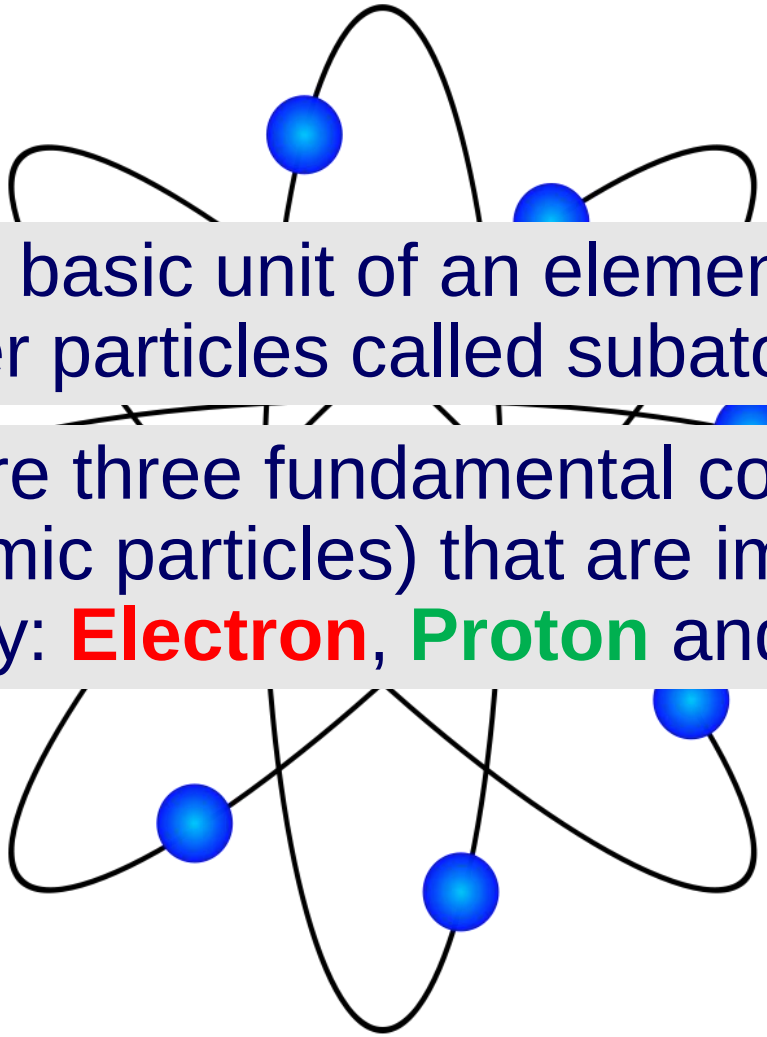
Atom, Molecules and Ions

Chapter 2

DMKC1033

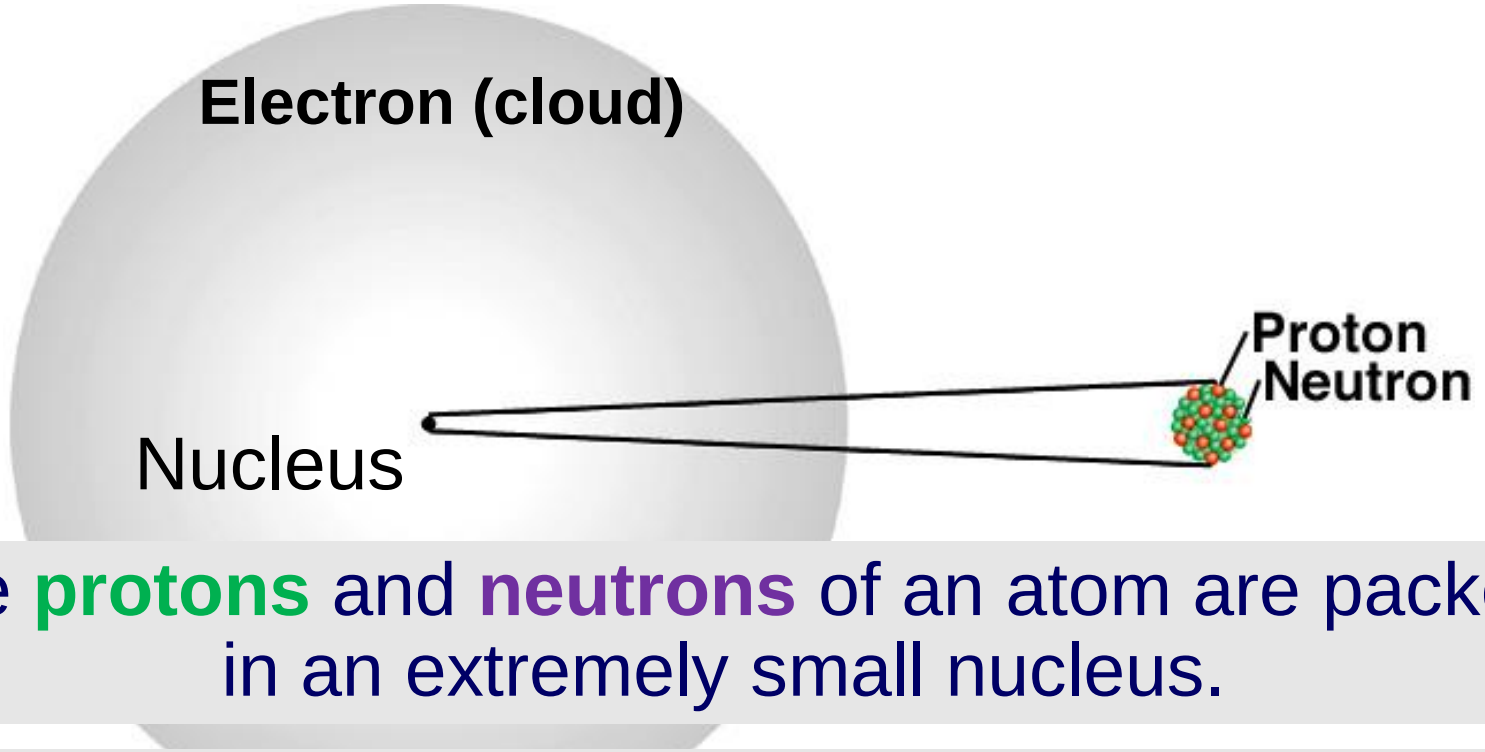
The Atom



Atom is the basic unit of an element, made up of even smaller particles called subatomic particles.

There are three fundamental components (subatomic particles) that are important in chemistry: **Electron**, **Proton** and **Neutron**.

The Structure of the Atom



The **protons** and **neutrons** of an atom are packed in an extremely small nucleus.

Electrons are shown as ‘clouds’ around the nucleus.

Subatomic particles

Particle	Mass (g)	Charge (Coulombs)	Charge (units)
Electron	9.1×10^{-28}	-1.6×10^{-19}	
Proton	1.67×10^{-24}	$+1.6 \times 10^{-19}$	
Neutron	1.67×10^{-24}	0	

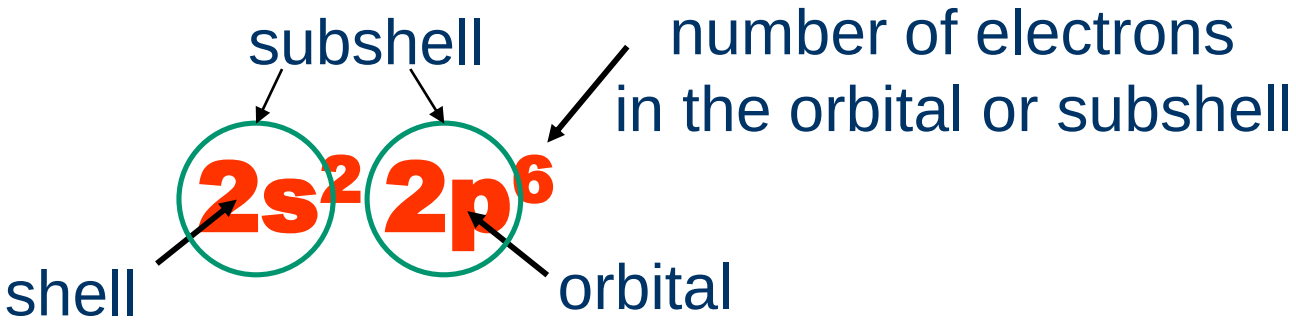
mass p = mass n = 1840 x mass e^-

Subatomic particles

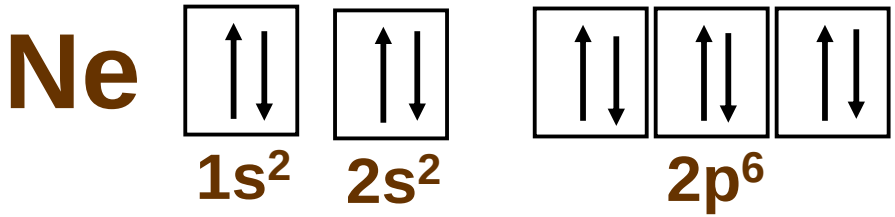
Particle	Mass (g)	Charge (Coulombs)	Charge (units)
Electron (e^-)	9.1×10^{-28}	-1.6×10^{-19}	-1
Proton (p^+)	1.67×10^{-24}	$+1.6 \times 10^{-19}$	+1
Neutron (n)	1.67×10^{-24}	0	0

mass p = mass n = 1840 x mass e^-

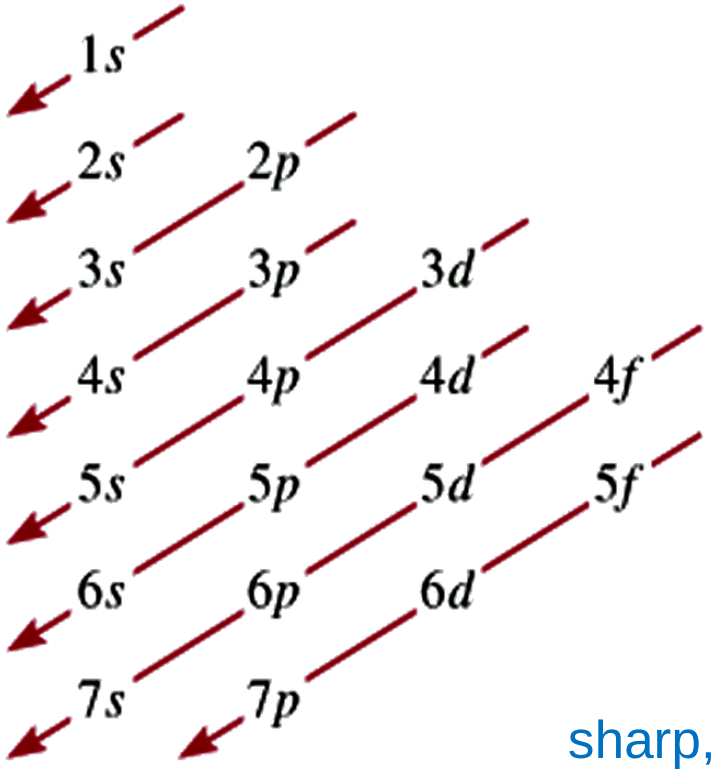
Electron configuration is how the electrons are distributed among the various atomic orbitals in an atom.



Orbital diagram



Order of orbitals (filling) in multi-electron atom

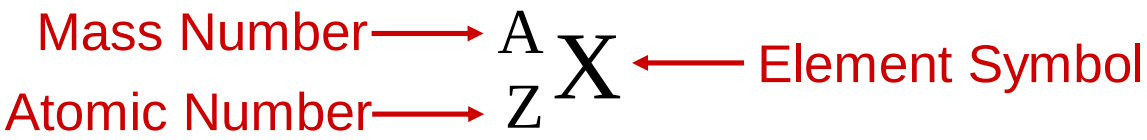


"Fill up" electrons in lowest energy orbitals (*Aufbau principle*)

sharp, principal, diffuse, and fundamental

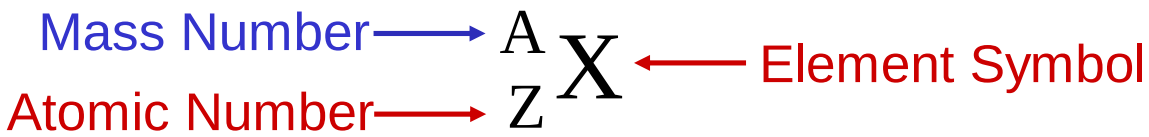
1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s

Atomic Number & Mass Number



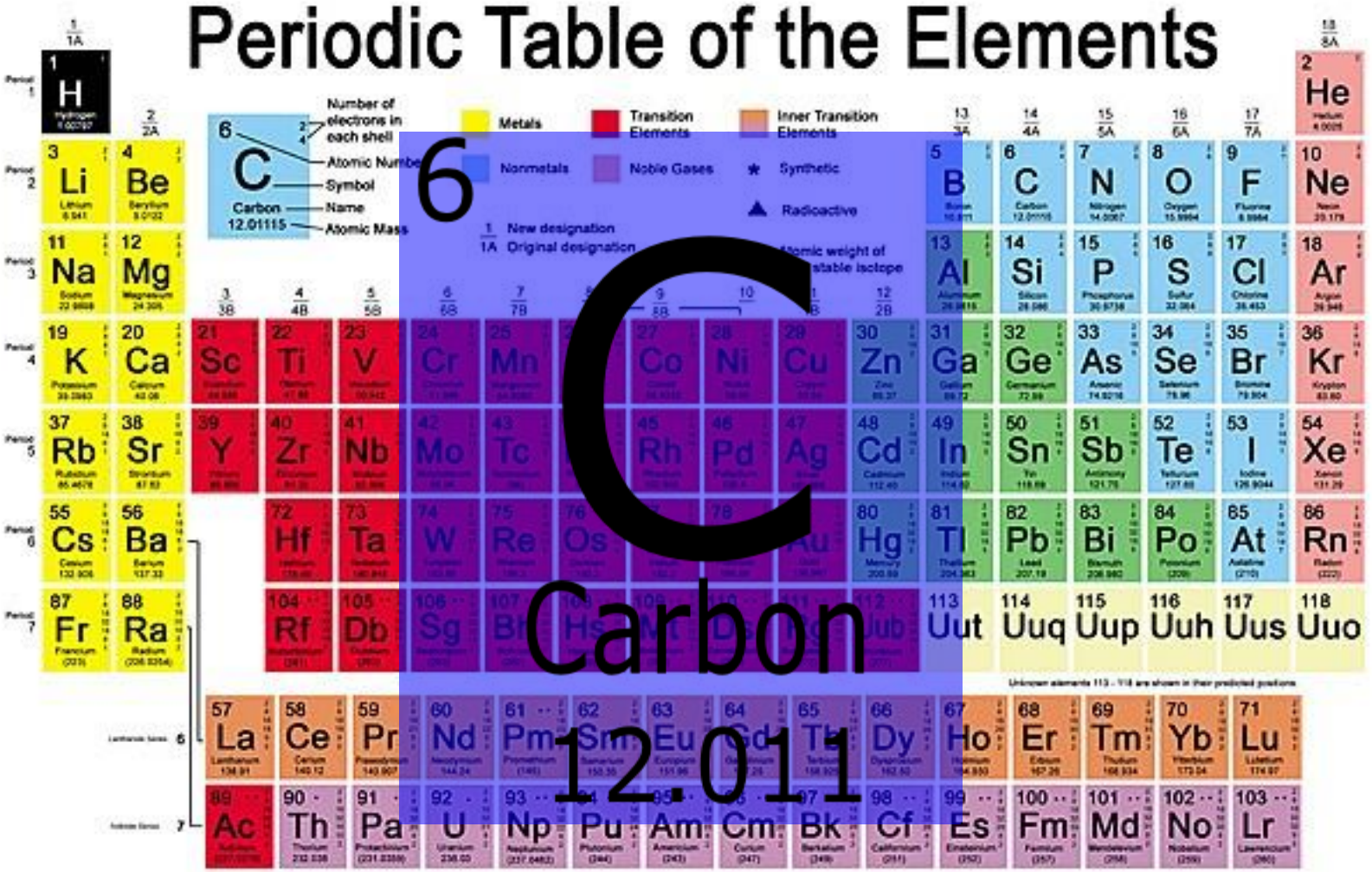
Atomic Number & Mass Number

Atomic number (Z) = number of protons in nucleus



Mass number (A) = atomic number (Z) + number of neutrons

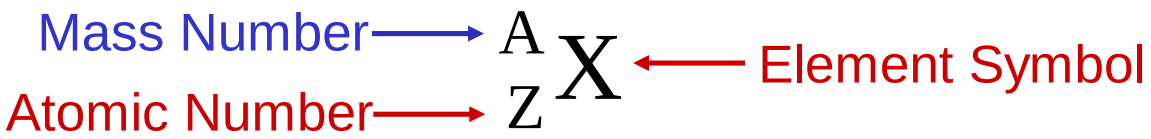
Mass number (A) = number of protons + number of neutrons


Periodic Table of the Elements
6
C
Carbon
12.011
Number of electrons in each shell
Atomic Number
Symbol
Name
Atomic Mass
Metals
Nonmetals
Transition Elements
Noble Gases
Inner Transition Elements
Synthetic
Radioactive
New designation
Original designation
Atomic weight of stable isotope

Isotopes

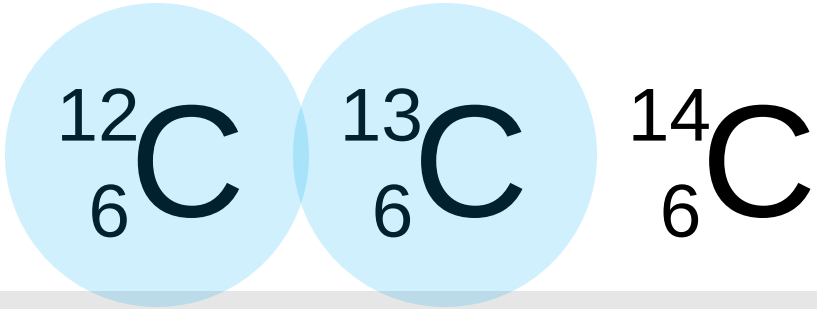
Isotopes are atoms of the same element (X) with same number of protons but different numbers of neutrons in their nuclei

The term isotope is formed from the Greek roots isos (equal) and topos (place), meaning "the same place".



Isotopes of Carbon

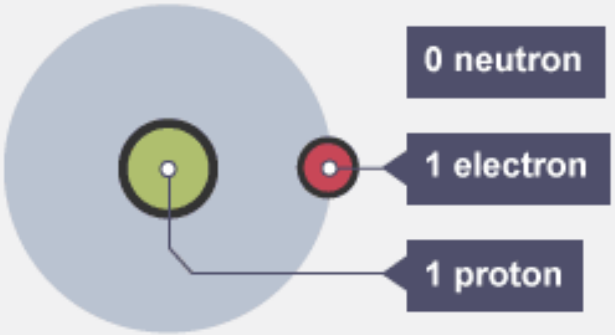
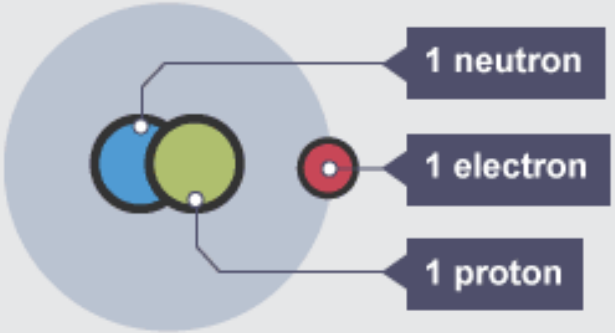
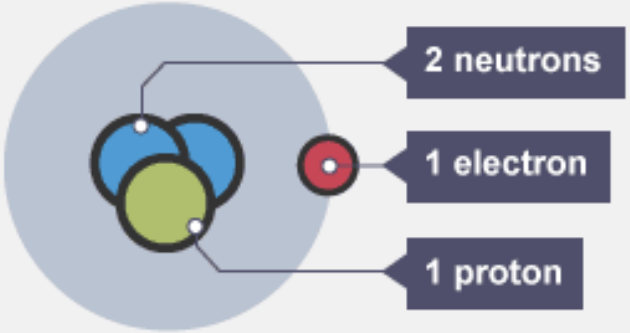
Carbon 12, Carbon 13, Carbon 14



stable and **unstable**

Carbon (**C**) has 15
known isotopes, from ^{8}C to ^{22}C

Isotopes of Hydrogen

Isotope	Diagram	Symbol
Hydrogen-1		$^{1}_{1}H$
Hydrogen-2		$^{2}_{1}H$
Hydrogen-3		$^{3}_{1}H$

Do You Understand Isotopes?

How many protons, neutrons, and electrons are in $^{14}_{6}\mathrm{C}$?

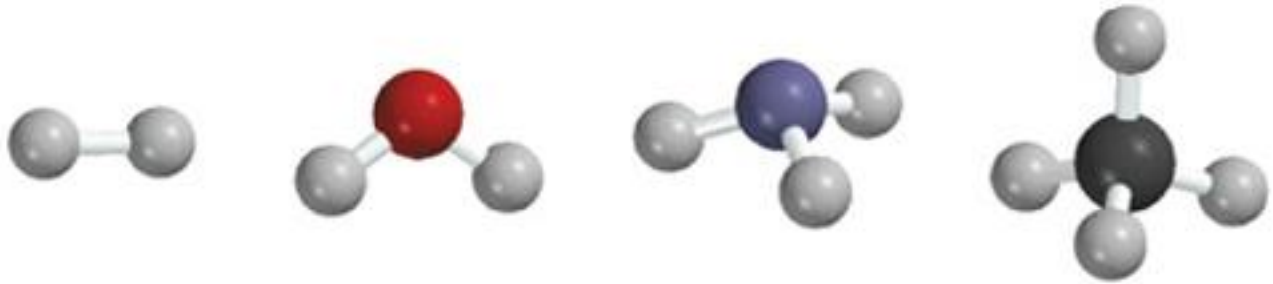
6 protons, 8 (14 - 6) neutrons, 6 electrons

How many protons, neutrons, and electrons are in $^{11}_{6}\mathrm{C}$?

6 protons, 5 (11 - 6) neutrons, 6 electrons

Molecules & Ions

A ***molecule*** is an aggregate of two or more atoms in a definite arrangement held together by chemical bonds



H_2 H_2O NH_3 CH_4

A ***diatomic molecule*** contains only two atoms

H_2, N_2, O_2, Br_2, HCl, CO

A ***polyatomic molecule*** contains more than two atoms

O_3, H_2O, NH_3, CH_4

An ***ion*** is an atom, or group of atoms, that has a net positive or negative charge.

cation – ion with a positive charge

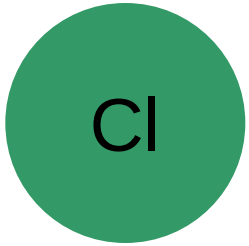
If a neutral atom **loses** one or more electrons it becomes a cation.

11 protons
11 electrons

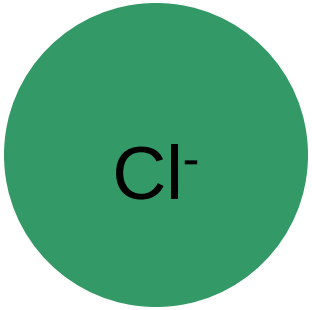
11 protons
10 electrons

anion – ion with a negative charge

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



17 protons
17 electrons



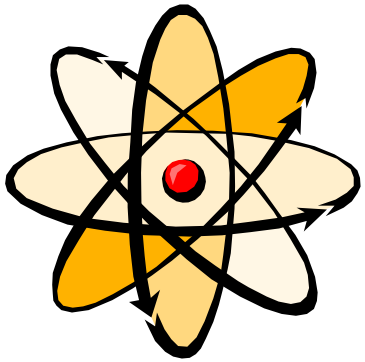
17 protons
18 electrons

A ***monatomic ion*** contains only one atom

Na^+, Cl^-, Ca^{2+}, O^{2-}, Al^{3+}, N^{3-}

A ***polyatomic ion*** contains more than one atom

OH^-, CN^-, NH_4^+, NO_3^-



Do You Understand Ions?

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

13 protons, 10 (13 – 3) electrons

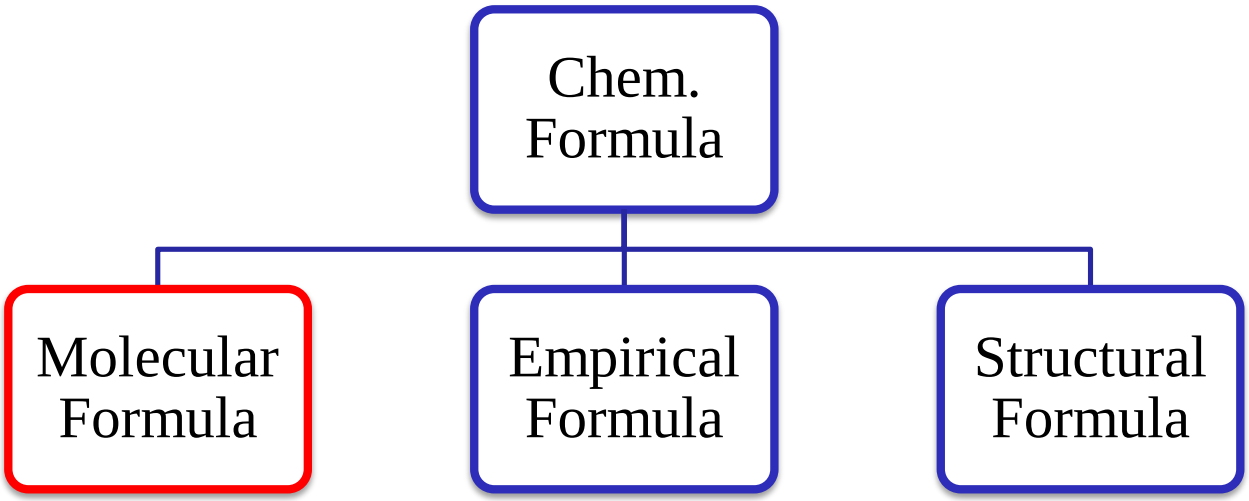
How many protons and electrons are in $^{78}_{34}Se^{2-}$?

34 protons, 36 (34 + 2) electrons

1. Give the number of protons, neutrons and electrons in each of the following species

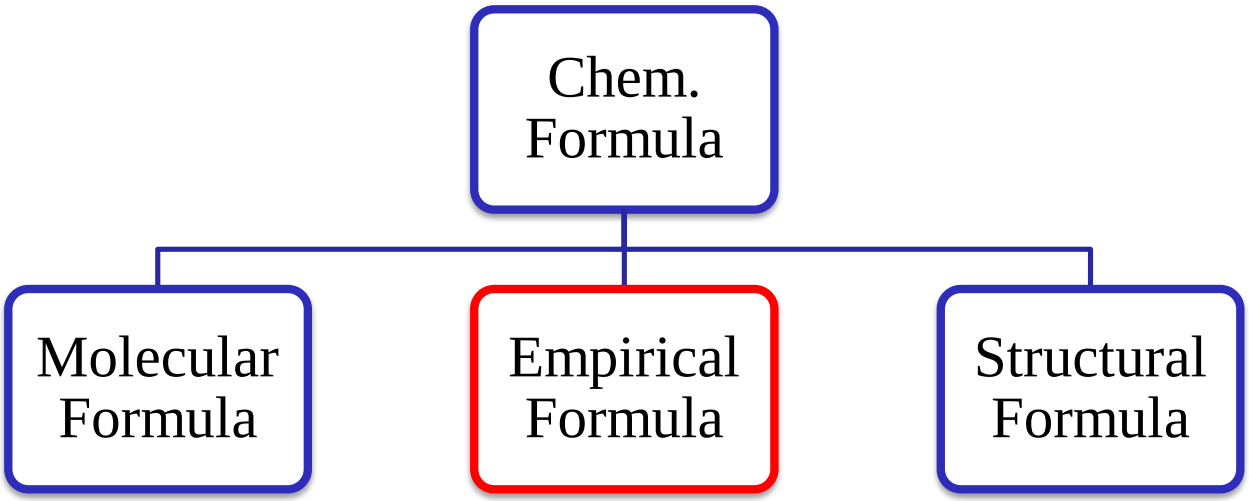
Spesies	$^{17}_{8}O$	$^{199}_{80}Hg$	$^{200}_{80}Hg$	$^{14}_{7}N^{3-}$	$^{54}_{26}Fe^{2+}$	$^{31}_{15}P^{3-}$	$^{107}_{47}Ag^{+}$
Proton	8	80	80	7	26	15	47
Neutron	9	119	120	7	28	16	60
Electron	8	80	80	10	24	18	46

Chemical Formulas



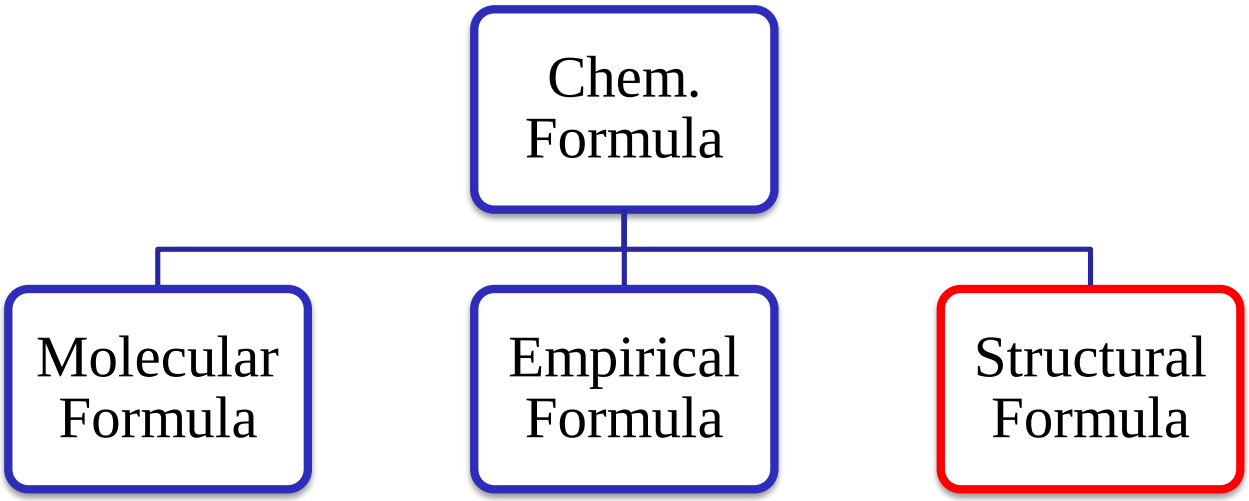
A ***molecular formula*** shows the exact number of atoms of each element in the smallest unit of a substance

Chemical Formulas



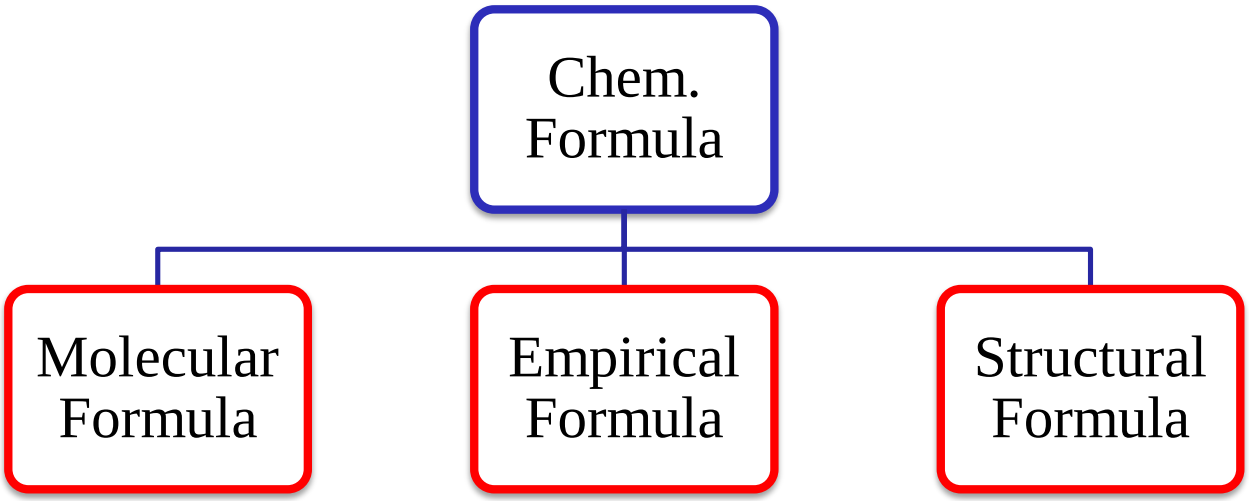
An ***empirical formula*** shows the simplest whole number ratio of the atoms in a substance

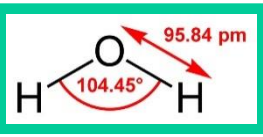
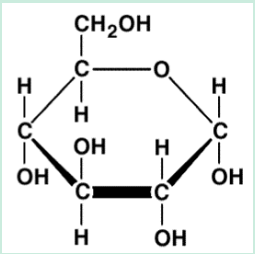
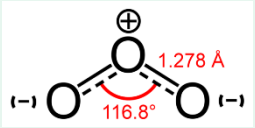
Chemical Formulas



The **structural formula** is a graphic representation of the molecular structure, showing how the atoms are arranged.

Chemical Formulas



water	**H_2O**	**H_2O**	
glucose	**$C_6H_{12}O_6$**	**CH_2O**	
ozone	**O_3**	**O**	

2. What are the empirical formulas of the following compounds:

Compound	C_2N_2	C_6H_6	P_4O_{10}	B_2H_6	Al_2Br_6	Na_2SO_3
Empirical formula	CN	CH	P_2O_5	BH_3	$AlBr_3$	Na_2SO_3

Compound

Ionic compound

Metal + nonmetal

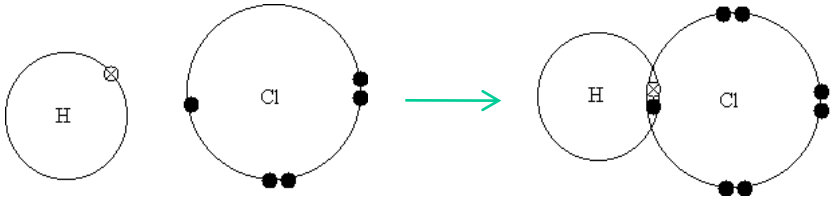
Transfer electron

Ionic Bond

Molecular compound

nonmetal + nonmetal/metaloid

Sharing electron



Covalent Bond

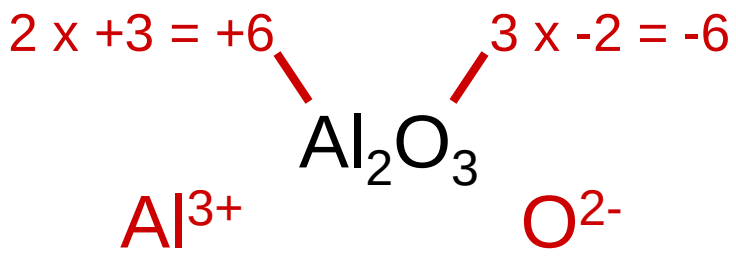
Ionic compounds consist of a combination of cations and an anions

The formula is always the same as the empirical formula

The sum of the charges on the cation(s) and anion(s) in each formula unit must equal zero

Writing a Formula of Ionic Compounds

Cation Al^{3+} and anion O^{2-}



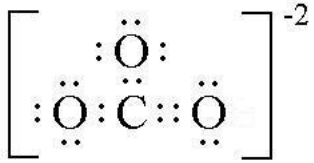
Writing a Formula of Ionic Compounds

Ca and Br

1 x +2 = +2 2 x -1 = -2

$CaBr_2$

Ca^{2+} Br^-

Na and carbonate 

1 x +2 = +2 1 x -2 = -2

Na_2CO_3

Na^+ CO_3^{2-}

Names and Formulas of Some Common Inorganic Cations and Anions

Cation	Anion
Aluminum (Al^{3+})	Bromide (Br^-)
Ammonium (NH_4^+)	Carbonate (CO_3^{2-})
Barium (Ba^{2+})	Chlorate (ClO_3^-)
Cadmium (Cd^{2+})	Chloride (Cl^-)
Calcium (Ca^{2+})	Chromate (CrO_4^{2-})
Cesium (Cs^+)	Cyanide (CN^-)
Chromium(III) or chromic (Cr^{3+})	Dichromate ($Cr_2O_7^{2-}$)
Cobalt(II) or cobaltous (Co^{2+})	Dihydrogen phosphate ($H_2PO_4^-$)
Copper(I) or cuprous (Cu^+)	Fluoride (F^-)
Copper(II) or cupric (Cu^{2+})	Hydride (H^-)
Hydrogen (H^+)	Hydrogen carbonate or bicarbonate (HCO_3^-)
Iron(II) or ferrous (Fe^{2+})	Hydrogen phosphate (HPO_4^{2-})
Iron(III) or ferric (Fe^{3+})	Hydrogen sulfate or bisulfate (HSO_4^-)
Lead(II) or plumbous (Pb^{2+})	Hydroxide (OH^-)
Lithium (Li^+)	Iodide (I^-)
Magnesium (Mg^{2+})	Nitrate (NO_3^-)
Manganese(II) or manganous (Mn^{2+})	Nitride (N^{3-})
Mercury(I) or mercurous (Hg_2^{2+})*	Nitrite (NO_2^-)
Mercury(II) or mercuric (Hg^{2+})	Oxide (O^{2-})
Potassium (K^+)	Permanganate (MnO_4^-)
Silver (Ag^+)	Peroxide (O_2^{2-})

Naming Ionic Compounds

- Cation goes first
- anion (nonmetal), add "**ide**" for it ending
- Polyatomic anion doesn't need it changed

$BaCl_2$	barium chloride
K_2O	potassium oxide
$CaCO_3$	calcium carbonate
$Mg(OH)_2$	magnesium hydroxide

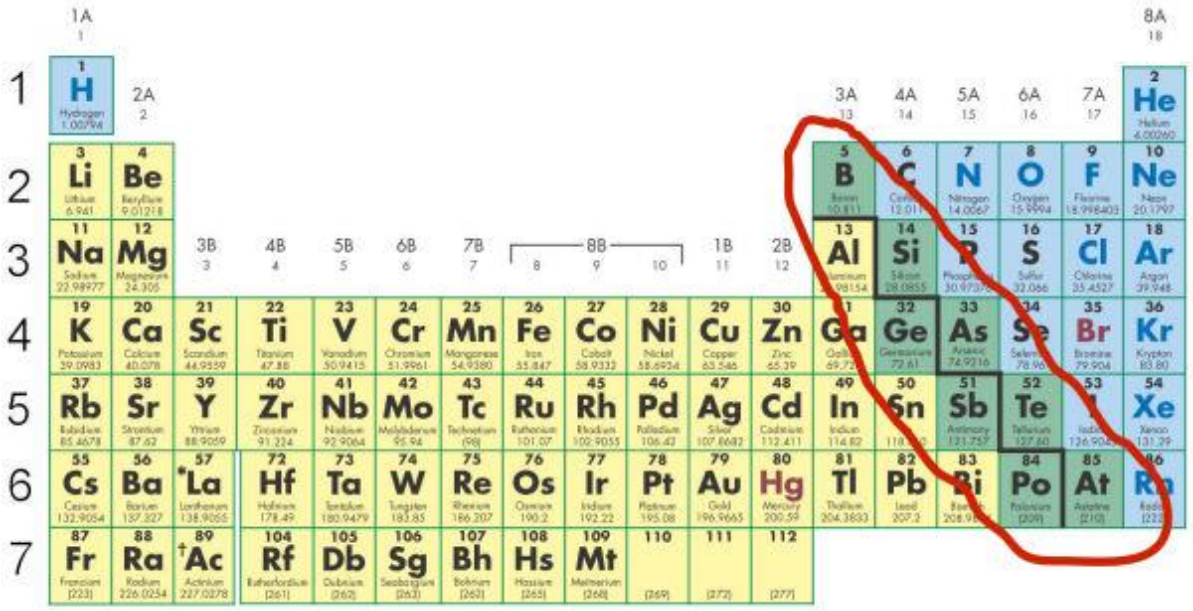
- Transition metal ionic compounds
  - indicate **charge on metal** with **Roman numerals**

$FeCl_2$	2 Cl^- -2 so Fe is +2	iron(**II**) chloride
$FeCl_3$	3 Cl^- -3 so Fe is +3	iron(**III**) chloride
Cr_2S_3	3 S^{-2} -6 so Cr is +3 (6/2)	chromium(**III**) sulfide

Molecular compounds

– nonmetals + nonmetals or **metalloids**

The *metalloids* or semimetals share some of the properties of metals and some of the properties of nonmetals proportions.



Writing a formula of molecular compounds

1C and 2O

CO_2 (greenhouse gases)

Naming molecular compounds

- common name
  - N_2, H_2O, CH_4, C_{60}
- element further left in periodic table must write 1st
  - NF_3 , NO_2
- element closest to bottom of group must write 1st
  - SO_2
- if more than one compound can be formed from the same elements, use prefixes to indicate number of each kind of atom. Prefix mono is never used with the first element.
- last element ends in **ide**

Greek Prefixes Used in Naming Molecular Compounds

Prefix	Meaning
Mono-	1
Di-	2
Tri-	3
Tetra-	4
Penta-	5
Hexa-	6
Hepta-	7
Octa-	8
Nona-	9
Deca-	10

Naming Molecular Compounds

HI	hydrogen iodide
NF_3	nitrogen trifluoride
SO_2	sulfur dioxide
N_2Cl_4	dinitrogen tetrachloride
NO_2	nitrogen dioxide
N_2O	dinitrogen monoxide

Toxic

Laughing gas

Acid

An ***acid*** can be defined as a substance that yields **hydrogen ions (H^+)** when dissolved in water.

HCl

- Pure substance, hydrogen chloride
- Dissolved in water (**H^+** Cl^-), hydrochloric acid

HF → **$H^+ + F^-$**

H_2S → **$2H^+ + S^{2-}$**

Acid

Acid without oxygen
Acid with oxygen (oxoacid)

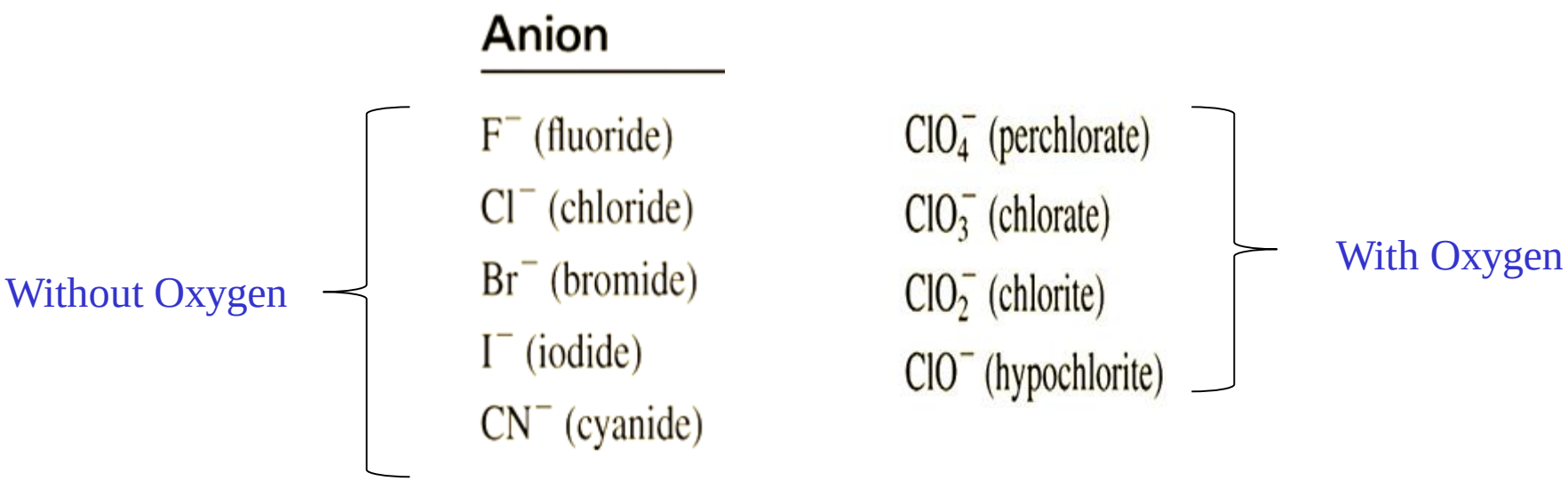
An ***oxoacid*** is an acid that contains hydrogen, **oxygen**, and another element.

$HNO_3 \rightarrow H^+ + NO_3^-$

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

Naming Acid

The name of an acid is based on the name of the **negative ion (anion)** that is part of the acid



Naming Acid without oxygen

#rule

Anion	Acid
-ide	hydro_____ic acid

HCl H^+ + Cl^-

Hydrochloric acid **chloride**

HCN H^+ + CN^-

Hydrocyanic acid **cyanide**

Anion

F^- (fluoride)

Cl^- (chloride)

Br^- (bromide)

I^- (iodide)

CN^- (cyanide)

Naming Acid without oxygen

#exceptional (contain Phosphorus & Sulfur)

Anion	Acid	Phosphorus	Sulfur
-ide	hydro_____ic acid	hydro_____oric acid	hydro_____uric acid

H_2S **H^+ + S^{2-}**

Hydrosulfuric acid **sulfide**

Anion
S^{2-} (sulfide)
P^{3-} (phosphide)

H_3P **H^+ + P^{3-}**

Hydrophosphoric acid **phosphide**

Naming Acid with oxygen (oxoacid)

#rule

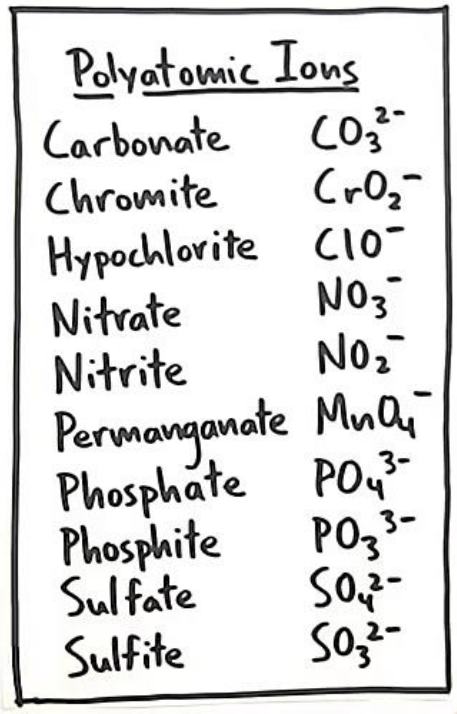
Anion	Acid
-ate	_____ic acid

HNO_3 $H^+ + NO_3^-$

Nitric acid **nitrate**

H_2CO_3 $2H^+ + CO_3^{2-}$

Carbonic acid **carbonate**



Naming Acid with oxygen (oxoacid)

#rule

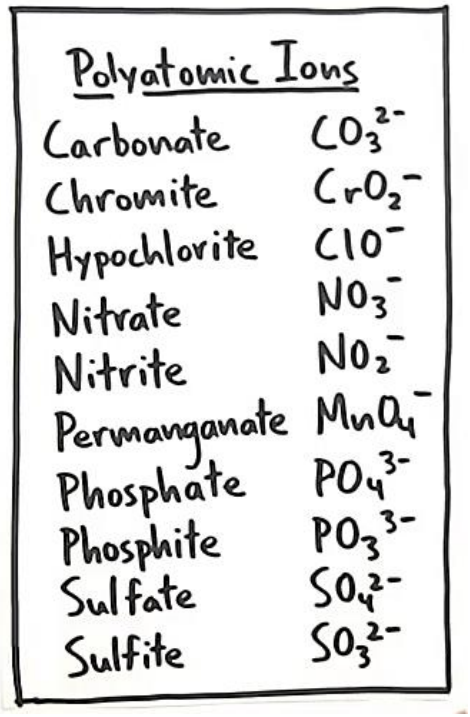
Anion	Acid
-ite	_____ous acid

HNO_2 $H^+ + NO_2^-$

Nitrous acid nitrite

$HCrO_2$ $H^+ + CrO_2^-$

Chromous acid chromite



Naming Acid with oxygen (oxoacid)

#exceptional (contain Phosphorus & Sulfur)

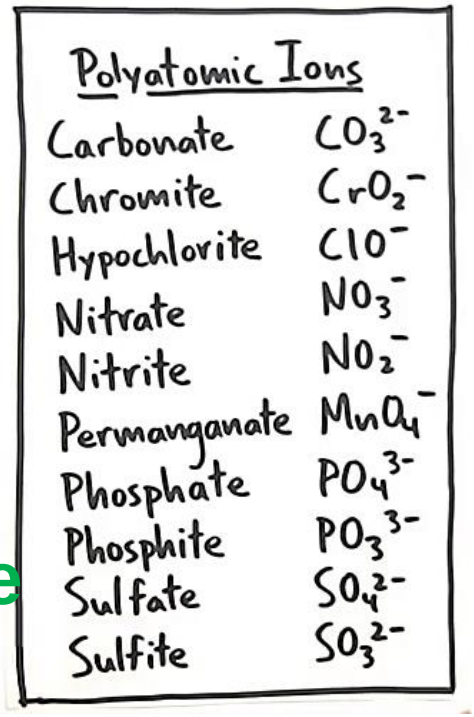
Anion	Acid	Phosphorus	Sulfur
-ate	_____ic acid	_____oric acid	_____uric acid

H_2SO_4 $2H^+ + SO_4^{2-}$

Sulfuric acid **sulfate**

H_3PO_4 $3H^+ + PO_4^{3-}$

Phosphoric acid **phosphate**



Naming Acid with oxygen (oxoacid)

#exceptional (contain Phosphorus & Sulfur)

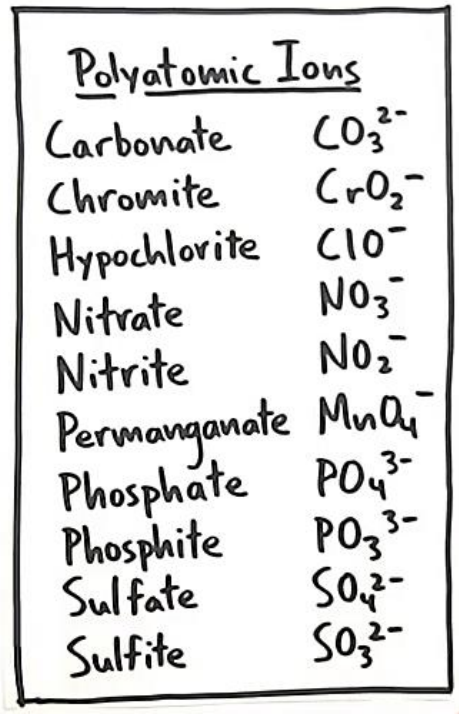
Anion	Acid	Phosphorus	Sulfur
-ite	_____ous acid	_____orous acid	_____urous acid

H_2SO_3 $2H^+ + SO_3^{2-}$

Sulfurous acid **sulfite**

H_3PO_3 $3H^+ + PO_3^{3-}$

Phosphorous acid **phosphite**



Names of Oxoacids and Oxoanions That Contain Chlorine

Acid	Anion
$HClO_4$ (perchloric acid)	ClO_4^- (perchlorate)
$HClO_3$ (chloric acid)	ClO_3^- (chlorate)
$HClO_2$ (chlorous acid)	ClO_2^- (chlorite)
$HClO$ (hypochlorous acid)	ClO^- (hypochlorite)

A ***base*** can be defined as a substance that yields **hydroxide ions (OH^-)** when dissolved in water.

$NaOH$	sodium hydroxide
KOH	potassium hydroxide
$Ba(OH)_2$	barium hydroxide

Q&A