Chemistry

Introduction

- Chemistry is the science of the materials that make up our physical world (physical science). Chemistry tends to focus on the properties of substances and the interactions between different types of matter, particularly reactions that involve electrons.
- No person could expect to master all aspects of such a vast field, so it has been found convenient to divide the subject into smaller areas. For example:
  - **Organic chemists** study compounds of carbon. Atoms of this element can form stable chains and rings, giving rise to very large numbers of natural and synthetic compounds.
  - **Biochemists** concern themselves with the chemistry of the living world.

Introduction

- **Inorganic chemists** are interested in all elements, but particularly in metals, and are often involved in the preparation of new catalysts.
- **Physical chemists** study the structures of materials, and rates and energies of chemical reactions.
- **Theoretical chemists** with the use of mathematics and computational techniques derive unifying concepts to explain chemical behavior.
- **Analytical chemists** develop test procedures to determine the identity, composition and purity of chemicals and materials. New analytical procedures often discover the presence of previously unknown compounds.

- One of the main functions of the chemist is to rearrange the atoms of known substances to produce new products.

Atomic and Molecular Structure

- **Atoms** are single units of an element. Ions can be made up of one or more types of elements and carry an electrical charge.
- Atoms cannot be divided using chemicals. They do consist of parts, which include protons, neutrons, and electrons.
- Each electron has a negative electrical charge.
- Each proton has a positive electrical charge. The charge of a proton and an electron are equal in magnitude, yet opposite in sign.
- Each neutron is electrically neutral.
- The nucleus of an atom contains protons and neutrons.
- Electrons move around outside the nucleus.

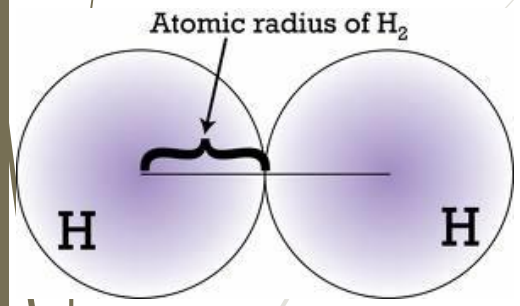
Atomic Numbers and Atomic Mass

- **The atomic number** is the number of protons in an atom
- **The atomic mass** is the mass of protons, neutrons, and electrons in an atom
- Atomic number doesn't always equate to increasing mass because many atoms don't have a number of neutrons equal to the number of protons.
- In other words, several **isotopes** of an element may exist (elements with the same atomic number but with different atomic mass).

Periodic Table

- A **periodic table** is a tabular display of the chemical elements, organized on the basis of their atomic numbers, electron configurations, and recurring chemical properties. Elements are presented in order of increasing atomic number (number of protons).
- A **group or family** is a vertical column in the periodic table. Elements in the same group tend to have a shared chemistry and exhibit a clear trend in properties with increasing atomic number.
- Elements in the same group tend to show patterns in atomic radius, ionization energy, and electronegativity.

Periodic Table

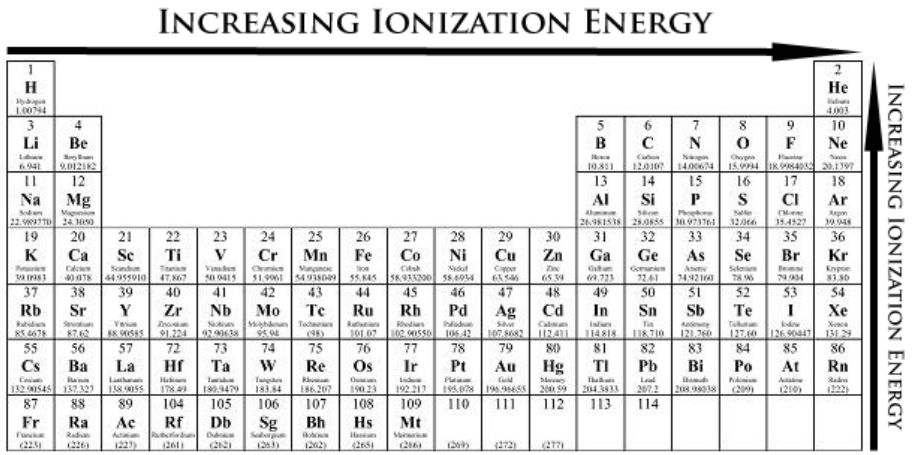


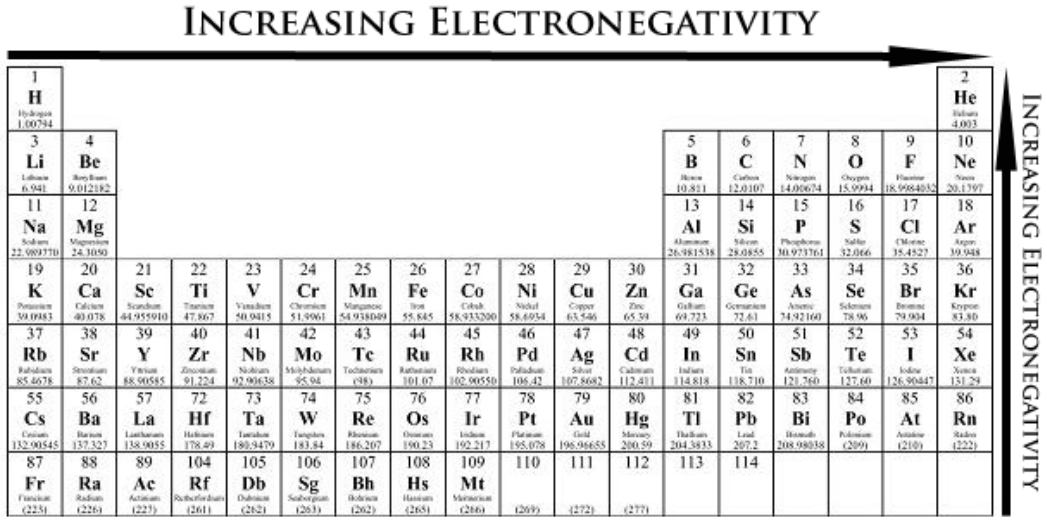
- **Atomic radius:** The radius of an atom; the distance from the atomic nucleus to the outermost stable electron orbital in an atom at equilibrium
- **Ionization energy:** It is the energy required to remove an electron from a gaseous atom or ion.
- **Electron affinity:** Amount of energy released or spent when an electron is added to a neutral atom or molecule in the gaseous state to form a negative ion
- **Electronegativity:** A measure of the ability of a specified atom to attract electrons in a molecule

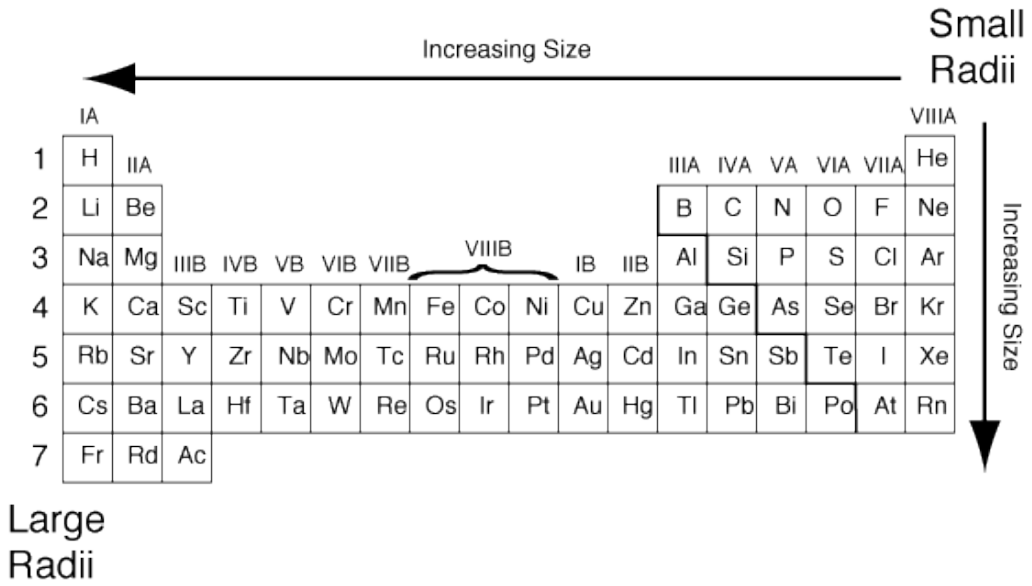
Periodic Table

- A **period** is a horizontal row in the periodic table. Elements in the same period show trends in atomic radius, ionization energy, electron affinity, and electronegativity.
- Moving left to right across a period, atomic radius usually decreases. This occurs because each successive element has an added proton and electron which causes the electron to be drawn closer to the nucleus.
- This decrease in atomic radius also causes the ionization energy to increase when moving from left to right across a period.
- Electronegativity increases in the same manner as ionization energy because of the pull exerted on the electrons by the nucleus.

Periodic Table







Molecules

$$mol = \frac{weight\ of\ sample\ (g)}{molar\ weight\ (\frac{g}{mol})}$$

- Molecules are small particles that make up all living and non-living things. Every molecule is unique due to its chemical properties. They are made up of even tinier particles called atoms.
- A **mole** is defined as the quantity of a substance that has the same number of particles as are found in 12.000 grams of carbon-12. This number, Avogadro's number, is 6.022x1023.
- One mole of a compound contains 6.022x1023 molecules of the compound. The mass of 1 mole of a compound is called its molar weight or molar mass. The units for molar weight or molar mass are grams per mole.

Chemical Bonds

- An **ionic bond** is formed when one atom accepts or donates one or more of its valence electrons to another atom.
- A **covalent bond** is formed when atoms share valence electrons. The atoms do not always share the electrons equally, so a polar covalent bond may be the result.
- When electrons are shared by two metallic atoms a **metallic bond** may be formed.

Definitions

- An **ion** is an atom or a molecule in which the total number of electrons is not equal to the total number of protons, giving the atom or molecule a net positive or negative electrical charge.
- If a neutral atom loses one or more electrons, it has a net positive charge and is known as a **cation (positive ion)**.
- If an atom gains electrons, it has a net negative charge and is known as an **anion (negative ion)**.

Definitions

- **Acids** are ionic compounds (a compound with a positive or negative charge) that break apart in water to form a hydrogen ion (H+).
- **Bases** are ionic compounds that break apart to form a negatively charged hydroxide ion (OH-) in water.
- **Oxidation number** is the state of an element or ion in a compound with regard to the electrons gained or lost by the element or ion in the reaction that formed the compound, expressed as a positive or negative number indicating the ionic charge of the element or ion.

Chemical Reactions

- A chemical reaction is a process that is usually characterized by a chemical change in which the starting materials (reactants) are different from the products. Chemical reactions tend to involve the motion of electrons, leading to the formation and breaking of chemical bonds.
- **Direct Combination or Synthesis Reaction:** In a synthesis reaction two or more chemical species combine to form a more complex product.

A + B --> AB

Chemical Reactions

- The combination of iron and sulfur to form iron (II) sulfide is an example of a synthesis reaction:

$$8\ Fe + S_8 \rightarrow 8\ FeS$$

- **Chemical Decomposition or Analysis Reaction:** In a decomposition reaction a compound is broken into smaller chemical species.

$$AB \rightarrow A + B$$

Chemical Reactions

- The electrolysis of water into oxygen and hydrogen gas is an example of a decomposition reaction:

$$2\,H_2O \dashrightarrow 2\,H_2 + O_2$$

- **Single Displacement or Substitution Reaction:** A substitution or single displacement reaction is characterized by one element being displaced from a compound by another element.

$$A + BC \dashrightarrow AC + B$$

Chemical Reactions

- An example of a substitution reaction occurs when zinc combines with hydrochloric acid. The zinc replaces the hydrogen:

$$Zn + 2\,HCl \rightarrow ZnCl_2 + H_2$$

- **Metathesis or Double Displacement Reaction:** In a double displacement or metathesis reaction two compounds exchange bonds or ions in order to form different compounds.

$$AB + CD \rightarrow AD + CB$$

Chemical Reactions

- An example of a double displacement reaction occurs between sodium chloride and silver nitrate to form sodium nitrate and silver chloride.

$$NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgCl(s)$$

- **Acid-Base Reaction:** An acid-base reaction is type of double displacement reaction that occurs between an acid and a base. The H+ ion in the acid reacts with the OH- ion in the base to form water and an ionic salt:

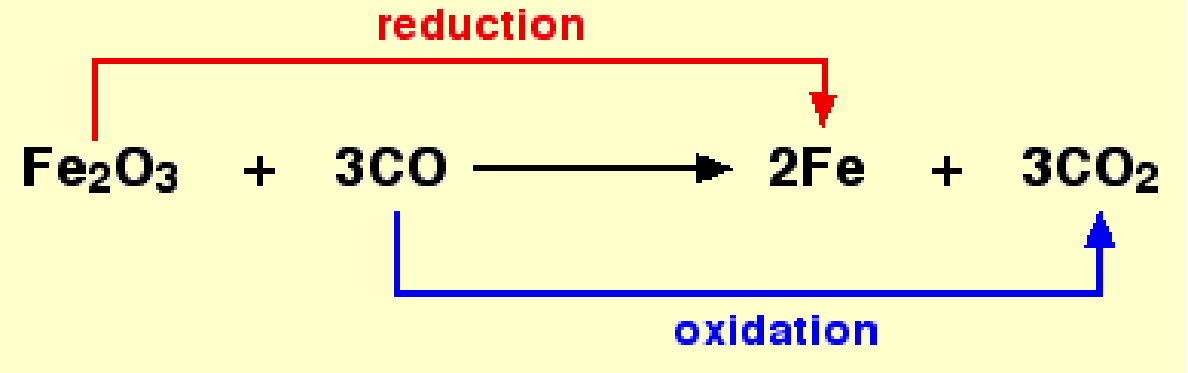
$$HA + BOH \rightarrow H_2O + BA$$

Chemical Reactions

- The reaction between hydrobromic acid (HBr) and sodium hydroxide is an example of an acid- base reaction:

$$HBr + NaOH \text{ -->} NaBr + H_2O$$

- **Oxidation-Reduction or Redox Reaction:** In a redox reaction the oxidation numbers of atoms are changed. Redox reactions may involve the transfer of electrons between chemical species.



Chemical Reactions

- **Combustion:** A combustion reaction is a type of redox reaction in which a combustible material combines with an oxidizer to form oxidized products and generate heat (exothermic reaction). Usually in combustion reactions oxygen combines with another compound to form carbon dioxide and water. An example of a combustion reaction is the burning of naphthalene:

$$C_{10}H_8 + 12\ O_2 \text{ ---> } 10\ CO_2 + 4\ H_2O$$

Chemical Reactions

- **Hydrolysis Reaction:** A hydrolysis reaction involves water. The general form for a hydrolysis reaction is:

$$X^-(aq) + H_2O(l) \leftrightarrow HX(aq) + OH^-(aq)$$