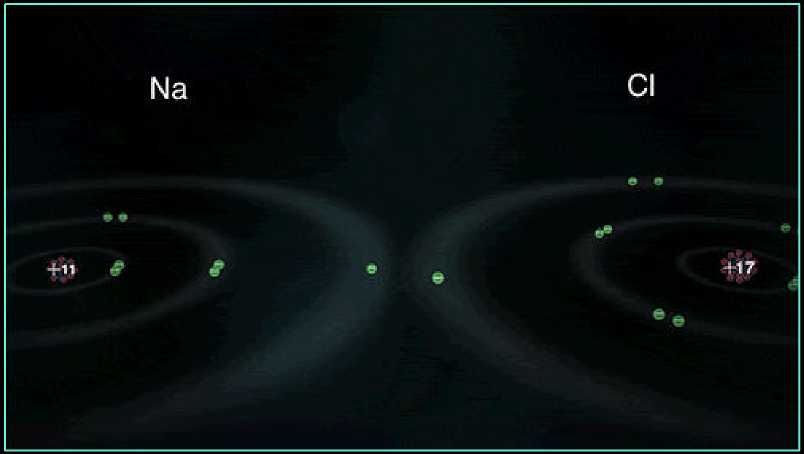
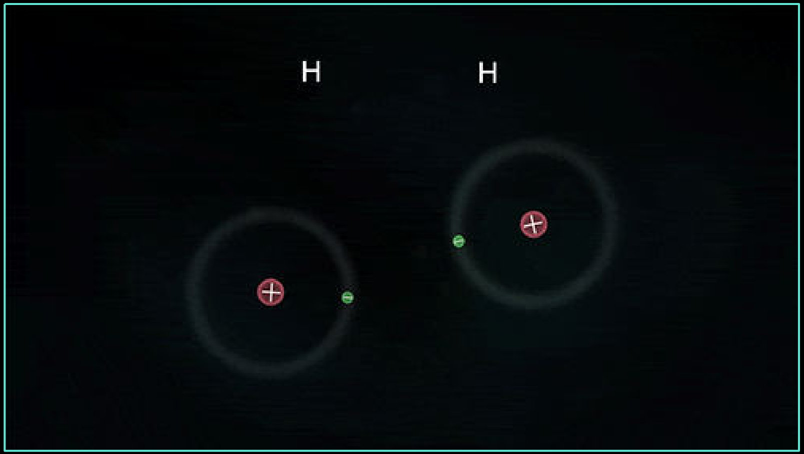
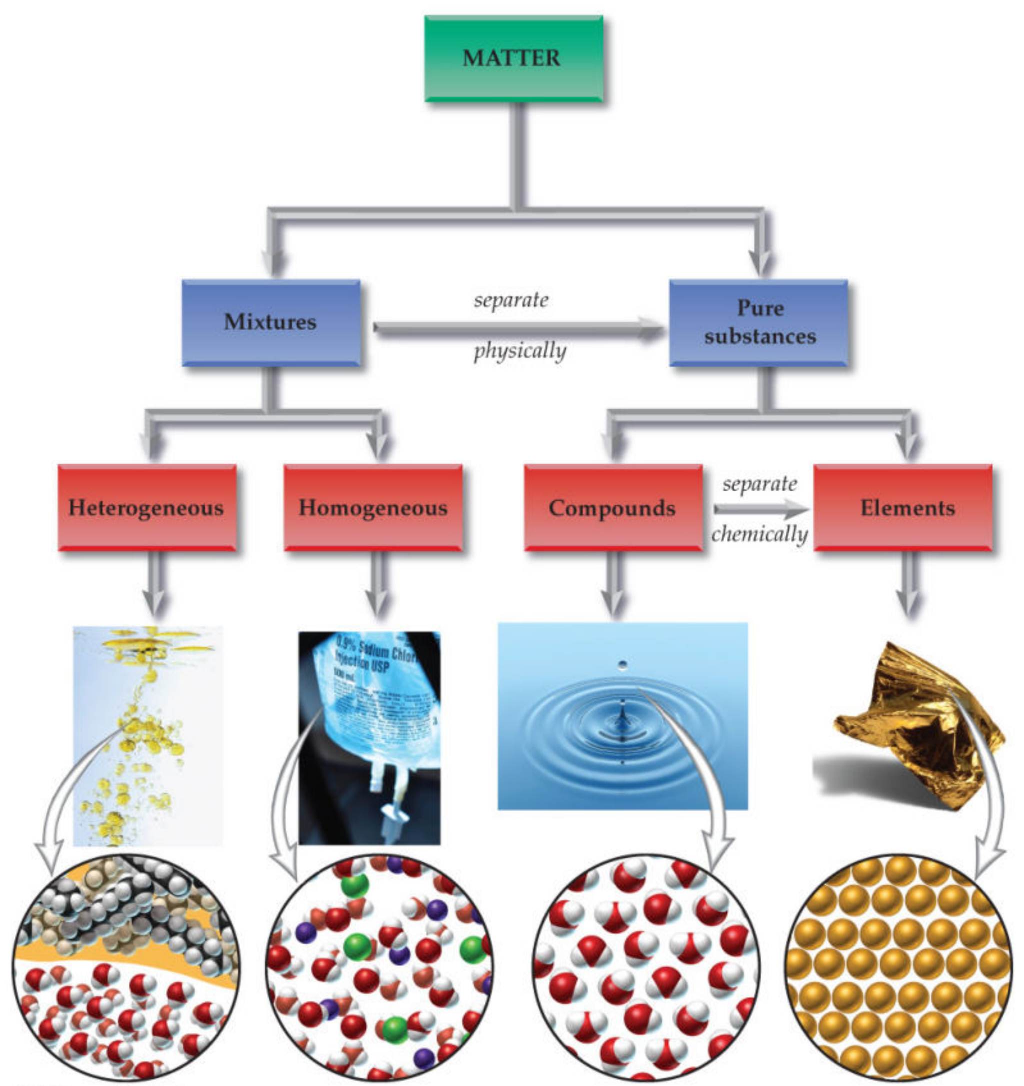
Unit 5:
Ions & Chemical Bonding





A Review of Matter



Elements, Compounds, or Mixtures

Concept Practice:

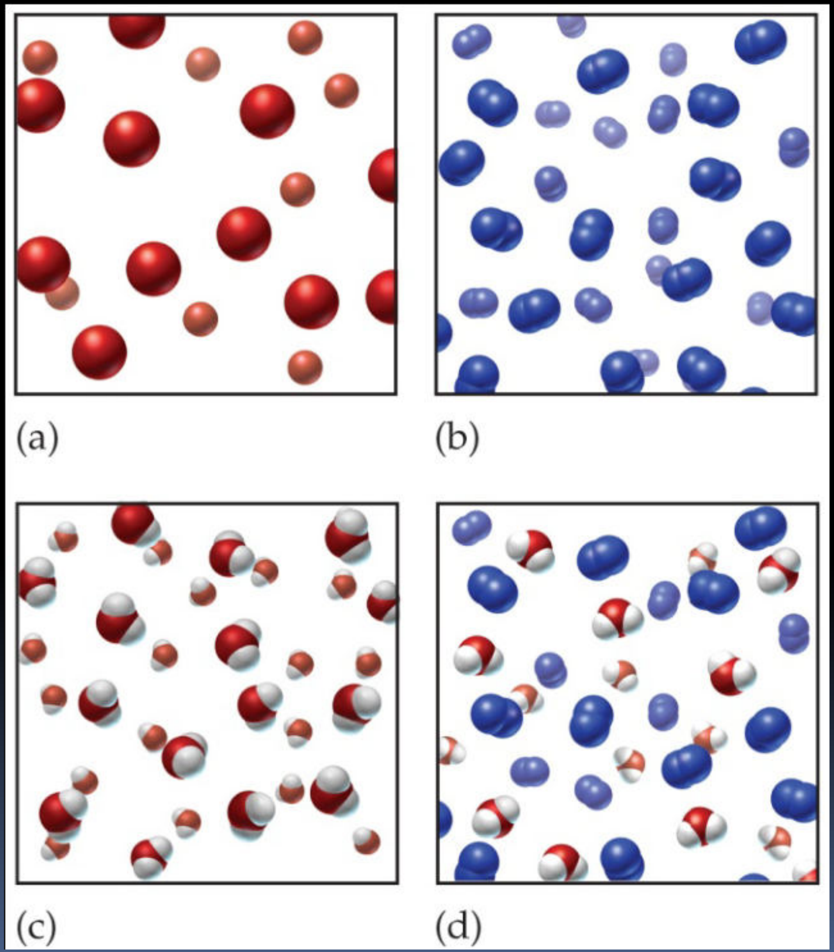
Classify each of the following as an element, a compound, or a mixture as shown in the illustration on the right.

a) Element

b) Diatomic Element

c) Compound/Molecule

d) Mixture



Names of the Elements

- **Each element has a unique name.**
- **Names have several origins:**
  - Hydrogen is derived from **Greek**.
  - Carbon is derived from **Latin**.
  - Scandium is named for **Scandinavia.**
  - Nobelium is named for **Alfred Nobel**.
  - Yttrium is named for the town of Ytterby, **Sweden**.

Pure Yttrium

Latin Symbols

Gold – Au 

Silver – Ag 

Copper – Cu 

Mercury – Hg 

Potassium – K 

Sodium – Na 

Antimony – Sb 

Tin – Sn 

Iron – Fe 

Tungsten – W 

Element Symbols vs Chemical Formulas

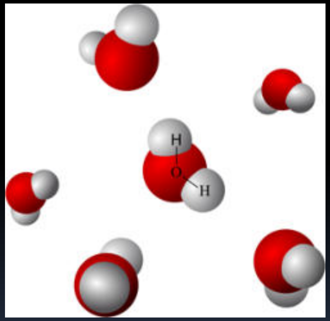
- **When an element symbol has two letters, the first is capitalized and the second is lowercase.**
  - **C** is the symbol for carbon
  - **Cd** is the symbol for cadmium

- **A chemical formula uses a capital letter for each new element.**
  - **Co** is the symbol for the element cobalt
  - **CO** is the formula for carbon monoxide
  - **CoO** is the formula for cobalt II oxide

Law of Definite Composition

- *Compounds always contain the same elements in a **constant proportion by mass**.*

Example: Water is always 11% hydrogen and 89% oxygen by mass



Water = H_2O

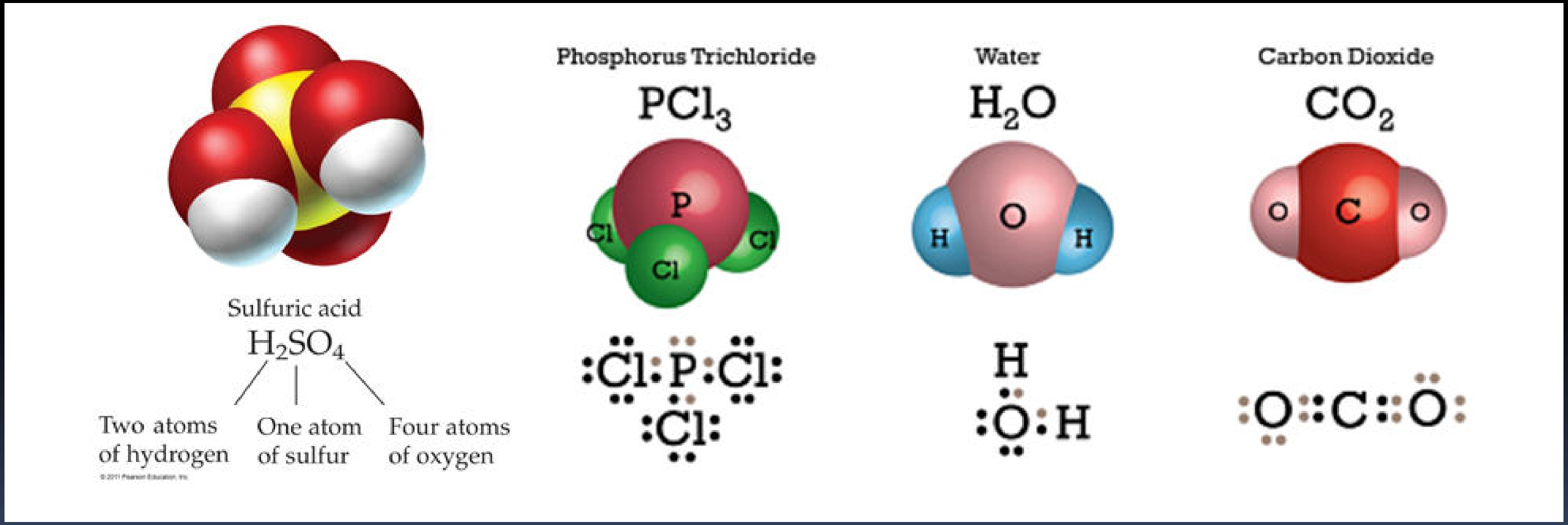
$$\begin{array}{rrcll} & \text{Hydrogen} = 1.00794 & \times 2 & = & 2.0159 \text{ grams} \\ + & \text{Oxygen} = 15.9994 & \times 1 & = & 15.9994 \text{ grams} \\ \hline & & \text{Water} & = & 18.0152 \text{ grams} \end{array}$$

Hydrogen = (2.0159/ 18.1052) × 100 = 11.19% H

Oxygen = (15.9994/ 18.1052) × 100 = 88.81% O

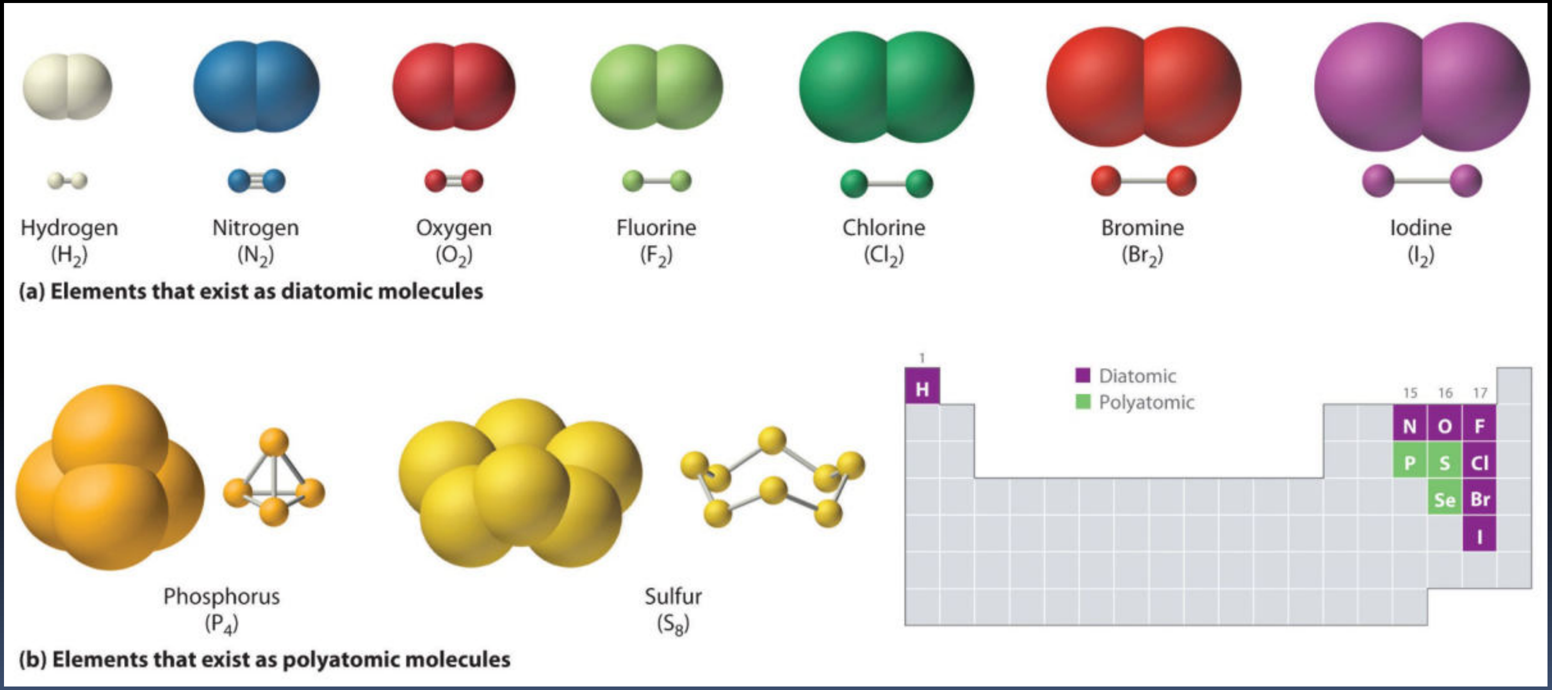
Molecule

- A **covalent** chemical composed of two or more **nonmetal** atoms is called a ***molecule***.



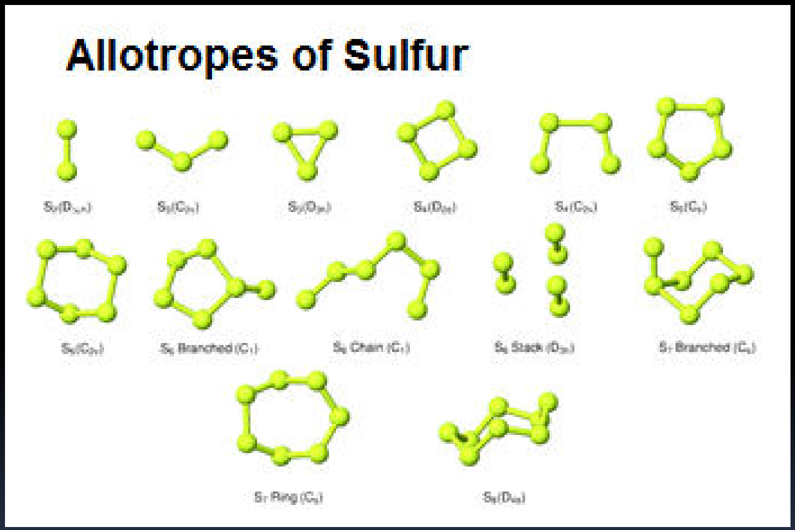
Diatomic Molecules

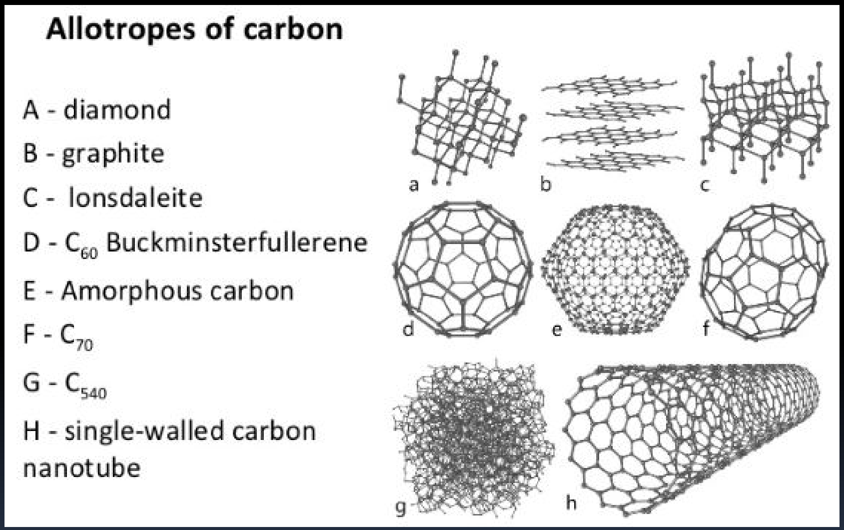
- **Diatomic Molecules** – elements made up of two of the same type of atom.



Allotropes

- **Allotrope** - when an element exists in more than one form in a given physical state

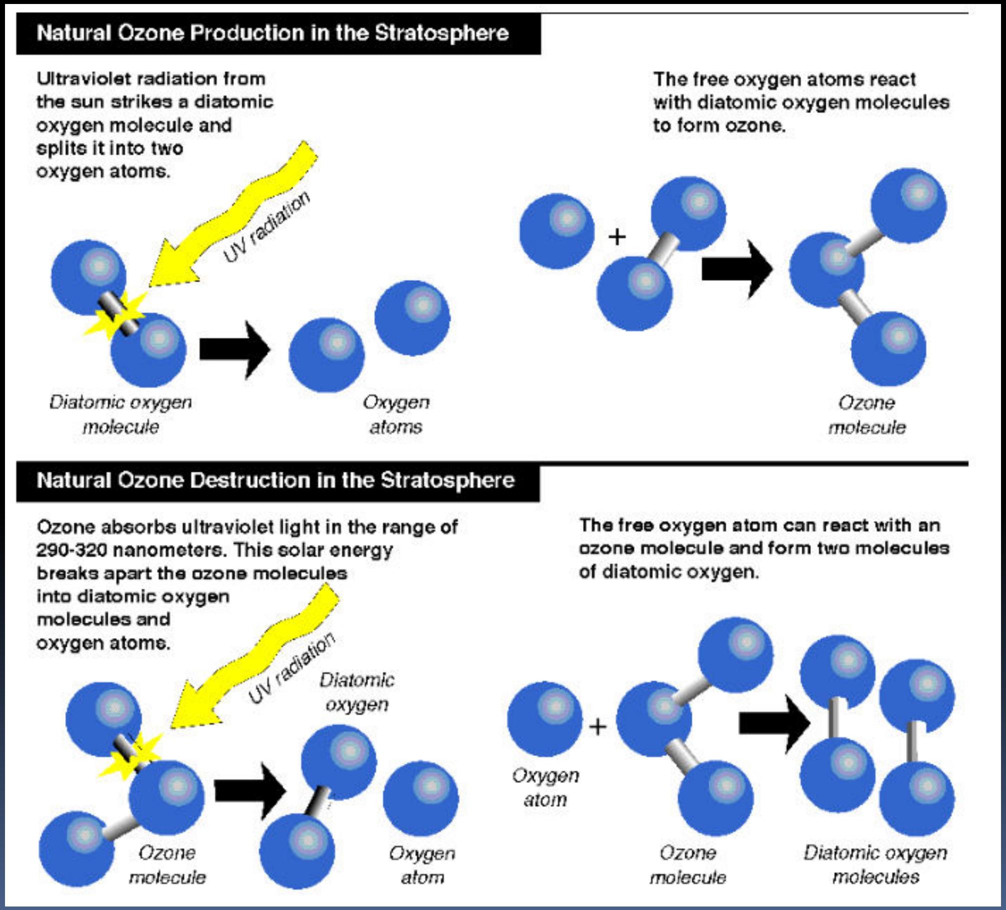




- **Sulfur and carbon have solid state allotropes**.

Allotropes of Oxygen

- Oxygen's allotropes are in the gas state.



Law of Multiple Proportions

- When elements combine in different ways to form different compounds, they always do it in whole number ratios.

Examples:

- **Theobromine** is a bitter alkaloid of the cacao plant: $C_7H_8N_4O_2$
- Vitamin B3, also called niacin, can treat high cholesterol and triglyceride levels: $C_6H_6N_2O$

Chemical Nomenclature

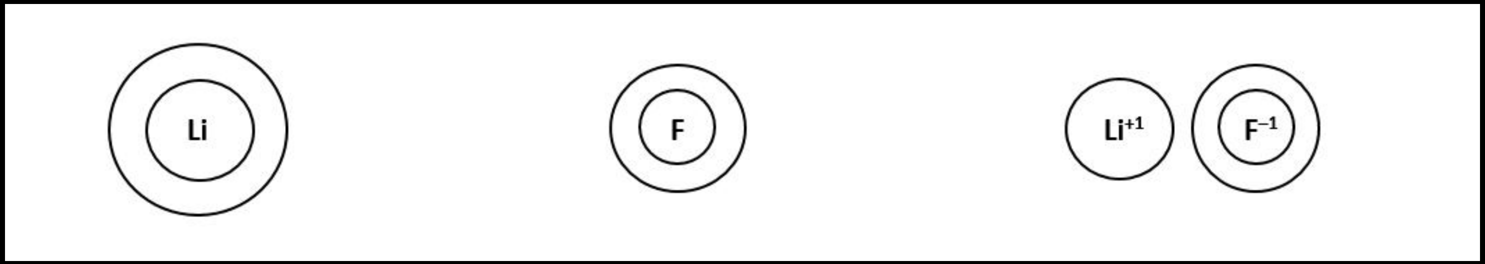
- **Chemical formulas** are used to represent compounds and molecules.

- **Subscripts** equa the number of atoms of each type of element in the formula

- The **International Union of Pure and Applied Chemistry (IUPAC)** system is used for naming compounds.

Ionic Bonding

- Occurs when a metal atom **TRANSFERS** valence electrons to a nonmetal atom to form a compound.

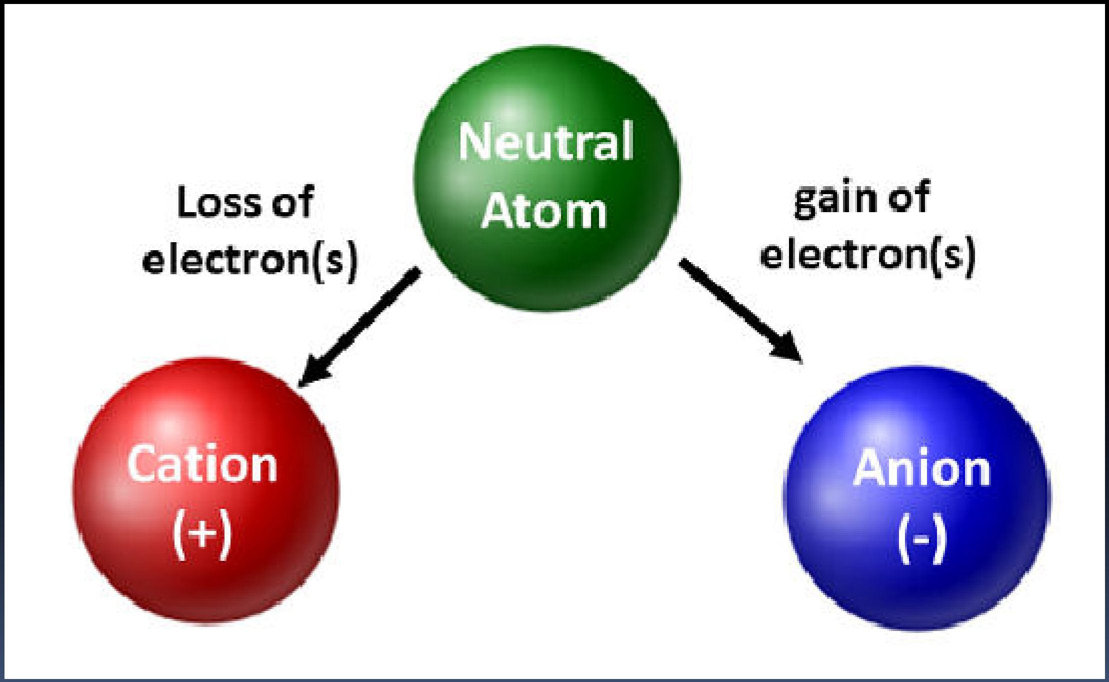


Notice that the valence orbitals of each ion are completely filled.

Lithium $1s^2$ Fluorine $1s^2\ 2s^2\ 2p^6$

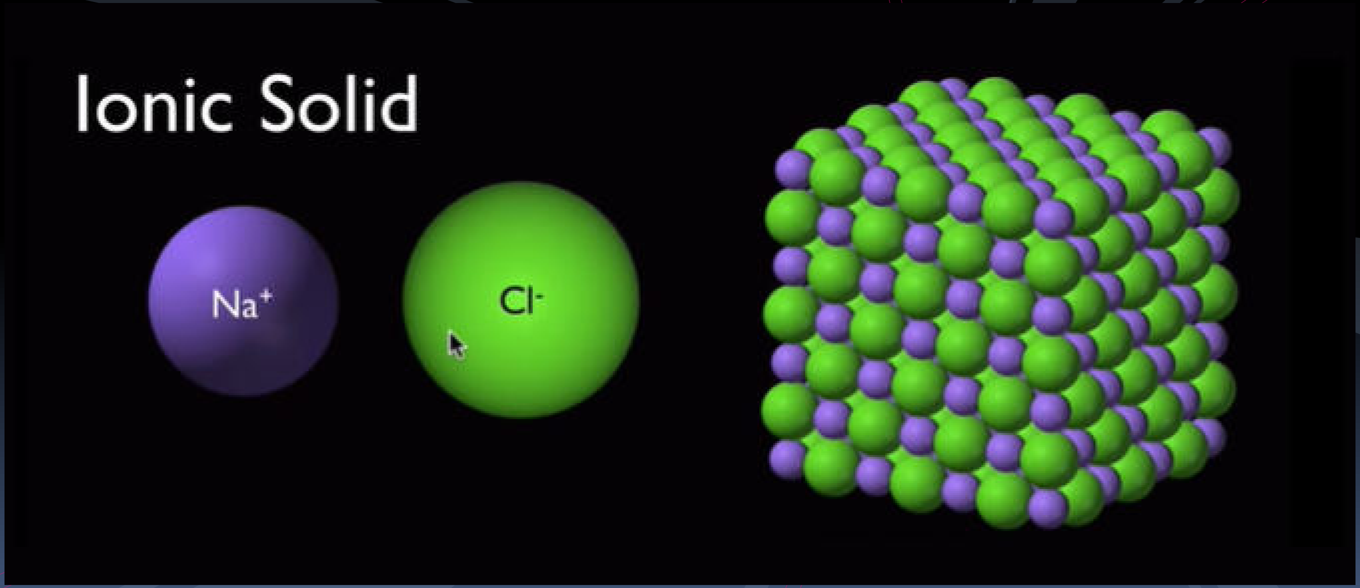
Ions & Chemical Bonding

- When neutral atoms lose or gain valence electrons, they become **IONS**.



Properties of Ionic Compounds

- Crystal Lattice
- High melting points
- Low Vapor Pressure
- Brittle
- Poor Conductors
- Aqueous Solution

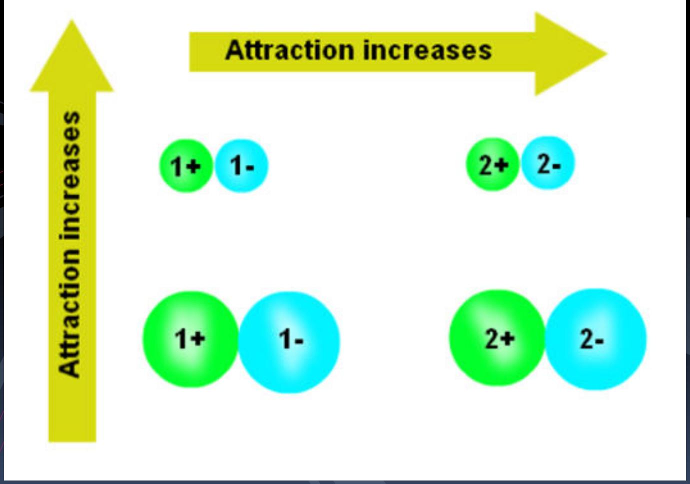


Lattice Energy

According to Coulomb's Law, the **closer** the charges the **stronger** the force. So as atoms get smaller, the ionic bond gets stronger and requires **more** energy to break apart.

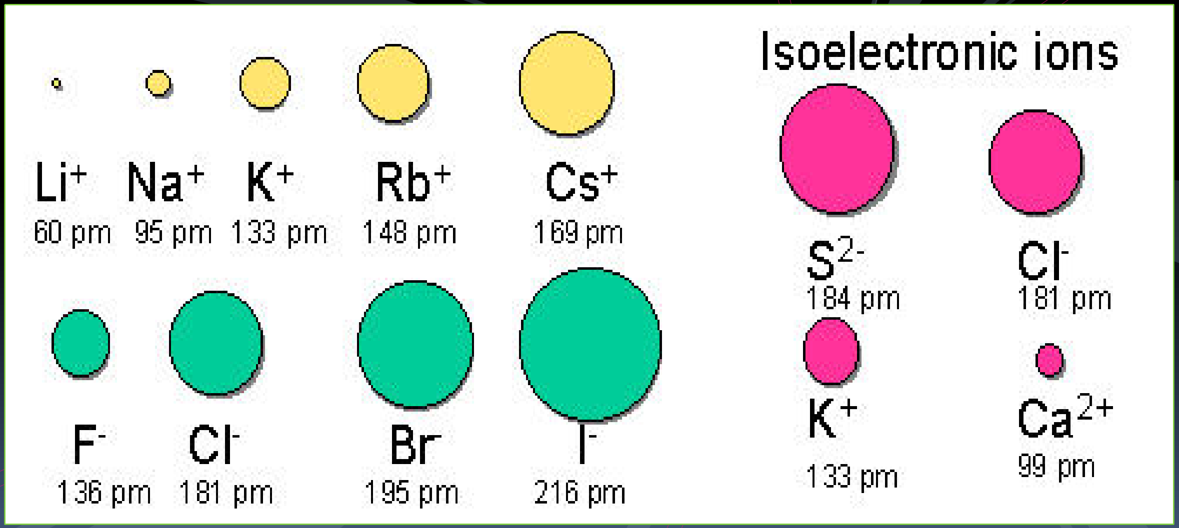
TABLE 6.3 Lattice Energies of Some Ionic Solids (kJ/mol)

	Anion				
Cation	**F^-**	**Cl^-**	**Br^-**	**I^-**	**O^{2-}**
Li^+	1036	853	807	757	2925
Na^+	923	787	747	704	2695
K^+	821	715	682	649	2360
Be^{2+}	3505	3020	2914	2800	4443
Mg^{2+}	2957	2524	2440	2327	3791
Ca^{2+}	2630	2258	2176	2074	3401
Al^{3+}	5215	5492	5361	5218	15,916



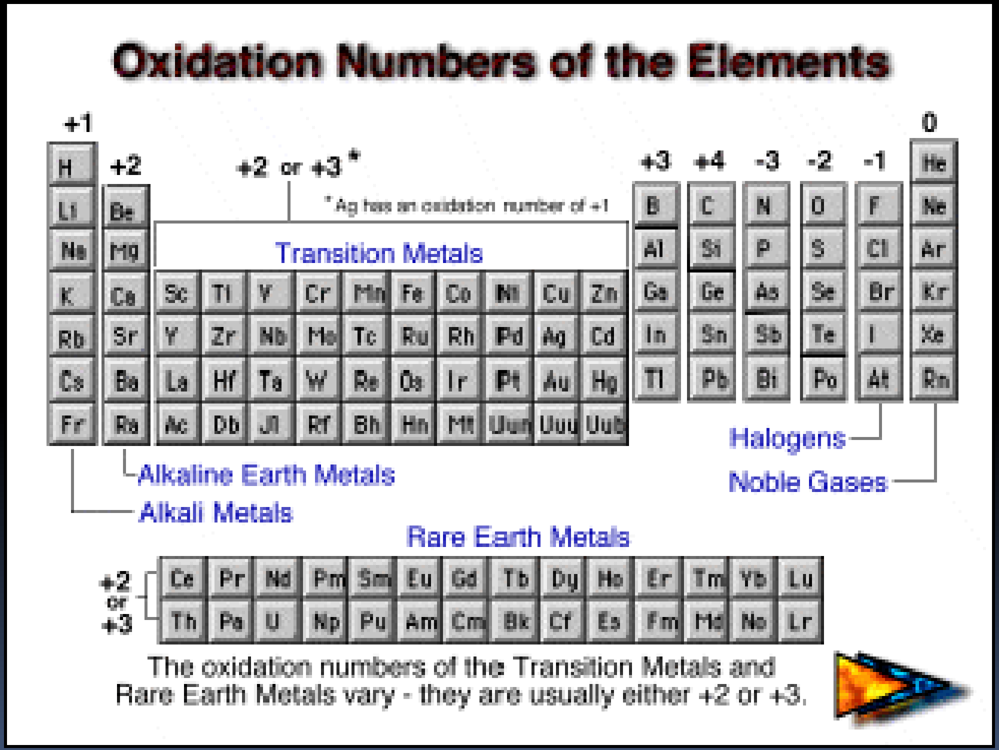
Practice Problems

- The lattice energy of NaCl is ___greater___ than RbCl.
- A bond between Ca and F is ___stronger___ than a bond between Na and Cl.
- The melting point of KBr is ___less___ than LiF.



Oxidation numbers

- **Ionic charge** based on the number of electrons lost or gained.



Net charge = zero

- When **opposite** ions attract, their charges **cancel out**.
  - 1 Na^{+1} + 1 Cl^{-1} → $NaCl$ sodium chloride
  - 2 Na^{+1} + 1 O^{-2} → Na_2O sodium oxide
  - 1 Mg^{+2} + 2 Cl^{-1} → $MgCl_2$ magnesium chloride
  - 1 Mg^{+2} + 1 O^{-2} → MgO magnesium oxide

Naming Transition Metals

- Transition Metals have multiple oxidation states because of the unpaired electrons in the **d-orbital**.
- The IUPAC naming system assigns **Roman Numerals** to indicate their **ionic charge**.

Examples:

$1\ Fe^{+2} + 1\ O^{-2} \rightarrow FeO$ iron **II** oxide

$2\ Fe^{+3} + 3\ O^{-2} \rightarrow Fe_2O_3$ iron **III** oxide

Polyatomic Ions

- **Nonmetal molecules** that form an ionic charge.

Must memorize the following:

NH_4^{+1}	Ammonium	CO_3^{-2}	Carbonate
OH^{-1}	Hydroxide	SO_4^{-2}	Sulfate
NO_3^{-1}	Nitrate	PO_4^{-3}	Phosphate

Common Polyatomic Ionic Bonds

- **Baking Soda – Sodium bicarbonate**

  $1\ Na^{+1} + 1\ HCO_3^{-1} \rightarrow NHCO_3$

- **Calcium phosphate** –

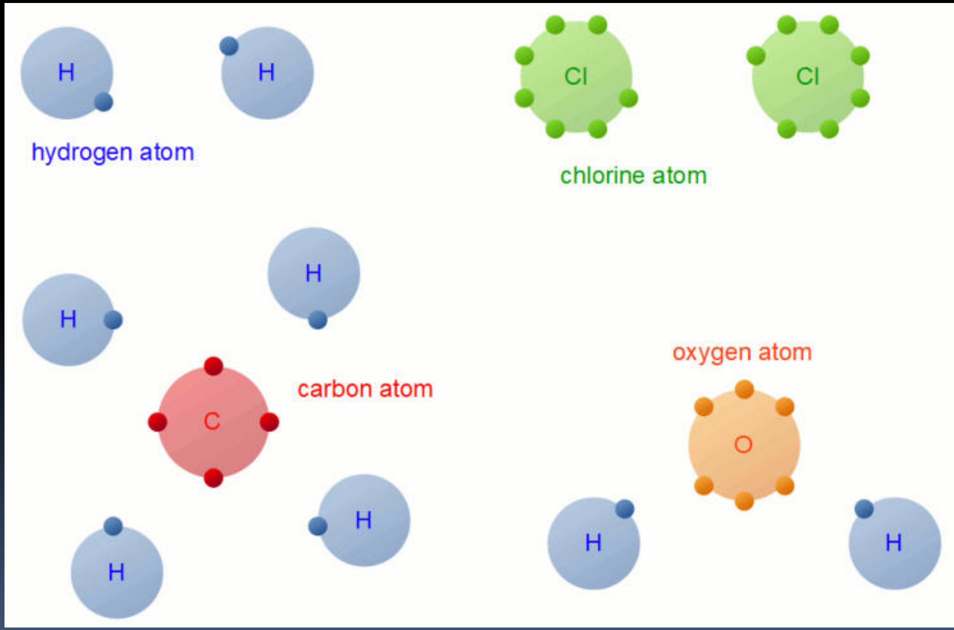
  $3\ Ca^{+2} + 2\ PO_4^{-3} \rightarrow Ca_3(PO_4)_2$

- **Iron II hydroxide** –

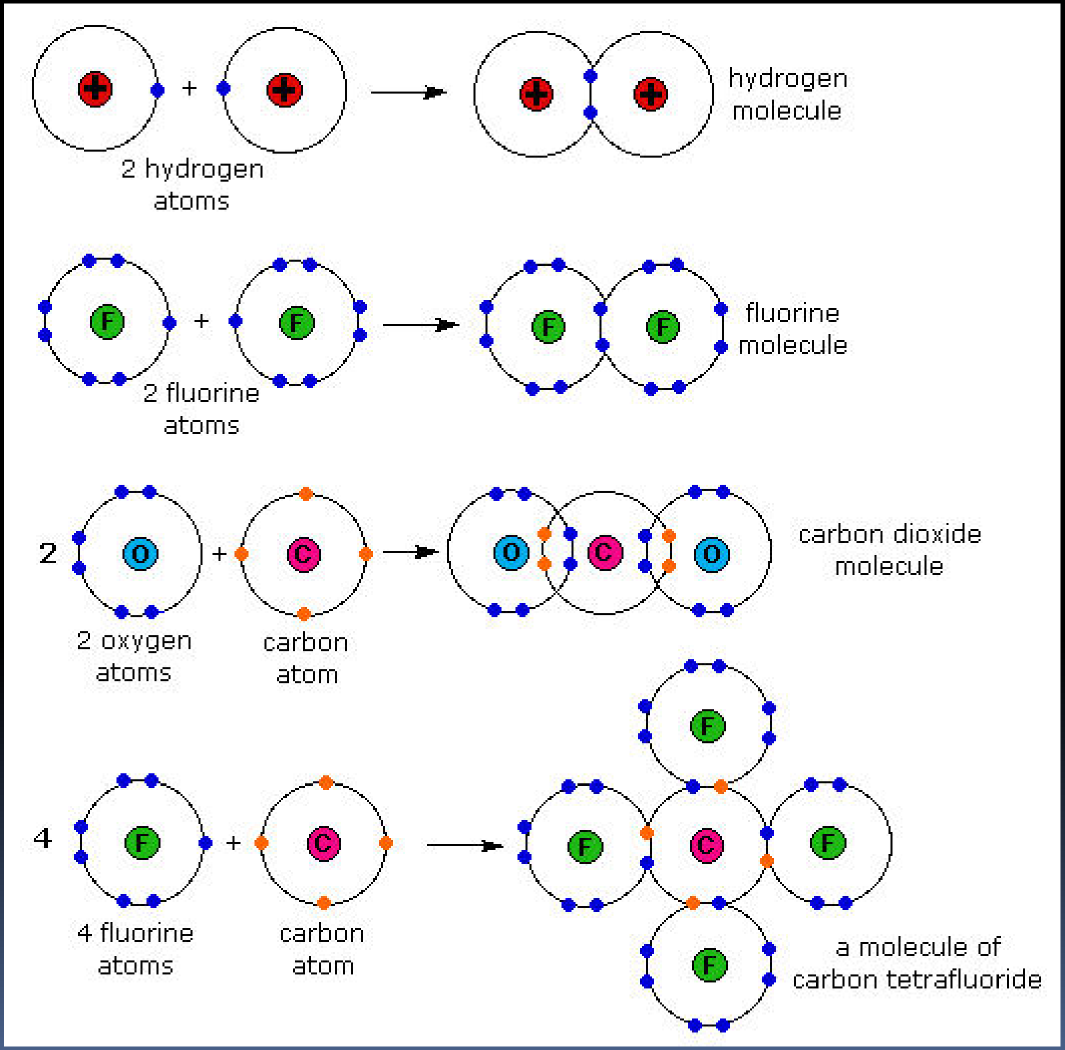
  $1\ Fe^{+2} + 2\ OH^{-1} \rightarrow Fe(OH)_2$

Covalent Bonding

- Occurs when two or more **nonmetal** atoms **SHARE** valence electrons to form a **molecule.**
- Generally follows the **OCTET RULE**, most atoms want 8 valence electrons in outer orbital



Examples of Covalent Bonding



H_2

F_2

CO_2

CF_4

Common Covalent Compounds

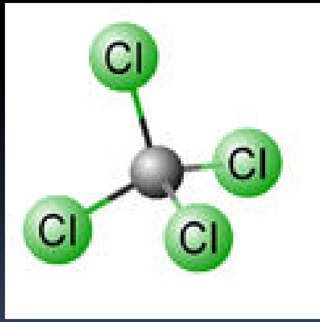
Ammonia NH_3

Water H_2O

Methane CH_4

Carbon Monoxide CO

Carbon Dioxide CO_2



Carbon Tetrachloride CCl_4

Sulfur Dioxide SO_2