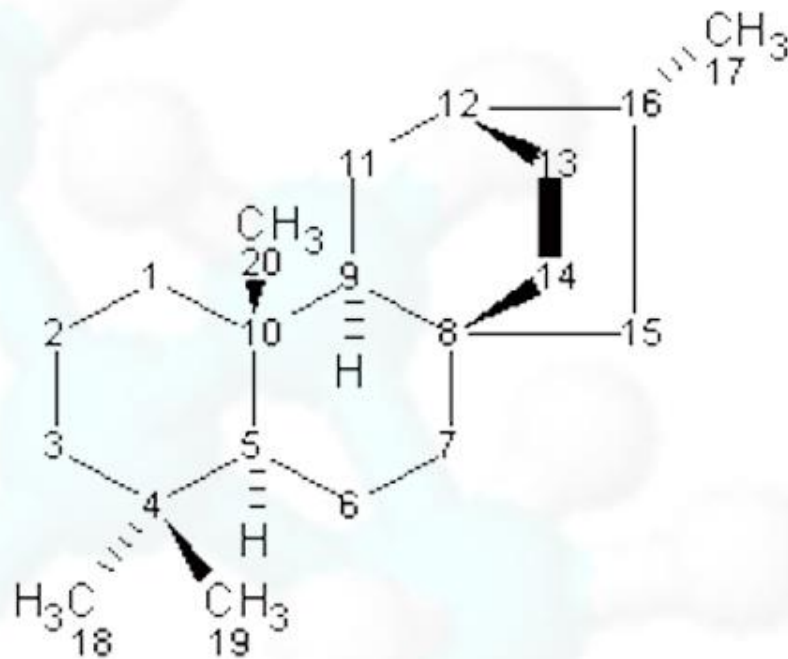
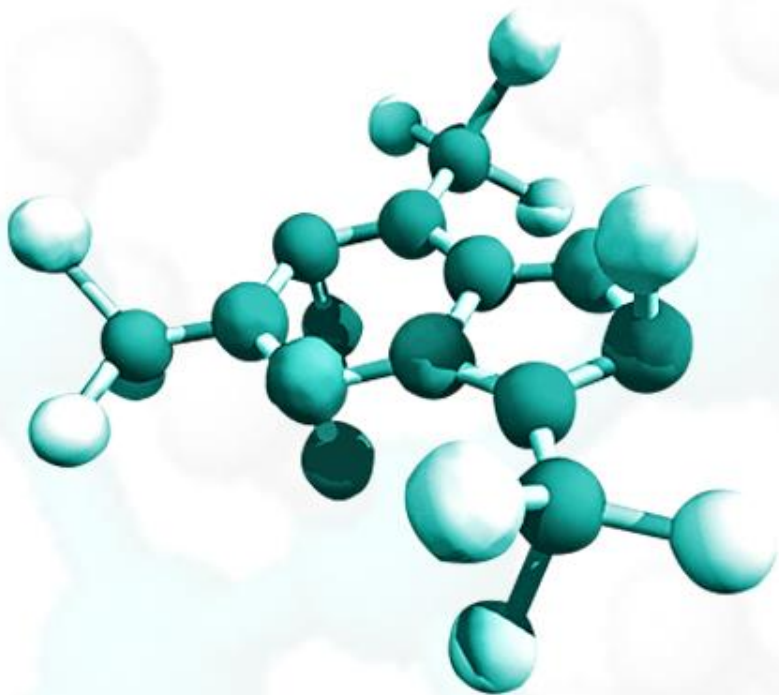
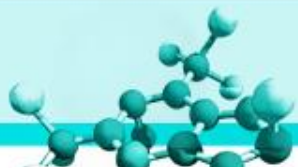




Chapter Two

Atoms, ions, molecules and compounds



The Atomic Theory

Dalton's atomic theory has four assumptions:

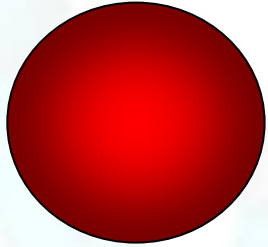
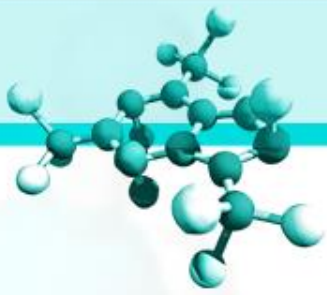
- 1. Atoms are the building blocks of elements.*
- 2. For the same element, all atoms are identical. The atoms for one element are different from the atoms of all other elements.*
- 3. Atoms combine in definite ratio to make compounds.*
- 4. A chemical reaction involves only the separation, combination and rearrangement of atoms. It does not result in their creation or destruction.*



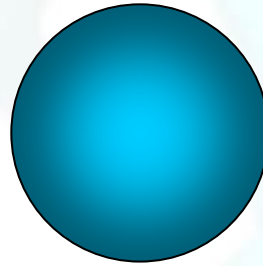
What is atom?

Atom is the basic unit of an element that can enter into chemical combination.

Structure of atom



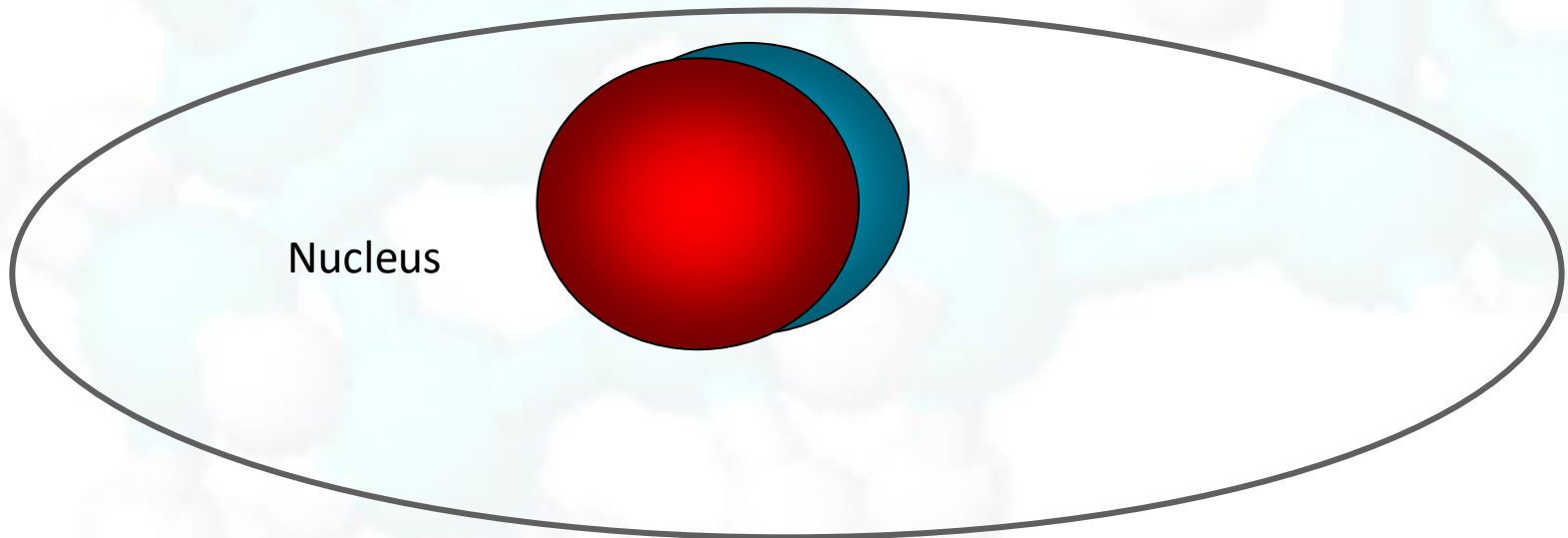
proton



Neutron



Electron



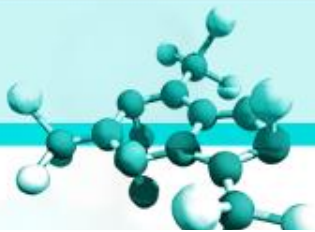


- *Protons and neutrons are together in the nucleus of an atom, whereas electrons are in motion in orbits around the central nucleus.*
- *Protons carry **a positive** electrical charge, electrons carry a **negative** charge, and neutrons carry **no charge**.*
- *Most **atoms** are electrically neutral, meaning that they have an equal number of protons and electrons*

Particle	Symbol	Charge	Mass
<i>Electron</i>	e^{-}	<i>-1</i>	<i>0.0005486 amu</i>
<i>Proton</i>	p^{+}	<i>+1</i>	<i>1.007276 amu</i>
<i>Neutron</i>	n^0	<i>0</i>	<i>1.008665 amu</i>

amu is *atomic mass unit*

$$1 \text{ amu} = 1.66053886 \times 10^{-27} \text{ kilograms}$$



Atomic Number and Mass Number

- *All atoms can be identified by the number of protons and neutrons they contain.*
- **Atomic number** *is the number of protons in the nucleus.*
- **In neutral atom** *the number of protons is equal to the number of electrons, thus the atomic number also refers to the number of electron.*
- *The chemical identity of an atom can be determined solely by the atomic number.*



Atomic Number and Mass Number

- **Example:** *the atomic number of Fluorine is 9 this means that each fluorine atom have 9 protons and 9 electrons.*

Any atom have 9 protons is Fluorine.

- **Atomic Mass** *is the total number of neutrons and protons present in the nucleus of an atom of an element.*

number of neutrons = atomic mass - atomic number

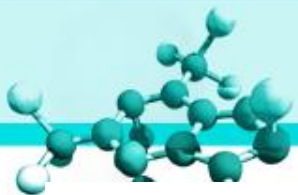


Periodic Table of the Elements

Periodic Table of the Elements																					
Atomic Number Symbol Name Atomic Mass																					
1 1A 1A																	18 VIIIA 8A				
1 H Hydrogen 1.008	2 IIA 2A															13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012															5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948				
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.09	35 Br Bromine 79.904	36 Kr Krypton 84.80				
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29				
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018				
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown				

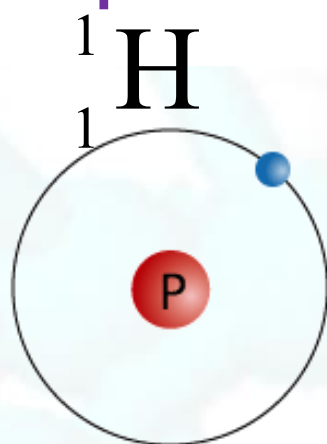
Lanthanide Series	57 La Lanthanum 138.906	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.966	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

Alkali Metal	Alkaline Earth	Transition Metal	Basic Metal	Semimetal	Nonmetal	Halogen	Noble Gas	Lanthanide	Actinide
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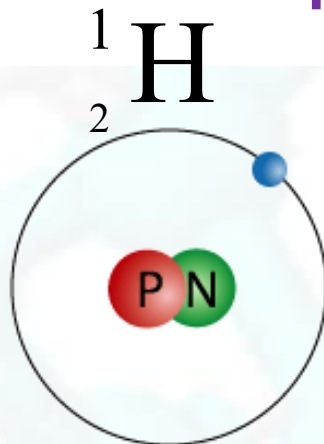
Isotopes

- **Isotopes** are atoms that have the same atomic number (proton number) but different mass numbers.
- This means the number of neutrons is the only difference between isotopes.
- For example there are 3 isotopes for hydrogen



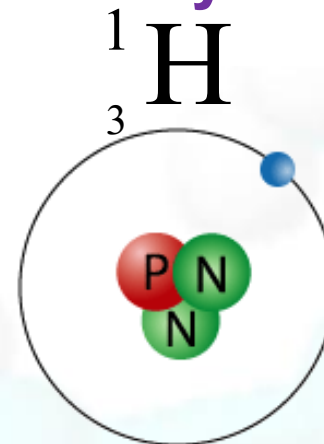
Hydrogen

Protium—one proton (●) and no neutrons; mass number = 1



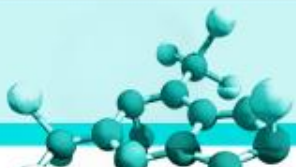
Deuterium

Deuterium—one proton (●) and one neutron (●); mass number = 2

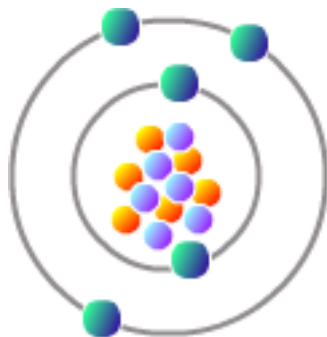


Tritium

Tritium—one proton (●) and two neutrons (●); mass number = 3



- **Example:** *Carbon (atomic number 6) has three natural isotopes with atomic weights of 12, 13 and 14.*



Carbon

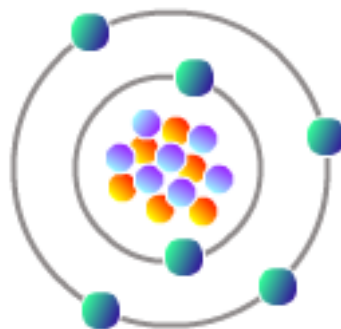
● 6 Protons

● 6 Neutrons

Nuclear number

$$= 6 + 6$$

$$= 12$$



Carbon-13

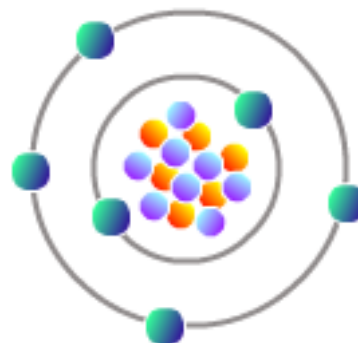
● 6 Protons

● 7 Neutrons

Nuclear number

$$= 6 + 7$$

$$= 13$$



Carbon-14

● 6 Protons

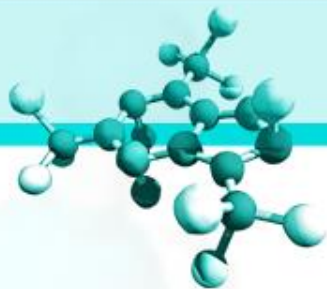
● 8 Neutrons

Nuclear number

$$= 6 + 8$$

$$= 14$$

- *With exception of hydrogen, which has different names for each of its Isotopes, isotopes of element are identified by their mass number. For example carbon isotopes are called : carbon-12 , carbon-13 and carbon-14*

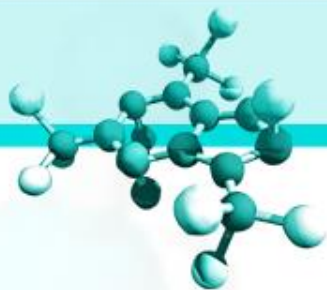


- **Important notice** : *as chemical properties of element is determined by the number of protons and electrons. Thus isotopes of an element have similar chemistries, forming the same type of compounds and displaying similar reactivity.*

Do you understand Isotopes?

- *How many protons, neutrons, and electrons are in* $^{14}_6\text{C}$

6 protons, 8 (14 - 6) neutrons, 6 electrons



Ions

Ion is an atom or a group of atoms that has a net of positive or negative charge.

Cation

An ion with positive charge

If a neutral atom loses one or more electrons it becomes a cation.

Na

11 protons
11 electrons

Cl

17 protons
17 electrons

Anion

An ion with negative charge

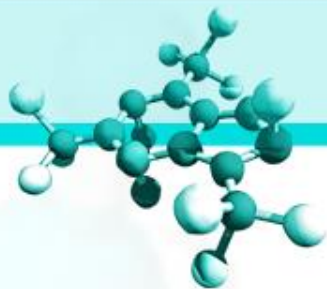
If a neutral atom gains one or more electrons it becomes an anion.

Na⁺

11 protons
10 electrons

Cl⁻

17 protons
18 electrons



Ions

Cation

An ion with positive charge

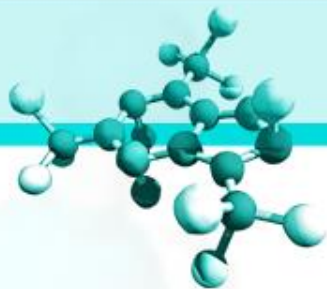
If a neutral atom loses one or more electrons it becomes a cation.

Na

11 protons
11 electrons

Na⁺

11 protons
10 electrons



Anion

An ion with negative charge

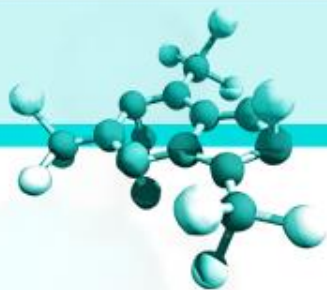
If a neutral atom gains one or more electrons it becomes an anion.

Cl

17 protons
17 electrons

Cl⁻

17 protons
18 electrons



Ions

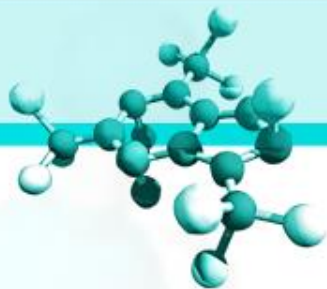
Monatomic ions

Ions contain only one atom.
Example : Na^+ , Mg^{+2} , S^{-2} ,

Polyatomic ions

Ions contain more than one atom
Example : NH_4^+ , CN^- , OH^-

1 1A	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
Li^+												Al^{3+}		C^{4-}	N^{3-}	O^{2-}	F^-
Na^+	Mg^{2+}	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B			P^{3-}	S^{2-}	Cl^-	
K^+	Ca^{2+}				Cr^{2+} Cr^{3+}	Mn^{2+} Mn^{3+}	Fe^{2+} Fe^{3+}	Co^{2+} Co^{3+}	Ni^{2+} Ni^{3+}	Cu^+ Cu^{2+}	Zn^{2+}				Se^{2-}	Br^-	
Rb^+	Sr^{2+}									Ag^+	Cd^{2+}		Sn^{2+} Sn^{4+}		Te^{2-}	I^-	
Cs^+	Ba^{2+}									Au^+ Au^{3+}	Hg_2^{2+} Hg^{2+}		Pb^{2+} Pb^{4+}				



Do You Understand Ions?

How many protons and electrons are in ${}_{27}^{13}\text{Al}^{3+}$?

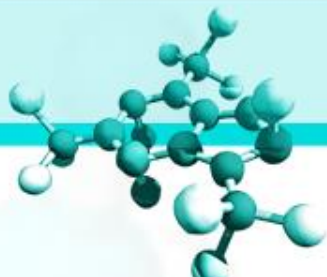
Proton = 13 , electron = $13 - 3 = 10$

Neutron = $27 - 13 = 14$

How many protons and electrons are in ${}_{78}^{34}\text{Se}^{2-}$?

Proton = 34 , electron = $34 + 2 = 36$

Neutron = $78 - 34 = 44$



Molecules

- Molecules : is an aggregate of at least two atoms or more in a definite arrangement held together by chemical forces.

- **What is the difference between molecule and compound?**

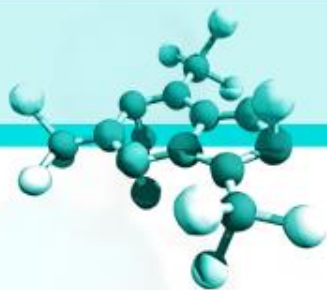
Molecules may contain two atoms of the same element or atoms of different elements.

Compound only contain two or more elements.

Thus all compounds are molecules but not all molecules are compounds.

Molecules or compounds ?

H₂O , I₂ , NaCl , H₂ , O₂ , NaOH



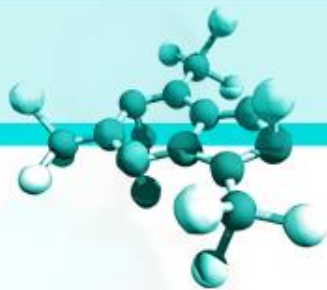
Molecules

Diatomic Molecules

Molecules contain only two atoms. Example : H_2 , O_2 , N_2 , HCl , CO

Polyatomic molecules

Molecules contain more than two atoms. Example : H_2O , NH_3 , O_3

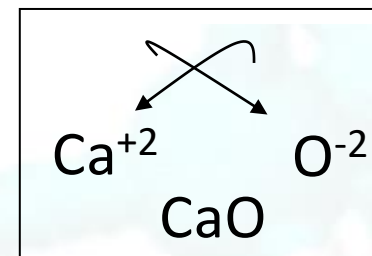
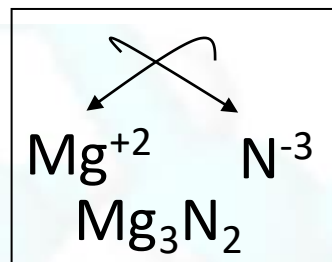
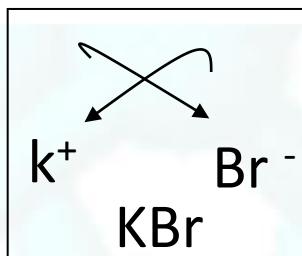
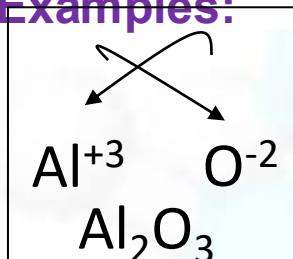


Ionic Compounds

Formula of Ionic Compounds

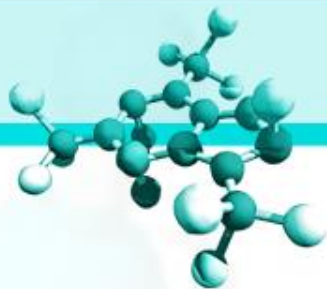
- Ionic compound consist of **a cation** and **an anion**.
- *The sum of the charges on the cation and anion in each formula unit must equal zero.*
- *The subscript of the cation is numerically equal to the charge on the anion, and the subscript on the anion is numerically equal to the charge on the cation*

Examples:



Metals ions have +ve charges (Cations)

[illegible]



The Name of Ionic Compounds

- *Mostly metals cation + nonmetal anion*
- *Rule: Name the metal first, then the nonmetal as -ide.*

Example :

NaCl Sodium chlor**ide**

ZnI₂ Zinc iod**ide**

Al₂O₃ Aluminum ox**ide**

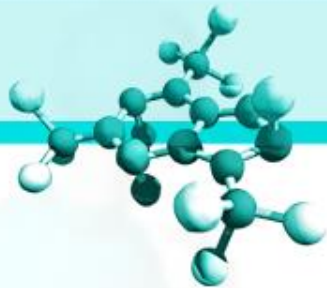
Na₃N Sodium nitri**de**

KBr Potassium brom**ide**

CaO Calcium ox**ide**

MgS Magnesium sulf**ide**

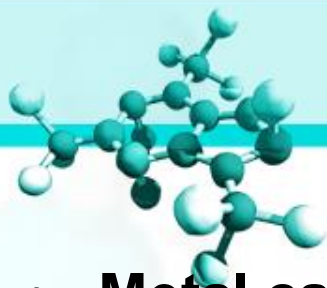
NH_4^+ is called ammonium



Ionic Compounds

Alkali metals ↓ 1A		Alkaline earth metals ↓ 2A												Group numbers ↓					Noble gases ↓ 8A	
1 H		4 Be		Transition metals										3A	4A	5A	6A	7A	2 He	
3 Li														5 B	6 C	7 N	8 O	9 F	10 Ne	
11 Na	12 Mg													13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr			
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe			
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn			
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113	114 Fl	115	116 Lv	117 **	118			
Lanthanides			58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu				
Actinides			90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr				

**Element 117 is currently under review by IUPAC.



Types of Metals

- **Metal cations can be divided into two categories:**

1- metal form one type of cation. Example: Alkali group and alkali earth group.

2- metal form more than one type of cation. Example: transition metals. (Fe^{+2} , Fe^{+3}).

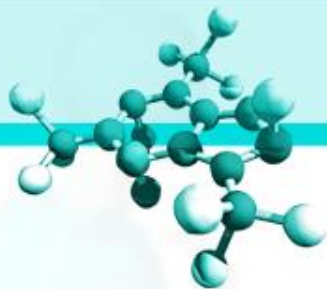
- **Rule Exceptions:**

If have a variable charged metal, then give its charge in the middle with a Roman Numeral in parenthesis. This called stock system.

Example:

$FeCl_2$ = Iron (II) Chloride.

$FeCl_3$ = Iron (III) chloride



Ionic Compounds

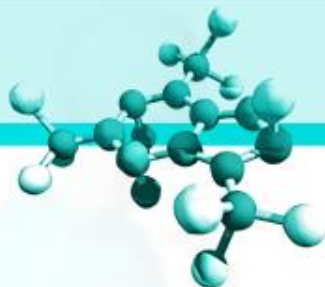
- **Nonmetal anion can be divided into two groups:**

1- *monoatomic anion. Example: Cl^- chloride, Br^- bromide, O^{2-} Oxide.*

2- *Polyatomic anion. Example: OH^- hydroxide, CN^- cyanide.*

- **Common names for some anions:**

CO_3^{2-} Carbonate,	PO_4^{3-} Phosphate,	SO_4^{2-} Sulphate
HCO_3^- Bicarbonate,	NO_3^- Nitrate,	SO_3^{2-} Sulphite



Ionic Compounds

TABLE 2.2

The “-ide” Nomenclature of Some Common Monatomic Anions According to Their Positions in the Periodic Table

Group 4A	Group 5A	Group 6A	Group 7A
C carbide (C^{4-})*	N nitride (N^{3-})	O oxide (O^{2-})	F fluoride (F^-)
Si silicide (Si^{4-})	P phosphide (P^{3-})	S sulfide (S^{2-})	Cl chloride (Cl^-)
		Se selenide (Se^{2-})	Br bromide (Br^-)
		Te telluride (Te^{2-})	I iodide (I^-)

*The word “carbide” is also used for the anion C_2^{2-} .



Ionic Compounds

- **Example 1:**

Name the following compounds :

a) $\text{Cu}(\text{NO}_3)_2$ b) K_3PO_4 c) NH_4OH

a) **Cu** from transition metal then it have more than one form of cation, NO_3^- has common name nitrate thus:

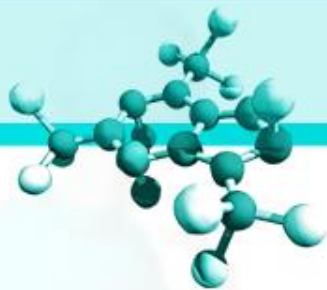
copper (II) nitrate

b) Potassium from group 1A thus it form only one type of cation, PO_4^{3-} has common name phosphate thus:

Potassium phosphate.

c) NH_4^+ has common name ammonium, OH^- has common name hydroxide thus:

Ammonium hydroxide



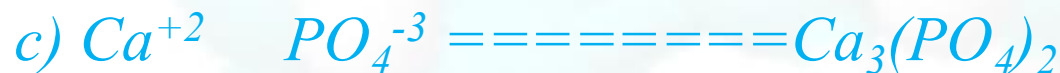
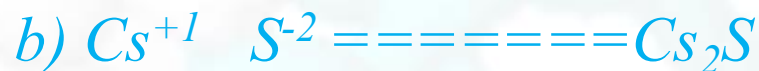
Ionic Compounds

- **Example 2:**

Write the chemical formula of the following compounds :

a) Mercury(II) nitrite, b) cesium sulfide

c) calcium phosphate.





Covalent Compounds

*When writing the name of a **Covalent compound**, as when writing the formula, the first element is the more metal-like one (From Elements of group 4 to Elements of group 7)*

The prefixes given to each element indicate the number of atoms present.

mono- 1

di- 2

tri- 3

tetra- 4

penta- 5

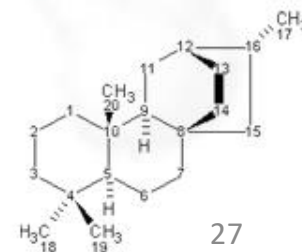
hexa- 6

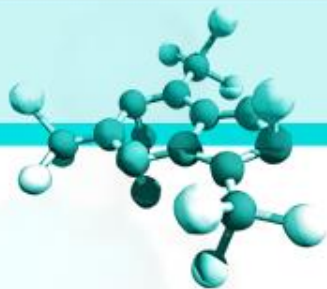
hepta- 7

octa- 8

nona- 9

deca- 10





If there is only one atom of the *first element*, the prefix *mono-* is normally omitted.



~~mono~~ carbon di- ox -ide

The full name is *carbon dioxide*.

The compound N_2O is named according to the first element, *nitrogen*, with the prefix *di-*, followed by the base name of the second element, *ox*, prefixed by *mono-*, and the suffix *-ide*.

Since *mono-* ends with a vowel and *oxide* begins with a vowel, an *o* is dropped and the two are combined as *monoxide*.

The entire name is *dinitrogen monoxide*.

