



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

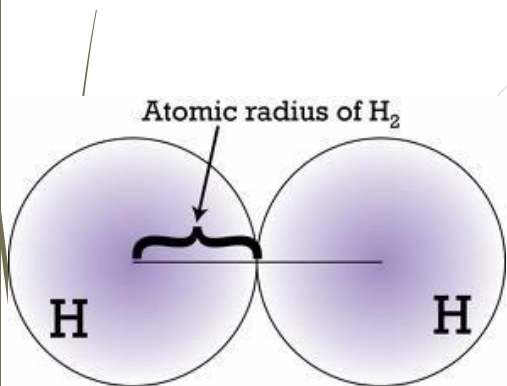
- **The atomic number** is the number of protons in an atom
- **The atomic mass** is the mass of protons, neutrons, and electrons in an atom
- Atomic number doesn't always equate to increasing mass because many atoms don't have a number of neutrons equal to the number of protons.
- In other words, several 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

INCREASING IONIZATION ENERGY

1 H Hydrogen 1.00794																	2 He Helium 4.003														
3 Li Lithium 6.941	4 Be Beryllium 9.012182															5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.00644	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797										
11 Na Sodium 22.989770	12 Mg Magnesium 24.3040															13 Al Aluminum 26.981538	14 Si Silicon 28.0855	15 P Phosphorus 30.973761	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948										
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955910	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938049	26 Fe Iron 55.845	27 Co Cobalt 58.933200	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80														
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.29														
55 Cs Cesium 132.90545	56 Ba Barium 137.327	57 La Lanthanum 138.9055	58 Ce Cerium 140.12	59 Pr Praseodymium 140.90768	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.50019	67 Ho Holmium 164.93033	68 Er Erbium 167.259	69 Tm Thulium 168.93032	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.967	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.222	78 Pt Platinum 195.078	79 Au Gold 196.96657	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98039	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	90 Th Thorium (232)	91 Pa Protactinium (231)	92 U Uranium (238)	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Cn Copernicium (285)	113 Nh Nihonium (286)	114 Fl Flerovium (289)	115 Mc Moscovium (288)	116 Lv Livermorium (293)	117 Ts Tennessine (294)	118 Og Oganesson (294)

INCREASING
IONIZATION ENERGY

INCREASING IONIZATION ENERGY

INCREASING ELECTRONEGATIVITY

1																	2
H Hydrogen 1.00794																	He Helium 4.003
3	4															10	
Li Lithium 6.941	Be Beryllium 9.012182															Ne Neon 20.1797	
11	12															18	
Na Sodium 22.989770	Mg Magnesium 24.3050															Ar Argon 39.948	
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K Potassium 39.0983	Ca Calcium 40.078	Sc Scandium 44.955910	Ti Titanium 47.867	V Vanadium 50.9415	Cr Chromium 51.9961	Mn Manganese 54.938049	Fe Iron 55.845	Co Cobalt 58.933200	Ni Nickel 58.6934	Cu Copper 63.546	Zn Zinc 65.39	Ga Gallium 69.723	Ge Germanium 72.61	As Arsenic 74.92160	Se Selenium 78.96	Br Bromine 79.904	Kr Krypton 83.80
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb Rubidium 85.4678	Sr Strontium 87.62	Y Yttrium 88.90585	Zr Zirconium 91.224	Nb Niobium 92.90638	Mo Molybdenum 95.94	Tc Technetium (98)	Ru Ruthenium 101.07	Rh Rhodium 102.90550	Pd Palladium 106.42	Ag Silver 107.8682	Cd Cadmium 112.411	In Indium 114.818	Sn Tin 118.710	Sb Antimony 121.760	Te Tellurium 127.60	I Iodine 126.90447	Xe Xenon 131.29
55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs Cesium 132.90545	Ba Barium 137.327	La Lanthanum 138.9055	Hf Hafnium 178.49	Ta Tantalum 180.9479	W Tungsten 183.84	Re Rhenium 186.207	Os Osmium 190.23	Ir Iridium 192.217	Pt Platinum 195.078	Au Gold 196.96655	Hg Mercury 200.59	Tl Thallium 204.3833	Pb Lead 207.2	Bi Bismuth 208.98038	Po Polonium (209)	At Astatine (210)	Rn Radon (222)
87	88	89	104	105	106	107	108	109	110	111	112	113	114				
Fr Francium (223)	Ra Radium (226)	Ac Actinium (227)	Rf Rutherfordium (261)	Db Dubnium (262)	Sg Seaborgium (266)	Bh Bohrium (264)	Hs Hassium (277)	Mt Meitnerium (268)									

INCREASING ELECTRONEGATIVITY

Increasing Size

Small Radii

	IA																		VIIIA	
1	H	IIA																	He	
2	Li	Be																		
3	Na	Mg	IIIB	IVB	VB	VIB	VIIIB	VIII B			IB	IIB	Al	Si	P	S	Cl	Ar		
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn		
7	Fr	Rd	Ac																	

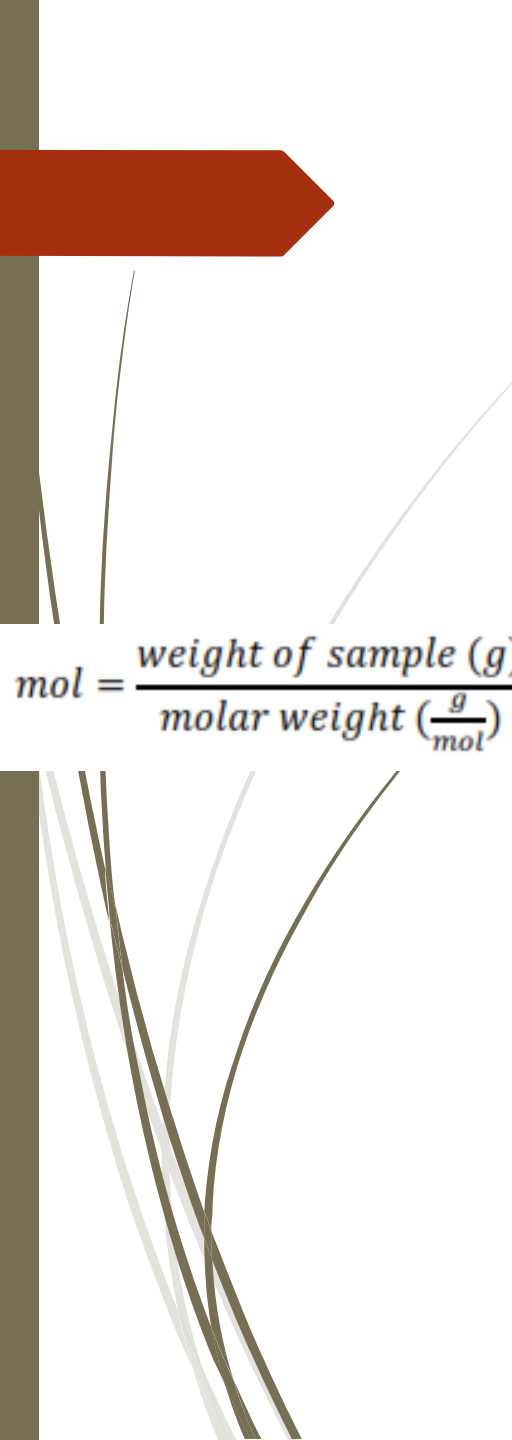
Increasing Size

Increasing Size

Large Radii

Molecules

- 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 6.022×10^{23} .
- One mole of a compound contains 6.022×10^{23} 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**.


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



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.

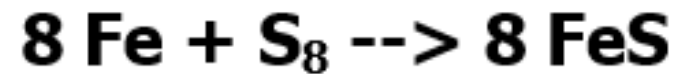
Chemical Reactions

- 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**.



Chemical Reactions

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

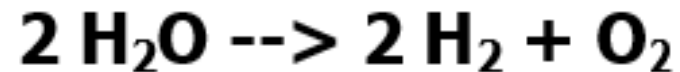


- **Chemical Decomposition or Analysis Reaction:**
In a decomposition reaction a compound is broken into smaller chemical species.



Chemical Reactions

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



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



Chemical Reactions

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

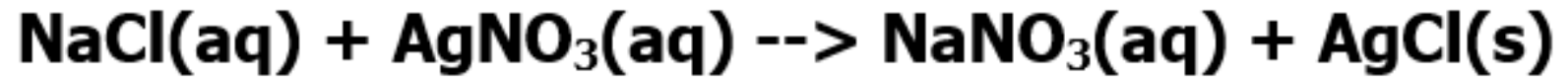


- **Metathesis or Double Displacement Reaction:** In a double displacement or metathesis reaction two compounds exchange bonds or ions in order to form different compounds.



Chemical Reactions

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



- **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:

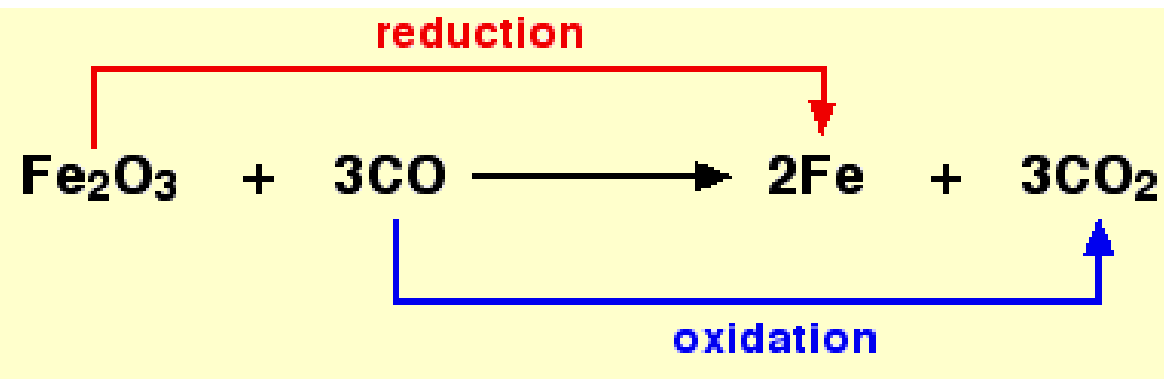


Chemical Reactions

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



- **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:





Chemical Reactions

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

