of which $6 \times N_{AV}$ = $3.61 \times 10^{24}$ are hydrogen atoms, $2xN_{AV}$ = $1.20 \times 10^{24}$ are C atoms, $6.022 \times 10^{23}$ are O atoms

The **molar mass** of a molecule is the **sum** of the individual atomic masses.

For example the molar mass of $CH_3CH_2OH$ = 12 + 3 + 12 + 2 + 16 + 1 = 46.0 g $mol^{-1}$

Molar mass also termed the **molecular weight** or for ionic compounds such as NaCl, the **formula weight**

**Worked Example:**
If coal is 3.00 % by mass sulphur, S, how many moles of S are contained in 1 tonne (1000 kg) of coal?

Mass of S in 1 tonne of coal = (3.00/100.0) x 1000 kg = 30.0 kg

30 kg = 30.0 x $10^3$ g. $\therefore$ The number of moles, n = (30.0 x $10^3$ g)/32 g $mol^{-1}$

n = 940 mol $tonne^{-1}$

## Molecular Formulas

Given a molecular formula, one can calculate the % composition of the elements present:

**Worked Example:**
for ethanol, $CH_3CH_2OH$ = $C_2H_6O$ the molar mass = 46 g $mol^{-1}$

Mass of C in compound =12 x 2 =24

$\therefore$ %C = (24.0/46.0) x 100% = 52.2%

Similarly, %H = ([6x 1.01]/46.0) x 100% = 13.2%
and
%O = (16.0/46.0) x 100% = 34.8%