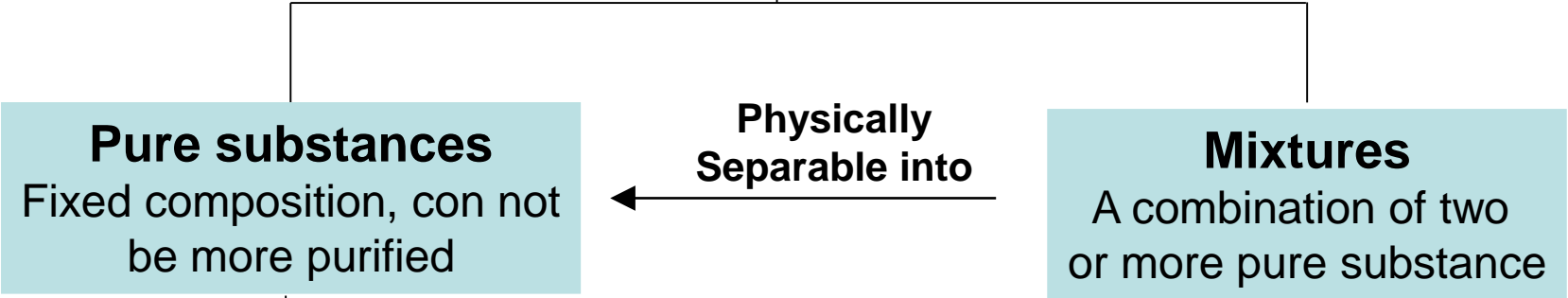


Elements, Atoms, and Compounds

Matter
Anything that occupies space and mass



Element
Cannot be subdivided by chemical or physical means

Combine Chemically To form

Compounds
Elements united In fixed ratios

Homogeneous matter
Uniform Composition throughout

Heterogeneous matter
Nonuniform composition

Elements

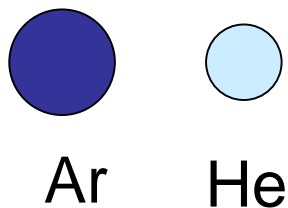
Element: is a substance consists of **identical atoms**.

Cannot be divided by chemical & physical methods.

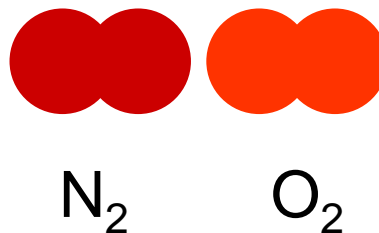
Carbon, Hydrogen, Oxygen

116 elements – 88 in nature

Monatomic



Diatomic



Polyatomic



Element Symbols

The first letter or two first letters of element name:

Oxygen O

Silicon Si

Carbon C

Argon Ar

Sometimes, two letters are not the first letters:

Chlorine Cl

Zinc Zn

Sometimes, old names are used (Latin or Greek):

Iron (Ferrum) Fe

Lead (Plumbum) Pb

Compounds

Compound: is a pure substance made up of two or more elements in a **fixed ratio** by mass.

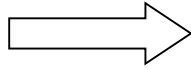
H₂O (Water): 2 Hydrogen & 1 Oxygen

CO₂: 1 Carbon & 2 Oxygen

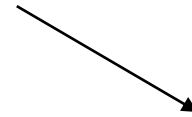
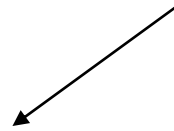
20 million compounds

Compounds $\xrightarrow{\text{By Chemical Methods}}$ Elements

Compounds

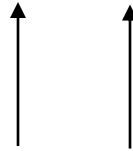


Formula



Identifies each element

Ratios



Subscript (number of each atom)

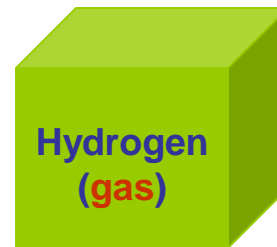
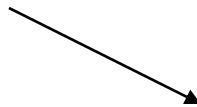
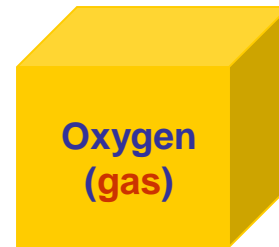
Subscript 1 is not written.

Elements & Compounds

The character of each element is lost when forming a compound.



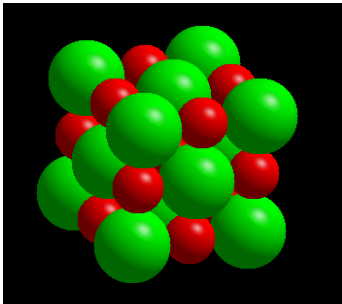
H₂O (liquid)



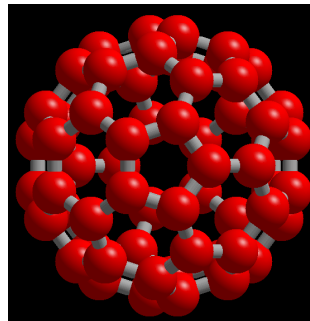
Compound & molecule

Molecule:

1. the smallest unit of a compound that retains the characteristics of that compound. H_2O , CO_2
2. atoms of one element bonded into a unit.
Buckyballs, C_{60} oxygen, O_2 ozone, O_3

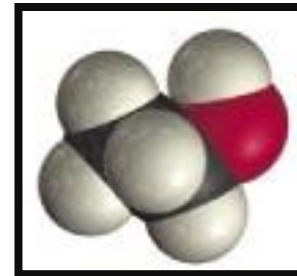


NaCl, salt
compound



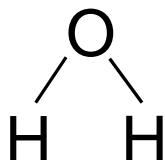
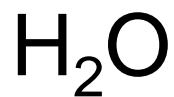
Buckyball, C_{60}

molecule



Ethanol, $\text{C}_2\text{H}_6\text{O}$
compound
molecule

Molecular models

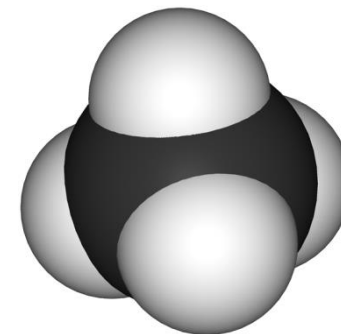
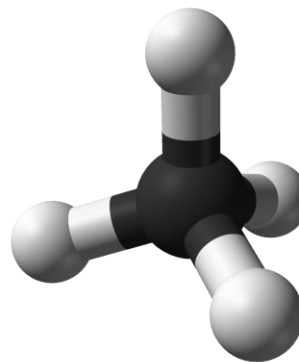
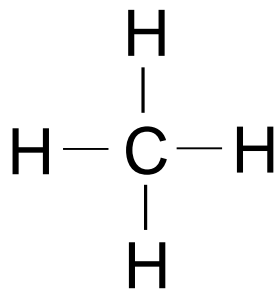


**Molecular
formula**

**Structural
formula**

**Ball-and-stick
model**

**Space-filling
model**



Pure substance & Mixture

Pure substance: same composition

Elements - Compounds

Water

Mixture: different composition

Different water samples (impurities).

salad dressing

Coffee

Mixtures

Mixture: is a combination of two or more pure substances.

Homogeneous (solutions): uniform and throughout

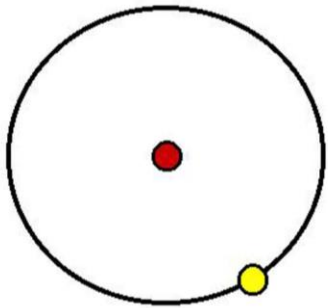
Air, Salt in water

Heterogeneous: nonuniform

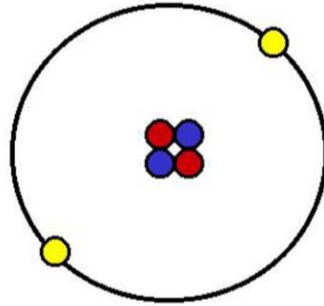
Soup, Milk, Blood, sand in water

Atom

hydrogen



helium



Nucleus: positive charge

Atoms are neutral.

● proton (+) ● neutron ● electron (-)

Atomic mass unit (amu) = 1.6605×10^{-24} g

mass of proton = 1 amu

mass of neutron = 1 amu

mass of electron = 5.48×10^{-4} amu



Like charges repel each other



Opposite charges attract each other

Atom

{ Mass number: Protons + Neutrons
Atomic number: Protons

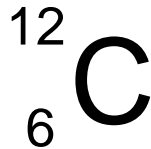
Mass number (A) \longrightarrow 12
Atomic number (Z) \longrightarrow 6 **C**

Isotopes

Isotopes: atoms with the same number of protons and electrons but different numbers of neutrons.

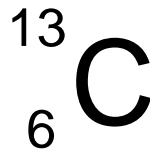


different mass number



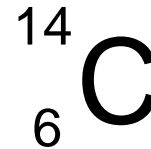
6 P + 6 N

Carbon-12



6 P + 7 N

Carbon-13



6 P + 8 N

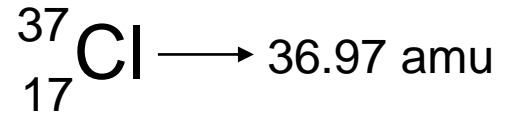
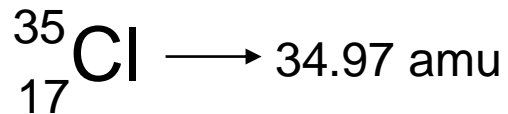
Carbon-14

Almost the same properties

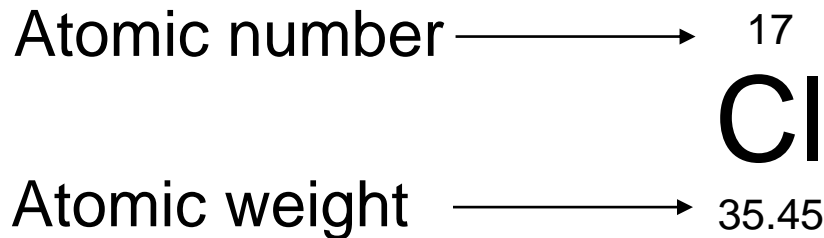
Atomic Weight

Atomic weight: of an element is average of the masses (in amu) of its isotopes found on the Earth.

Cl



$$(75.77/100 \times 34.97 \text{ amu}) + (24.23/100 \times 36.97 \text{ amu}) = 35.45 \text{ amu}$$



PERIODIC TABLE OF THE ELEMENTS

1A 1																	8A 18						
1 H Hydrogen 1.00794																	2 He Helium 4.00260						
		2A 2											3A 13	4A 14	5A 15	6A 16	7A 17						
3 Li Lithium 6.941	4 Be Beryllium 9.01218																	5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.998403	10 Ne Neon 20.1797
11 Na Sodium 22.98977	12 Mg Magnesium 24.305	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	9	10	1B 11	2B 12	13 Al Aluminum 26.98154	14 Si Silicon 28.0855	15 P Phosphorus 30.97376	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 44.9559	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.9380	26 Fe Iron 55.847	27 Co Cobalt 58.9332	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 74.9216	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 88.9059	40 Zr Zirconium 91.224	41 Nb Niobium 92.9064	42 Mo Molybdenum 95.94	43 Tc Technetium [98]	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.82	50 Sn Tin 118.710	51 Sb Antimony 121.757	52 Te Tellurium 127.60	53 I Iodine 126.9045	54 Xe Xenon 131.29						
55 Cs Cesium 132.9054	56 Ba Barium 137.327	57 *La Lanthanum 138.9055	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.2	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.9804	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)						
87 Fr Francium (223)	88 Ra Radium 226.0254	89 †Ac Actinium 227.0278	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (268)	110 (269)	111 (272)	112 (277)												

*Lanthanide Series	58 Ce Cerium 140.115	59 Pr Praseodymium 140.9077	60 Nd Neodymium 144.24	61 Pm Promethium [145]	62 Sm Samarium 150.36	63 Eu Europium 151.965	64 Gd Gadolinium 157.25	65 Tb Terbium 158.9254	66 Dy Dysprosium 162.50	67 Ho Holmium 164.9303	68 Er Erbium 167.26	69 Tm Thulium 168.9342	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
† Actinide Series	90 Th Thorium 232.0381	91 Pa Protactinium 231.0359	92 U Uranium 238.0289	93 Np Neptunium 237.048	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 [260]

main-group elements: 1A to 8A

transition elements: 1B to 8B (3 – 12)

inner transition elements: between B3 & B4
(58 to 71 and 90 to 103)

Column: the same properties (main group)

Row or Period (7 rows)

Classification of the elements

PERIODIC TABLE OF THE ELEMENTS

1A 1																	8A 18						
1 H Hydrogen 1.00794																	2 He Helium 4.00260						
3 Li Lithium 6.941	4 Be Beryllium 9.01218																	5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.998403	10 Ne Neon 20.1797
11 Na Sodium 22.98977	12 Mg Magnesium 24.305	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8 9 10			1B 11	2B 12	13 Al Aluminum 26.98154	14 Si Silicon 28.0855	15 P Phosphorus 30.97376	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948						
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37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.9059	40 Zr Zirconium 91.224	41 Nb Niobium 92.9064	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 106.42	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.82	50 Sn Tin 118.710	51 Sb Antimony 121.757	52 Te Tellurium 127.60	53 I Iodine 126.9045	54 Xe Xenon 131.29						
55 Cs Cesium 132.9054	56 Ba Barium 137.327	57 *La Lanthanum 138.9055	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.2	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.9804	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)						
87 Fr Francium (223)	88 Ra Radium 226.0254	89 *Ac Actinium 227.0278	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (268)	110 (269)	111 (272)	112 (277)												
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metals



nonmetals



metalloids

Metals:

solid (except mercury), shiny, conductors of electricity and heat, ductile, malleable

Nonmetals: solid, liquid or gas, do not conduct electricity (except graphite)

Metalloids (Semimetals): between metals and nonmetals

Group 1A: Alkali metals

Li-Na-K-Rb-Cs-Fr

too reactive, unstable, solid metal



Group 2A: Alkaline metals or earth metals

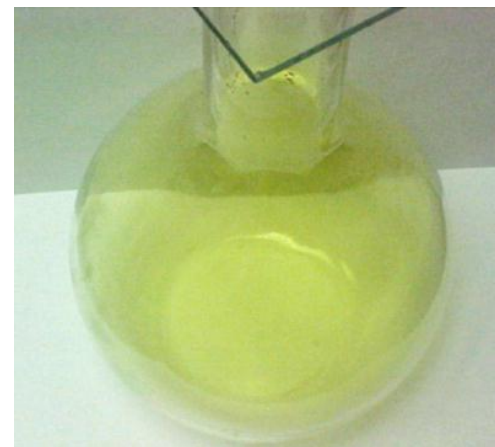
Be-Mg-Ca-Sr-Ba-Ra

reactive, solid metal

Group 7A: Halogens

F-Cl-Br-I-At

reactive, colored, gas, nonmetal



Group 8A: Noble gases

He-Ne-Ar-Kr-Xe-Rn

non reactive, stable, gas, nonmetal

Ions

Total number of protons = Total number of electrons

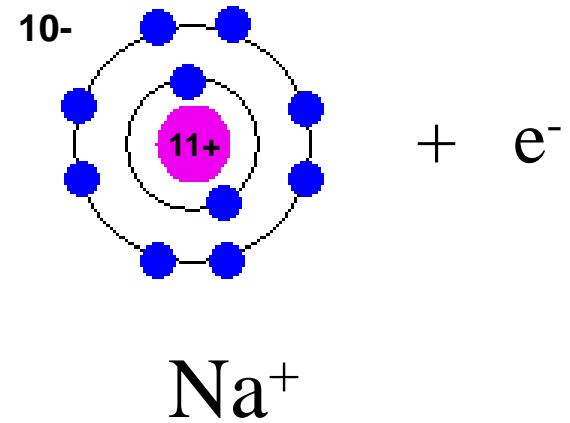
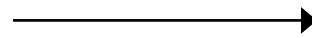
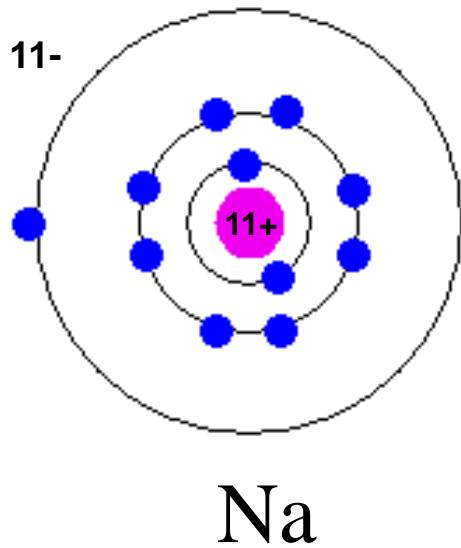
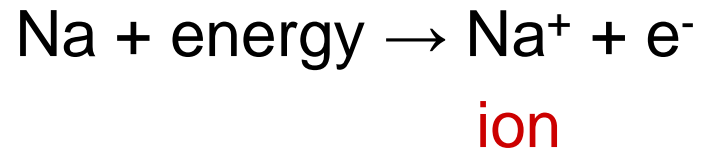
Atom is neutral (zero net charge).

Ion: atom with any charges (positive or negative).



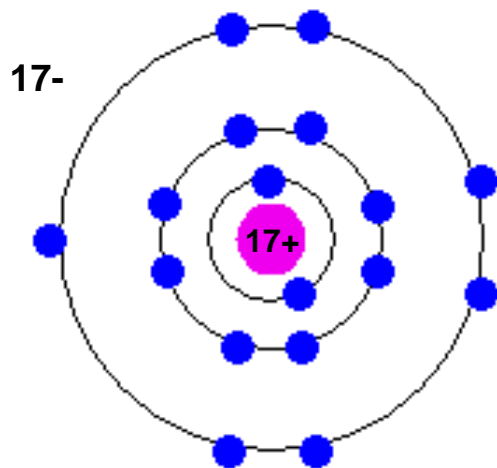
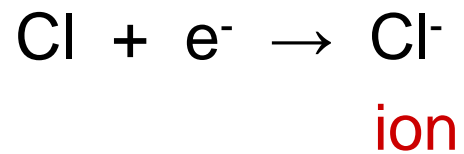
Number of protons and neutrons in the nucleus remains unchanged.

Ions & Ionization

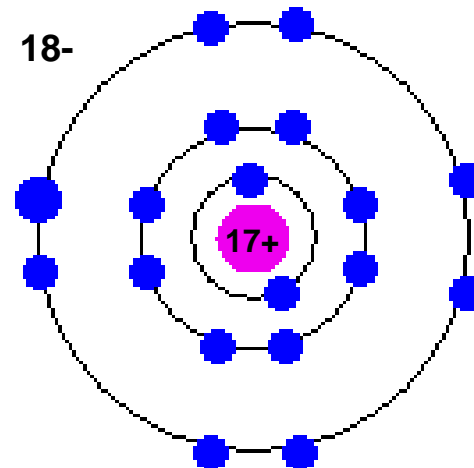
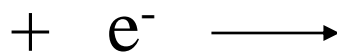


The size of the cation is smaller than the neutral atom.

Ions & Ionization



Cl



Cl⁻

Metals: lose 1, 2 or 3 e⁻ → Cation (Y⁺)

Nonmetals: gain 1, 2 or 3 e⁻ → Anion (X⁻)

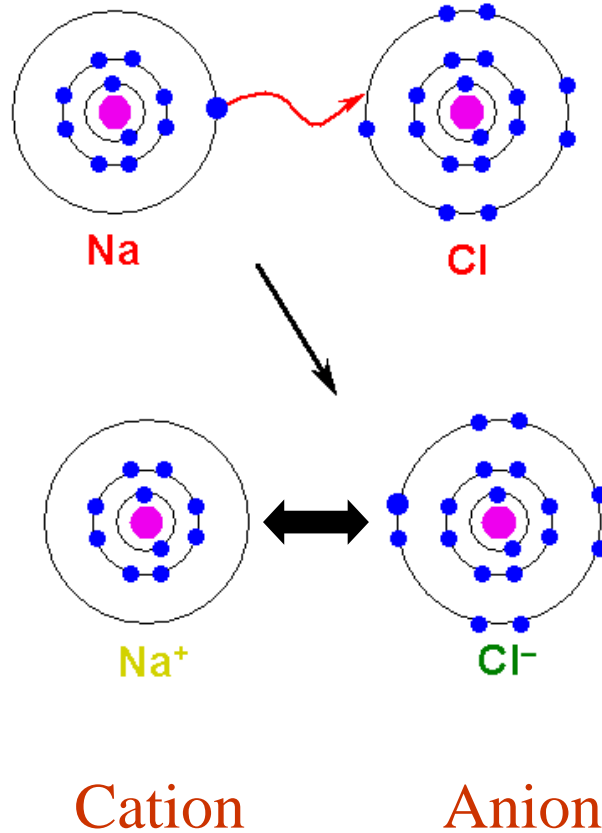
Ions

Ionic Charges

1A	2A		3A	4A	5A	6A	7A	8A
+1	+2		+3	+/.4	-3	-2	-1	0
		Variable Charges						
		← Transition elements →						

Ionic bonds

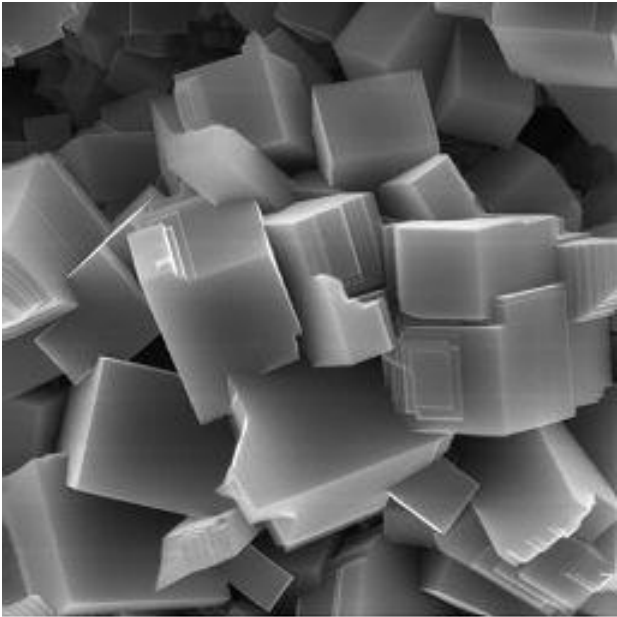
Metal-Nonmetal



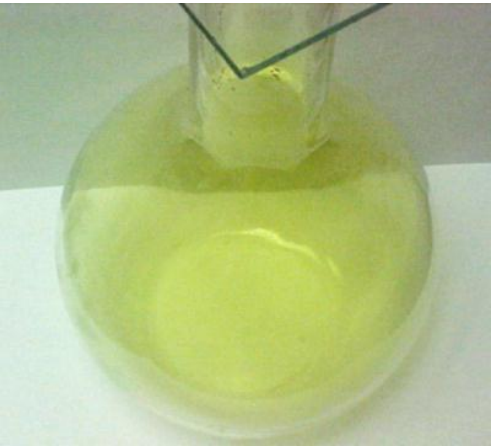
Opposite charges
attract each other.



Sodium (Na)

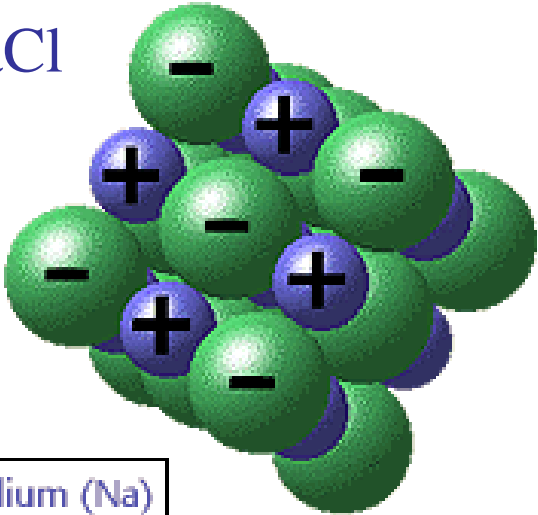


6µm 5000X



Chlorine (Cl)

NaCl



sodium (Na)
chlorine (Cl)

Type I Monatomic Cations

Metal has only one type of cation (main group elements)

International Union of Pure and Applied Chemistry (IUPAC)
systematic names

Name of the metal + “ion”

H⁺ Hydrogen ion

Li⁺ Lithium ion

Ca²⁺ Calcium ion

Al³⁺ Aluminum ion

Type II Monatomic Cations

Metal has two (or more) type of cations (transition elements)

IUPAC or Systematic names

Table 5.2 Common Type II Cations

Ion	Systematic Name	Older Name
Fe^{3+}	iron(III)	ferric
Fe^{2+}	iron(II)	ferrous
Cu^{2+}	copper(II)	cupric
Cu^{+}	copper(I)	cuprous
Co^{3+}	cobalt(III)	cobaltic
Co^{2+}	cobalt(II)	cobaltous
Sn^{4+}	tin(IV)	stannic
Sn^{2+}	tin(II)	stannous
Pb^{4+}	lead(IV)	plumbic
Pb^{2+}	lead(II)	plumbous
Hg^{2+}	mercury(II)	mercuric
Hg_2^{2+*}	mercury(I)	mercurous

1 = I
2 = II
3 = III
4 = IV
5 = V
6 = VI

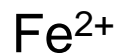
Memorize!!!

*Mercury(I) ions always occur bound together in pairs to form Hg_2^{2+} .

Type II Monatomic Cations

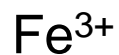
Common name (old name)

Name of the metal + “-ous” smaller charge
“-ic” larger charge



Iron(II) ion

Ferrous ion



Iron(III) ion

Ferric ion



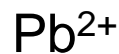
Copper(I) ion

Cuprous ion



Copper(II) ion

Cupric ion



Lead(II) ion

Plumbous ion



Lead(IV) ion

Plumbic ion



Tin(II) ion

Stannous ion



Tin(IV) ion

Stannic ion



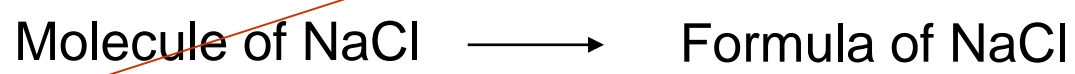
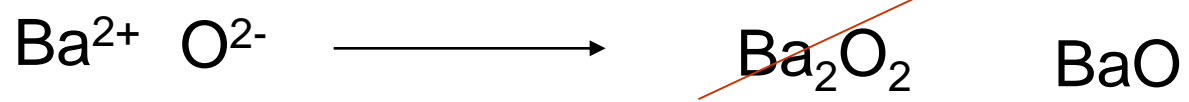
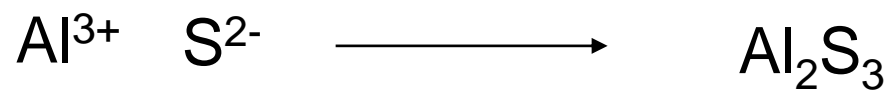
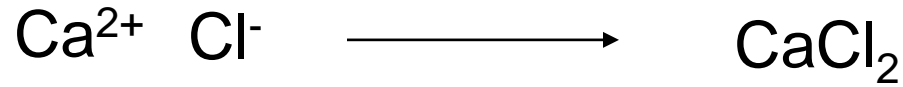
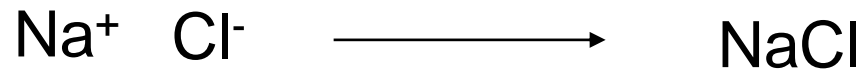
Naming Monatomic Anions

Stem part of name + “-ide ion”

Anion	Stem name	Anion name
F⁻	fluor	Fluoride ion
Cl⁻	chlor	Chloride ion
Br⁻	brom	Bromide ion
I⁻	iod	Iodide ion
O²⁻	ox	Oxide ion
S²⁻	sulf	Sulfide ion
P³⁻	phosph	Phosphide ion
N³⁻	nitr	Nitride ion

matter are neutral (uncharged):

total number of positive charges = total number of negative charges



Naming Binary Ionic compounds

Name of metal cation

**Base name of anion
+ -ide**

NaCl Sodium chloride

CaO Calcium oxide

Cu₂O Copper(I) oxide

Cuprous oxide

CuO Copper(II) oxide

Cupric oxide

CsBr Cesium bromide

MgS Magnesium sulfide

FeCl₂ Iron(II) chloride

Ferrous chloride

FeCl₃ Iron(III) chloride

Ferric chloride

Binary Compounds

1. Ionic compounds (a metal and a nonmetal)
2. Covalent compounds (two nonmetals)
(Molecular Compounds)

Binary Compounds

2. Covalent compounds (**two nonmetals**)

Naming Binary Covalent compounds (type III)

1 2 3 4 5 6 7 8 9 10

Mono – Di – Tri – Tetra – Penta – Hexa – Hepta – Octa – Nona – Deca

Prefix

**Name of
1st Element**

Prefix

**Name of
2nd Element + -ide**

Rules:

1. Don't use "mono" for the 1st element.
2. Drop the "a" when followed by a vowel.

Naming Binary Covalent compounds (type III)

NO_2 Nitrogen dioxide

CCl_4 Carbon tetrachloride

N_2O_4 Dinitrogen tetroxide

S_2O_3 Disulfur trioxide

PCl_5 Phosphorous pentachloride

SF_6 Sulfur hexafluoride

Naming Polyatomic Ionic Compounds

They contain more than two elements.

Naming Polyatomic Ions

Table 5.4 Names of Common Polyatomic Ions

Ion	Name	Ion	Name
NH_4^+	ammonium	CO_3^{2-}	carbonate
NO_2^-	nitrite	HCO_3^-	hydrogen carbonate (bicarbonate is a widely used common name)
NO_3^-	nitrate	ClO^-	hypochlorite
SO_3^{2-}	sulfite	ClO_2^-	chlorite
SO_4^{2-}	sulfate	ClO_3^-	chlorate
HSO_4^-	hydrogen sulfate (bisulfate is a widely used common name)	ClO_4^-	perchlorate
OH^-	hydroxide	$\text{C}_2\text{H}_3\text{O}_2^-$	acetate
CN^-	cyanide	MnO_4^-	permanganate
PO_4^{3-}	phosphate	$\text{Cr}_2\text{O}_7^{2-}$	dichromate
HPO_4^{2-}	hydrogen phosphate	CrO_4^{2-}	chromate
H_2PO_4^-	dihydrogen phosphate	O_2^{2-}	peroxide

Cation ←

Oxyanions

Polyatomic anions with different numbers of oxygen atoms.

When we have two oxyanions in a series:

Smaller number of oxygen atoms ends with **-ite**.

Larger number of oxygen atoms ends with **-ate**.

NO_2^- Nitrite

NO_3^- Nitrate

SO_3^{2-} Sulfite

SO_4^{2-} Sulfate

HSO_3^- Hydrogen Sulfite
(bisulfite)

HSO_4^- Hydrogen sulfate
(bisulfate)

PO_3^{3-} Phosphite

PO_4^{3-} Phosphate

HPO_4^{2-} Hydrogen phosphate

H_2PO_4^- Dihydrogen phosphate

Oxyanions

When we have more than two oxyanions in a series:

(Fewest oxygen atoms) \longrightarrow Prefix **hypo-**

(Most oxygen atoms) \longrightarrow Prefix **per-**

ClO^- **hypo**chlorite

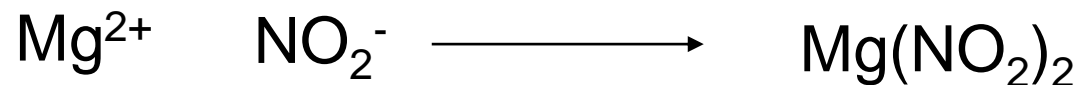
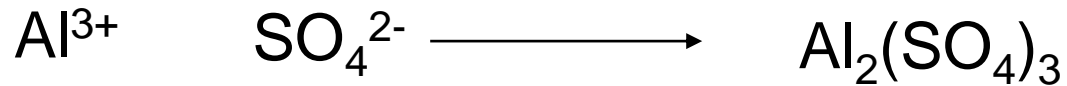
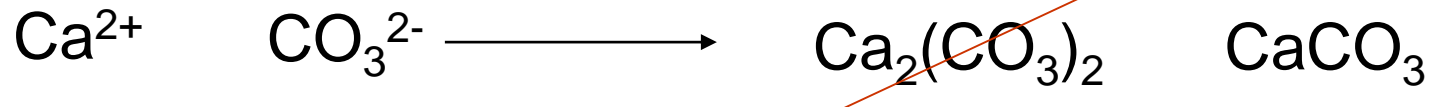
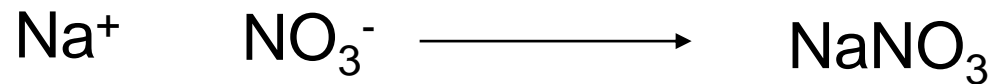
ClO_2^- chlorite

ClO_3^- chlorate

ClO_4^- **per**chlorate

matter are neutral (uncharged):

total number of positive charges = total number of negative charges



Naming Polyatomic Ionic compounds

Name of metal cation

Name of polyatomic ion



Sodium nitrate



Calcium carbonate



Aluminum sulfate



Magnesium nitrite

Naming Polyatomic Ionic compounds

Name of
metal cation

(Charge of cation in
Roman numerals)

Name of polyatomic ion



Iron(II) carbonate



Iron(III) carbonate

Binary Compounds

Yes

Metal present?

No

Type III
Use prefixes

Yes

Does the metal form more than one cation?

No

Type I
Use the element name for the cation

Yes

Type II
Find the charge of the cation
Use a Roman number after the element name.

Naming binary acids

Hydro + Anion : ~~-ide ion~~ → -ic acid

HF F⁻ : flouride ion Hydroflouric acid

HCl Cl⁻ : chloride ion Hydrochloric acid

H₂S S²⁻ : sulfuride ion Hydrosulfuric acid

Naming Polyatomic Acids

Anion: ~~-ite ion~~ \longrightarrow -ous acid
~~-ate ion~~ \longrightarrow -ic acid



NO_2^- : Nitrite ion

Nitrous acid



NO_3^- : Nitrate ion

Nitric acid



CO_3^{2-} : Carbonate ion

Carbonic acid



SO_3^{2-} : Sulfurite ion

Sulfurous acid