Chapter 2

Classification of Matter

Substances (pure)

Elements

112 known
88 exist naturally
Periodic table

Tabulation of elements according to properties
Each element has specific character and properties

Compounds

Two or more elements combined chemically in a fixed proportion by weight
Must undergo chemical change for separation of the elements in a compound. Requires considerable energy.

Mixtures

Two or more substances mixed, not chemically combined
Unlike compounds, proportions can vary.
Mixtures separated mechanically without change of identity of the substances. No chemistry occurs.

Daltons' Atomic Theory

Explains, for example

The law of conservation of mass (A. Lavoisier)
The law of constant composition (J. Proust)

(Know the postulates of the theory)

The Atom and its Composition

Primary constituents of chemical interest

Proton – positively charged, relatively massive
Neutron – no charge, relatively massive
Electron – negatively charged, relatively very little mass

Charge

Positive charge attracted to negative
Positive charge repels positive
Negative charge attracted to positive
Negative charge repels negative
Proton has +1 charge
Electron has –1 charge

Mass

Mass of atoms conveniently given in atomic mass units.
1 amu = 1.67×10^{-24} g.
Proton mass is 1.0073 amu.
Neutron mass is 1.0087 amu.
Electron mass is 1/1835 that of a proton.
1 amu (= 1.67×10^{-24} g) x 6.02×10^{23} = 1 g.
6.02×10^{23} is called the Avagadro number, conversion between amu and g.

The mass number of an atom – is the sum of the number of neutrons and protons that an atom has.

The atomic number of an atom is the number of protons that an atom has. This gives the atom identity.

Isotopes result when atoms with the same number of protons have different numbers of neutrons or different mass numbers.
The atomic weight is the natural isotopic distribution weighted average of the of the isotopic masses of an element.

Ions are produced when electrons are added to or removed from a substance.

A neutral substance has an equal number of electrons and protons
A substance with additional electrons is negatively charged and called an anion. The charge equals the number of added electrons.
A substance with fewer electrons is positively charged and called a cation. The charge is equal to the number of electrons removed from the neutral species.

The Periodic Table

Organization in groups (columns) of elements with similar properties.

Column number at the top increases from left to right.
Noble gases
Halogens
Alkali metals
Alkaline earth metals
Monatomic, diatomic and polyatomic elements

Rows in the table are called periods. Period numbers increase from top to bottom.

The periodic law (D. Mendeleev) – There is a periodic repeat of the properties of the elements with increasing atomic number (weight).

There are regular changes (trends) in the properties of the elements within a group, as the period number increases.

Names of group sets and regions of the periodic table.

Main groups or representative elements
Transition elements and inner transition elements (lanthanides and actinides)
Metals, metalloids and non-metals

Electronic Structures of Atoms

Energies of electrons in atoms are quantized (N. bohr)

The lowest energy possible is called the ground state.

Regions of space around the nucleus that can be occupied by up to 2 electrons are called orbitals.

Orbitals have particular energies and specified shapes.
Sets of orbitals with particular energies and shapes are designated by number and letter symbols like 1s, 2p, 3s, 4d, 5s, 6f, etc,.
Sets designated by s have 1 orbital, p sets have 3 orbitals, d sets have 5 and f have 7. (s holds 2, p holds 6, d holds 10, f holds 14)
The number before the letter designates the principal energy level (n) of the orbital set. (n = 1,2,3,4,5,6,7…)
The s set is a part of all energy levels, p sets are only in those above 2, d is a part of levels above 3, and f is a part of those above 4.
When two electrons occupy an orbital they must have opposite spins, +1/2 and –1/2 (Pauli exclusion principle). They are said to be paired. If only one is in an orbital, it is unpaired.
Hund's rule – orbitals with the same energy will all take one electron before pairing with the second.
Sets of orbitals occupy a spherical space around the nucleus.

In the hydrogen atom, 1s is the lowest energy orbital (ground state) and others at higher energies are excited states.

For multi-electron atoms the electrons occupy the lowest to the highest energy orbitals. The energy order is given by the Aufbau principle; 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s,…

The electron configurations of the elements can be written by adding the given number of electrons into orbitals with successively higher energies according to the rules.

Electrons can be excited to higher energies by energy input and emit energy upon return to lower energies.

Electronic Configuration and the Periodic Table

Elements in the same group have the same outer electron configuration, that is, the same orbital shape and orientation but with different size or energy.

The block character of the periodic table is also explained.

These outer electrons are those that undergo change when chemistry occurs, and generally account for the properties of the element.

Varying properties down a group depend on the different energies that the outer electrons have.

- Ionization energy
  - Metals
  - Non-metals
- Electron affinity
- Atomic radius

The Size of Atoms

The nucleus contains 99.98 % of the mass of an atom.

The diameters of atoms are on the order of tenths of nanometers while nuclear diameters are on the order of hundredths of picometers. Atomic volume is space occupied by the electrons.