Atoms and Molecules

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We now define an <u>atom</u> as the simplest unit of an element and a <u>molecule</u> as the simplest unit of a compound, but the ability of sort out mixtures from substances and elements from compounds was not an easy road.

The beginnings of chemistry start in the 1600's and 1700's with experiments showing the existence of "basic" materials – those which could not be broken down further – and how they came together to form materials with different properties. These "basic" materials we now call <u>elements</u> and the new materials they can form are called <u>compounds</u>.

John Dalton summarized about 1800 the experimental evidence of the day with a general theory about the structure of these elements and compounds.

Dalton's Atomic Theory

1800 - First Comprehensive Atomic Theory

1. **Matter is composed of atoms that are indivisible**
2. **All atoms of the same element are identical**
3. **Atoms combine in small whole number ratios to form compounds**
4. **Atoms are not created or destroyed in chemical reactions - Conservation of Matter - Lavoisier**

Today's knowledge of Atomic Structure

A. Atoms have a small dense positively nucleus surrounded by negatively charged electrons.

Electron	**9.11×10^{-28} g**	**-1 charge**
Proton	**1.673×10^{-24} g**	**+1 charge**
Neutron	**1.675×10^{-24} g**	**neutral**

Radius of atom	**10^{-10} m**
Radius of nucleus	**10^{-14} m**
Radius of proton & neutron	**10^{-15} m**
Radius of electron	**10^{-18} m**

Atomic number - number of protons (identifies the element)

Mass number - number of protons plus neutrons

$$\text{Mass number}\ X\ \text{Atomic Number}$$

Atomic mass unit - 1/12 the mass of a carbon 12 atom (1.66×10^{-24} g)

Each atom has an atomic mass based on the amu (atomic mass unit)

B. Isotopes - different forms of an element, same atomic number but different mass numbers

C. Atomic weight - the weighted average (based on relative abundance) of the atomic masses of the isotopes of an element

$$\text{Atomic weight} = \frac{\text{mass of a given number of atoms}}{\text{given number of atoms}}$$

History of the Periodic Table

Mendeleev - 1850

- Arranged elements by atomic mass in periodic table

Moseley - 1915

- Discovered how to find atomic number of elements
- Arranged elements by atomic number - this is modern periodic law

The arrangement of elements is by reactivity and structure. Reactivity was known before structure was known.

The Structure of the Table

Periods - horizontal rows, numbered from top to bottom

- Be able to identify lanthanide and actinide series of elements. Collectively they both belong to the "rare earths".

Groups - vertical columns, numbered in several ways: using A and B designations or by numbers

Names of Groups to know -

- Alkali Metals – IA or column 1
- Alkaline Earth Metals – IIA or column 2
- Transition Metals - IIIB – IIB or columns 3-12
- Chalcogens - VI A or column 16
- Halogens – VIIA or column 17
- Noble Gases – VIIIA or column 18

Another way to divide the table

- Metals - have a tendency to lose electrons in bonding, good electrical and thermal conductivity; elements on the left side of the table
- Nonmetals - have a tendency to gain electrons in bonding, usually have poor electrical and thermal conductivity; elements on the upper right of the table
- Metalloids - have properties between metals and nonmetals, reside along the "stairstep"

Molecules

Most chemists use the term "molecule" in a very general way to refer to two or more atoms join together by either sharing or transferring electrons. The electrons that are shared or transferred are the outermost ones and are called the valence electrons.

Ionic and Covalent

Although there are several variations, the simplest classifications of bonding are that ionic compounds involve more transfer of electrons than sharing and covalent compounds involve more sharing than transfer. Strictly speaking the simplest unit of an ionic compound is a "formula unit" and that of a covalent compound is a "molecule".

Ionic compounds

Metals and nonmetals usually form compounds that involve a great deal of transfer of electrons. Thus these compounds are classified as primarily ionic.

When an atom loses or gains an electron it is called an ion. The loss of a negatively charged electron forms a positively charged cation. The gain of a negatively charged electron forms a negatively charged anion. Ionic compounds are held together by the attractions between the cations and anions that compose it.

Molecular or covalent compounds

Nonmetals bond with other nonmetals to form compounds classified as molecular with principally covalent bonds. It is the sharing of the electrons that holds these compounds together.

Organic and Inorganic compounds

Another way to classify compounds is by the elements that compose it. Organic compounds contain the element carbon. There are a few carbon containing compounds that are not thought of as organic such as carbon dioxide.

Inorganic compounds contain other elements besides carbon. Although carbon is only 1 of about 118 elements there are millions of organic compounds and less than one million inorganic compounds.

Naming Compounds

Oxidation number

Oxidation numbers are a way of keeping up with the number of electrons that an atom has - it is a bookkeeping system. They measure the combining capacity of an atom.

In ionic compounds the oxidation number can be thought of as the charge on the ion. In covalent compounds we assign the oxidation number as though the compound had ionic bonds.

The oxidation number is related to the electron configuration. Some elements can have more than one oxidation number. The handout gives a list of commonly used oxidation number or states. Many compounds are named according to the name of the oxidation state.

Sometimes you may have to assign oxidation numbers in a compound. Use these rules in conjunction with your handout.

* **The oxidation number of atoms in a pure element is zero.**
* **The oxidation number of a monatomic ion is the same as its charge.**
* **In binary compounds of two different elements, the element with greater electronegativity is assigned a negative oxidation number equal to its charge in simple ionic compounds.**
* **The sum of the oxidation numbers in a neutral species is 0; in a polyatomic ion, it equals the charge on that ion.**

Naming Ionic Compounds

Positive Ions

* **If only 1 oxidation number, then the name is simply the name of the metal**
* **If more than 1 possible oxidation number, then you must put the oxidation number in ( ) [This is called the Stock or Roman numeral system] after the name of the element or use the common name**
* **Polyatomic cations have special names**

Negative Ions

* **Monatomic anions end in -ide**
* **Polyatomic anions end in -ate, -ite, a few end in -ide**

Naming Molecular (Covalent) Compounds

The oxidation number concept is still useful. The element with the positive ox # is usually first followed by the negative ox #.

Nonmetal binary compounds can be named using the Roman numeral system or by using prefixes. In these compounds we must assign one nonmetal a positve ox #. Usually it is written first and is the least electronegative element. We will learn what electronegativity is and how to predict it in later chapter.

mono	1
di	2
tri	3
tetra	4
penta	5
hexa	6
hepta	7
octa	8
nona	9
deca	10

Examples: P_2O_5
diphosphorus pentoxide or phosphorus (V) oxide

SO_3
Sulfur trioxide or sulfur (VI) oxide

Acids and Bases

Acids give H^+ when dissolved in water.

Bases give OH^- when dissolved in water.

Terms and Types

Acids	**$HA_{(aq)}$**	**anions with H^+**
Bases	**$M^+(OH)^-_{(aq)}$**	**metal ions with hydroxides**
	$NH_{3\ (aq)}$	**and derivatives**

Naming

Binary acid (2 element acid, H and a nonmetal)

Acid name	Anion name
hydro_____ic acid	_____ide

Ternary acid (3 element acid; H,O and nonmetal)

Acid name	Anion name
per_____ic acid	per_____ate
_____ic acid	_____ate
_____ous acid	_____ite
hypo_____ous acid	hypo____ite

Hydrates

Ionic compounds which have a specific number of water molecules attached to them. Prefixes are used to indicate the number of water molecules attached – the same prefixes we used to name molecular compounds.

Example: $MgSO_4 \bullet 7\ H_2O$

$Na_2CO_3 \bullet 10\ H_2O$

Introduction to organic compounds – the Alkanes

There are many other types of compounds with different naming systems.

For example, the simplest type of organic compounds are called hydrocarbons. They only contain the elements hydrogen and carbon.

One type of hydrocarbons are the alkanes. They are often used as fuels in products such as natural gas, gasoline, diesel fuel, and kerosene. In simple organic compounds the beginning of the name indicates the number of carbons and the end indicates the type of bonding present.

Examples: methane, ethane, propane, butane, pentane, hexane, heptane, octane