UNIVERSITI TEKNIKAL MALAYSIA MELAKA

TECHNICAL CHEMISTRY - BETV 1013

Atom, Molecules & Ions

Chapter 2

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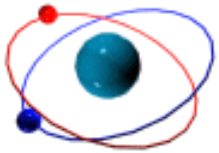
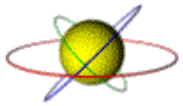
The Atom

- 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 protons and neutrons of an atom are packed in an extremely small nucleus.
- Electrons are shown as ‘clouds’ around the nucleus.



The Structure of the Atom

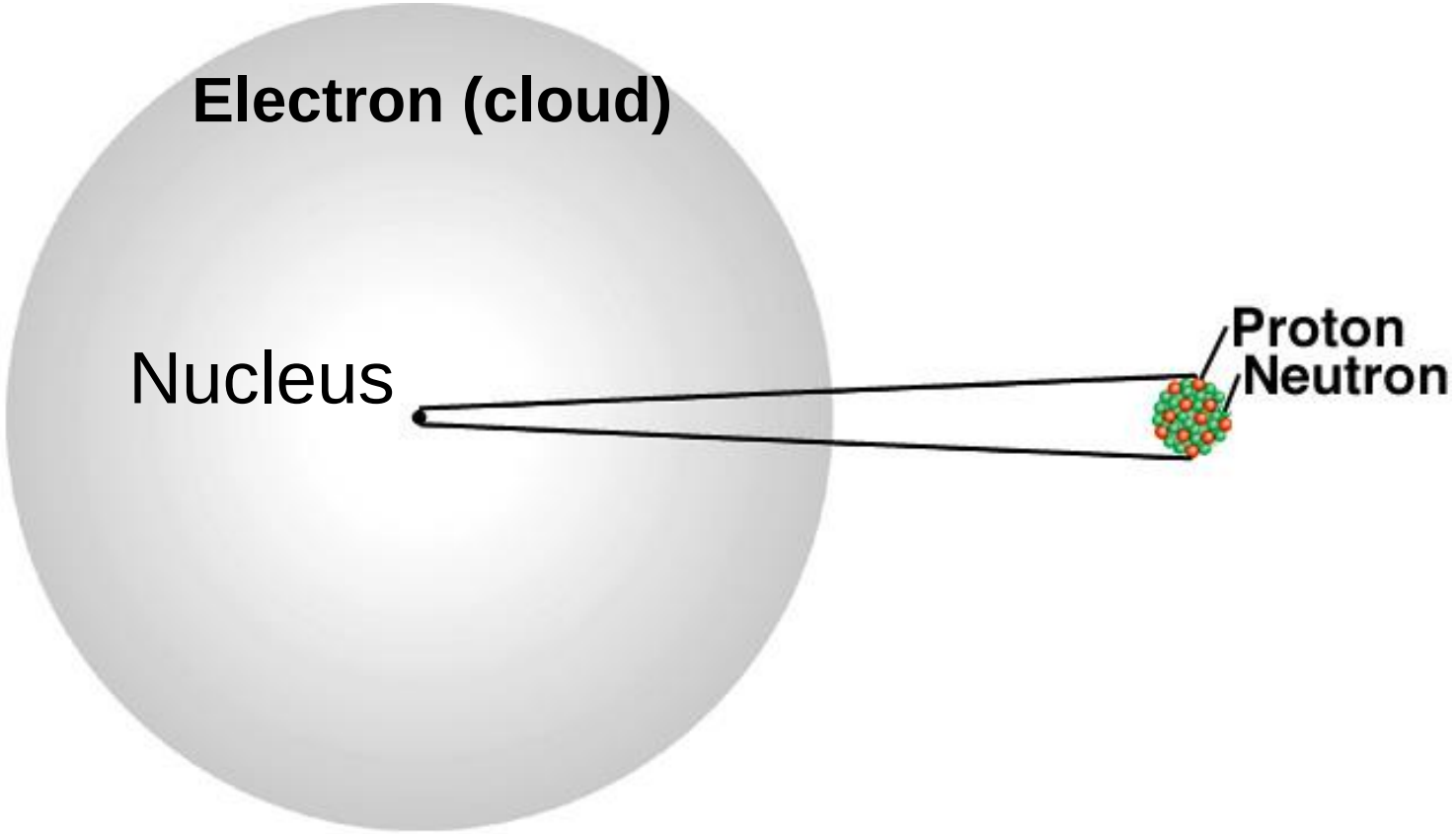
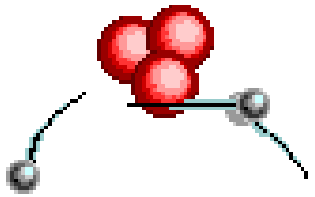


Figure above shows the location of the protons, Neutrons and electrons in an atom

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^-

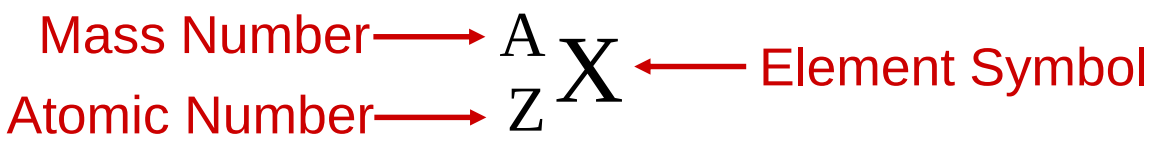
Atomic Number, Mass Number & Isotopes

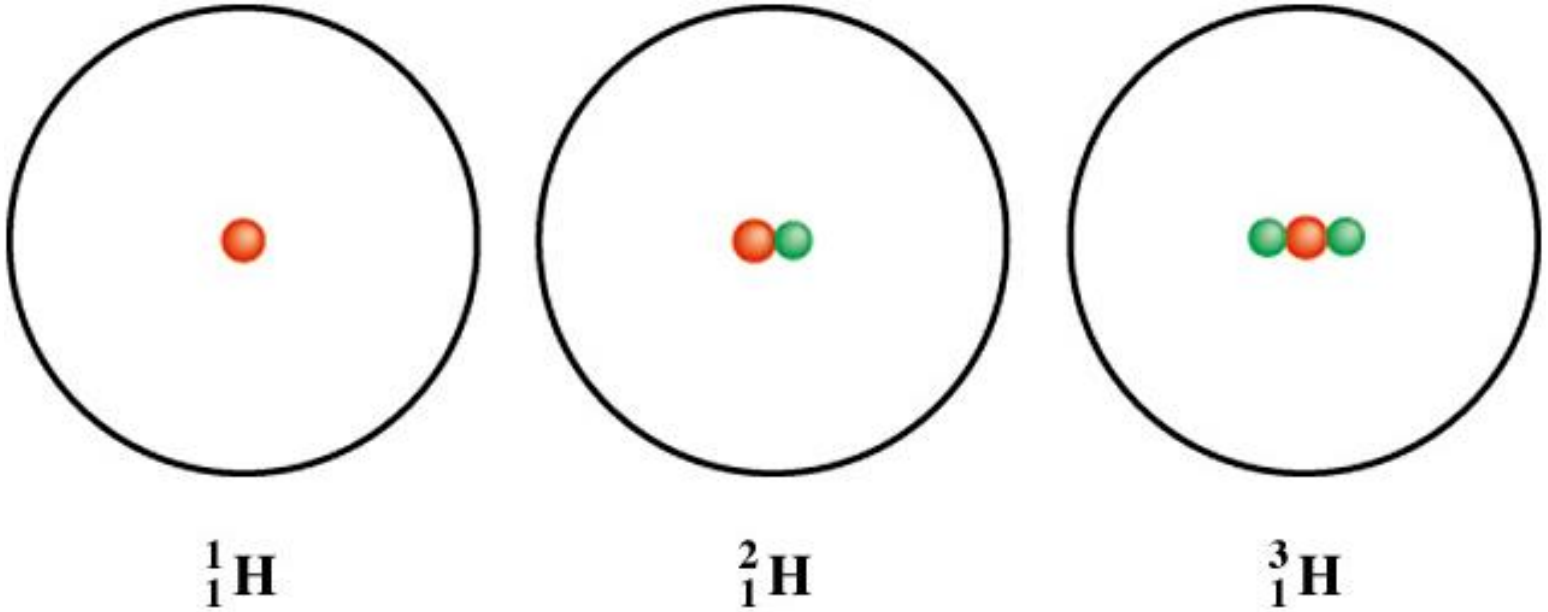
Atomic number (Z) = number of protons in nucleus

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

= atomic number (Z) + number of neutrons

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





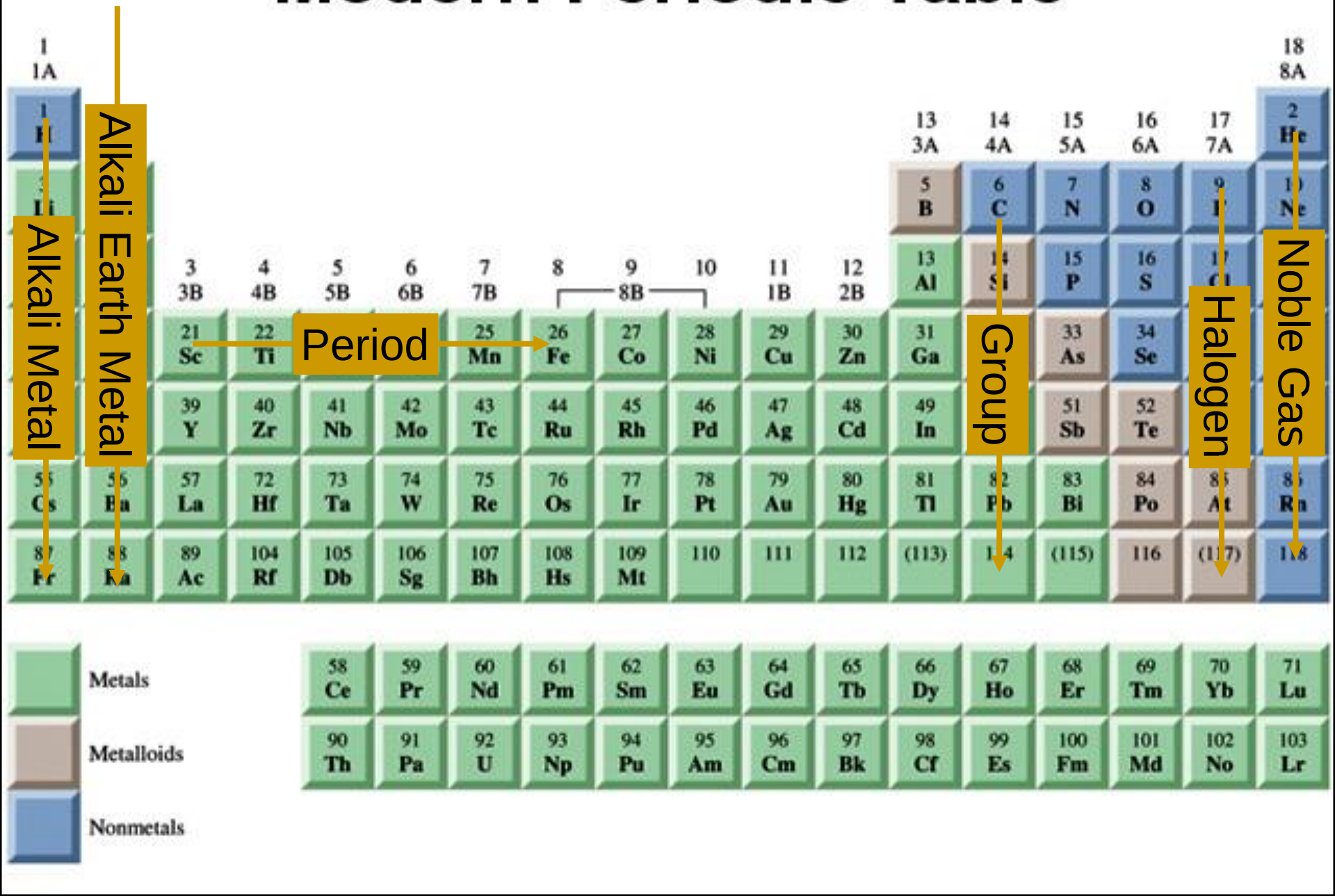
$^{1}_{1}H$ hydrogen $^{2}_{1}H$ (D) deuterium $^{3}_{1}H$ (T) tritium

Do You Understand Isotopes?

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

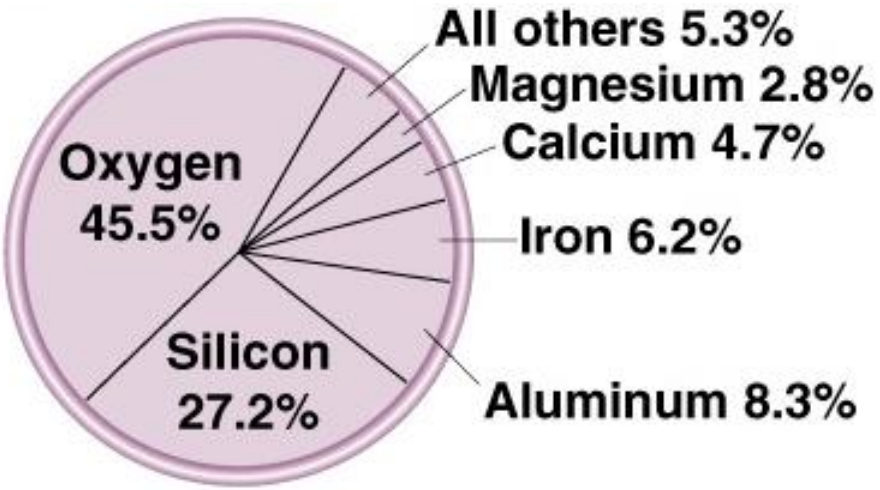
How many protons, neutrons, and electrons are in $^{11}_{6}\mathrm{C}$?

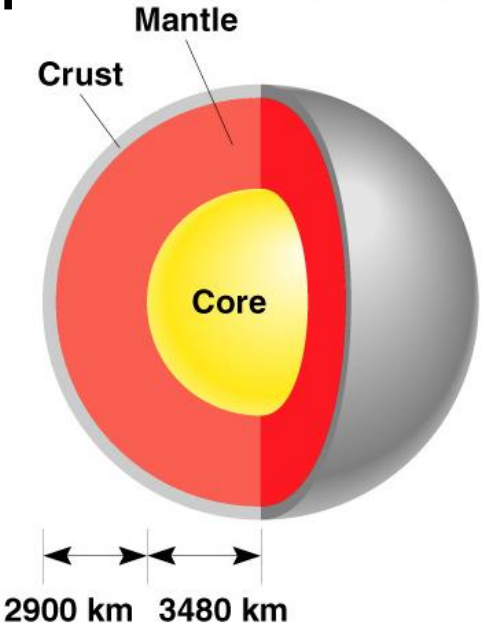
Modern Periodic Table

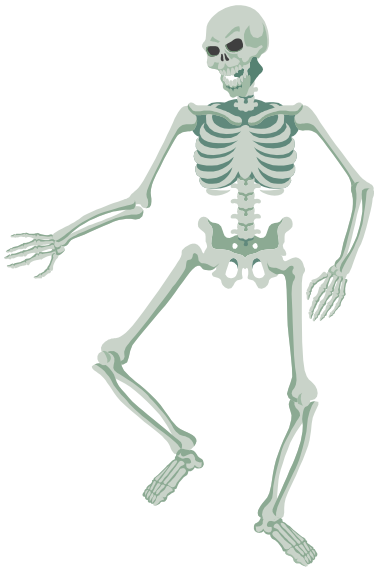


Chemistry In Action

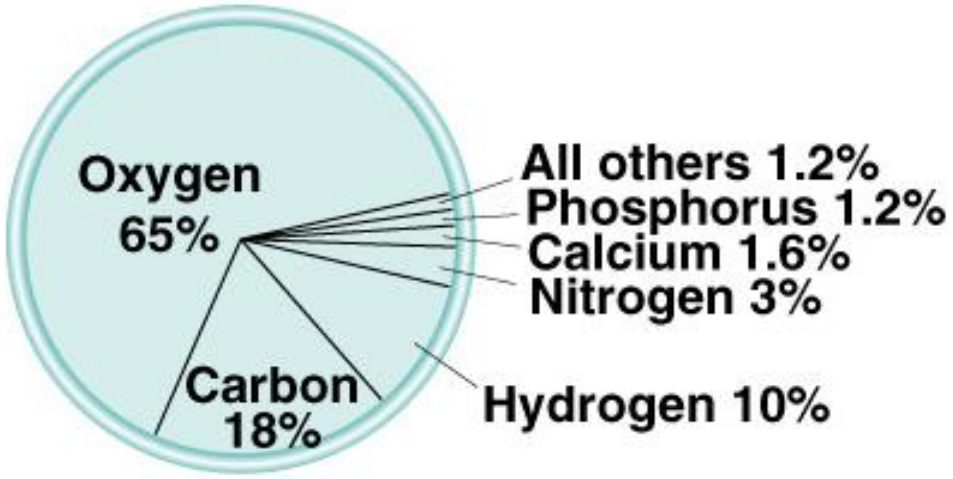
Natural abundance of elements in Earth's crust





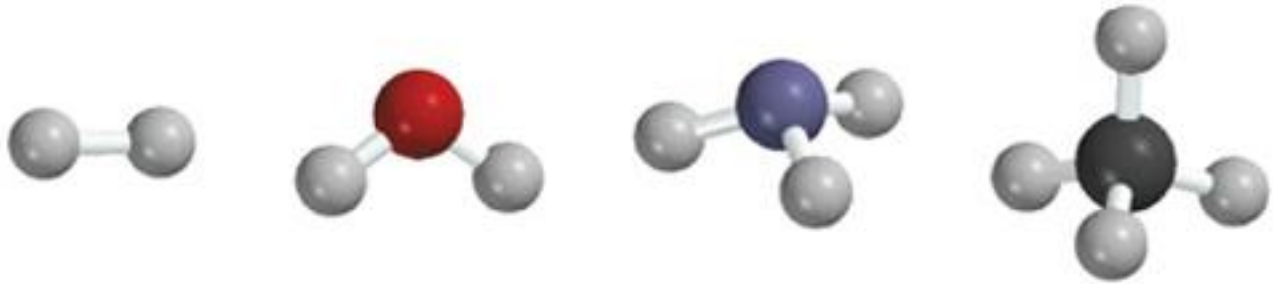


Natural abundance of elements in human body



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

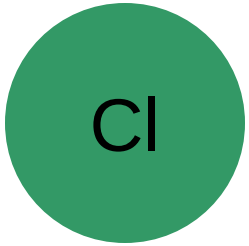
If a neutral atom **loses** one or more electrons it becomes a cation.

11 protons
11 electrons

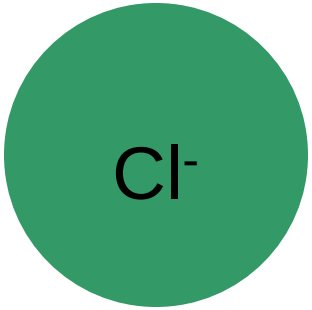
11 protons
10 electrons

anion – ion with a negative charge

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



17 protons
17 electrons



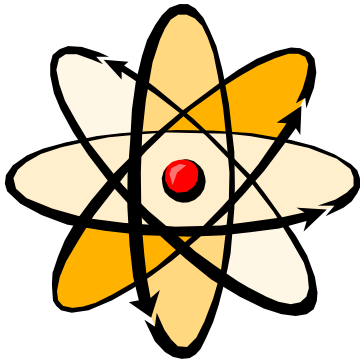
17 protons
18 electrons

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^-

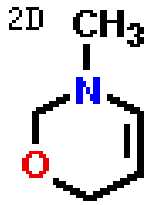


Do You Understand Ions?

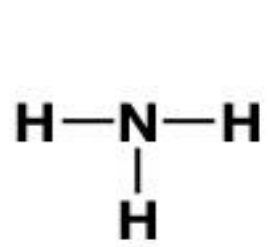
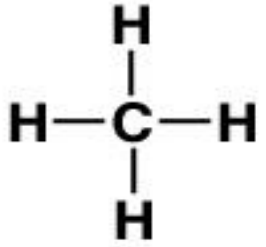
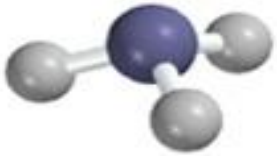
How many protons and electrons are in $^{27}_{13}Al^{3+}$?

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

Chemical Formulas



Standard Types of Formulas and Models

	Hydrogen	Water	Ammonia	Methane
Molecular formula	H_2	H_2O	NH_3	CH_4
Structural formula	H—H	H—O—H		
Ball-and-stick model				
Space-filling model				

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

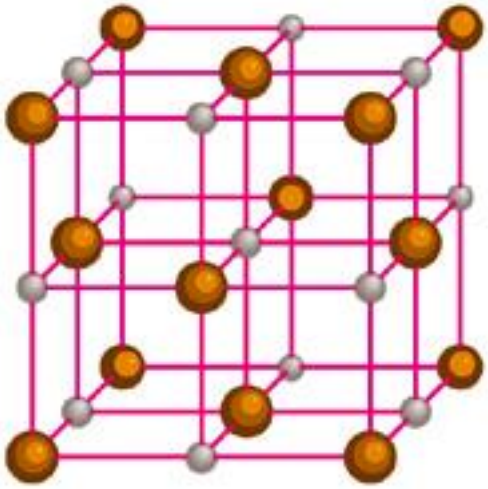
An ***empirical formula*** shows the simplest whole-number ratio of the atoms in a substance

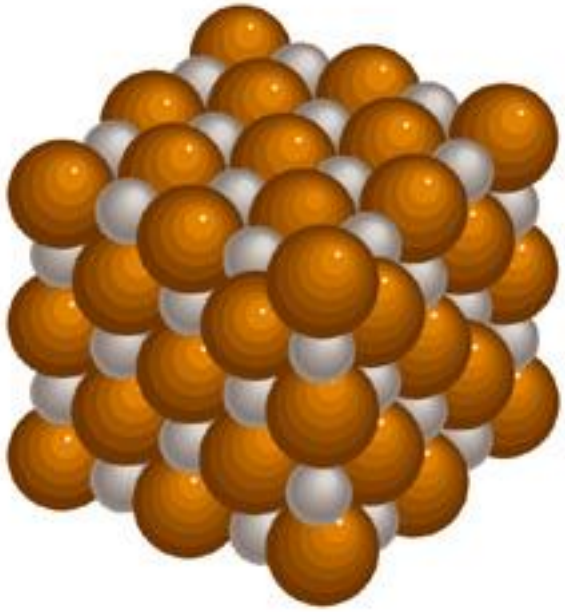
molecular	**empirical**
H_2O	
$C_6H_{12}O_6$	
O_3	
N_2H_4	

ionic compounds consist of a combination of cations and an anions

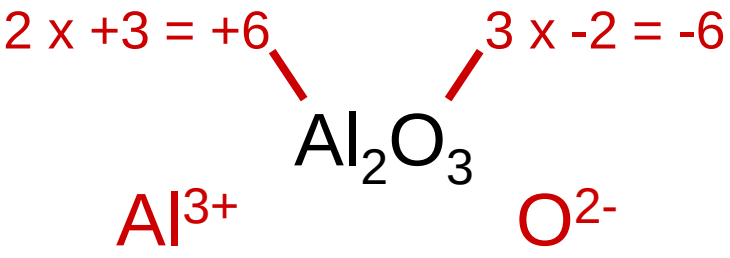
- the formula is always the same as the empirical formula
- the sum of the charges on the cation(s) and anion(s) in each formula unit must equal zero

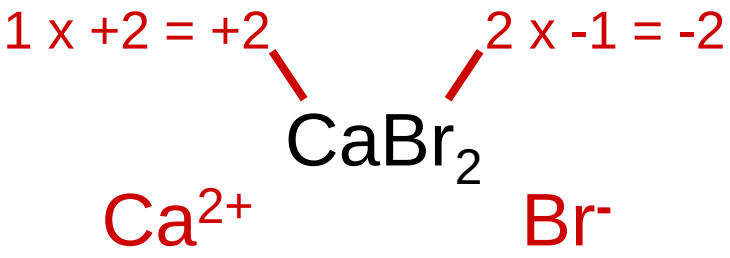
The ionic compound NaCl





Formula of Ionic Compounds





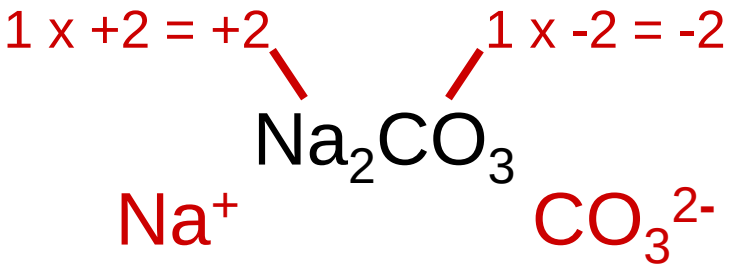


TABLE 2.3

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 Compound

- **Ionic Compounds**
  - often a metal + nonmetal
  - anion (nonmetal), add “ide” to element name

$BaCl_2$

K_2O

$Mg(OH)_2$

KNO_3

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

$FeCl_2$ 2 Cl^- -2 so Fe is +2

$FeCl_3$ 3 Cl^- -3 so Fe is +3

Cr_2S_3 3 S^{-2} -6 so Cr is +3 (6/2)

Molecular compounds

- nonmetals or nonmetals + metalloids
- common names
  - H_2O, NH_3, CH_4, C_{60}
- element further left in periodic table is 1st
  - NF_3 , NO_2
- element closest to bottom of group is 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
- last element ends in ide

TABLE 2.4 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

Molecular Compounds

HI

NF_3

SO_2

N_2Cl_4

NO_2

N_2O

Acid & Bases

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

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

HNO_3	nitric acid
H_2CO_3	carbonic acid
H_2SO_4	sulfuric acid

TABLE 2.5

Some Simple Acids

Anion	Corresponding Acid
F^- (fluoride)	HF (hydrofluoric acid)
Cl^- (chloride)	HCl (hydrochloric acid)
Br^- (bromide)	HBr (hydrobromic acid)
I^- (iodide)	HI (hydroiodic acid)
CN^- (cyanide)	HCN (hydrocyanic acid)
S^{2-} (sulfide)	H_2S (hydrosulfuric acid)

Naming Oxoacids and Oxoanions

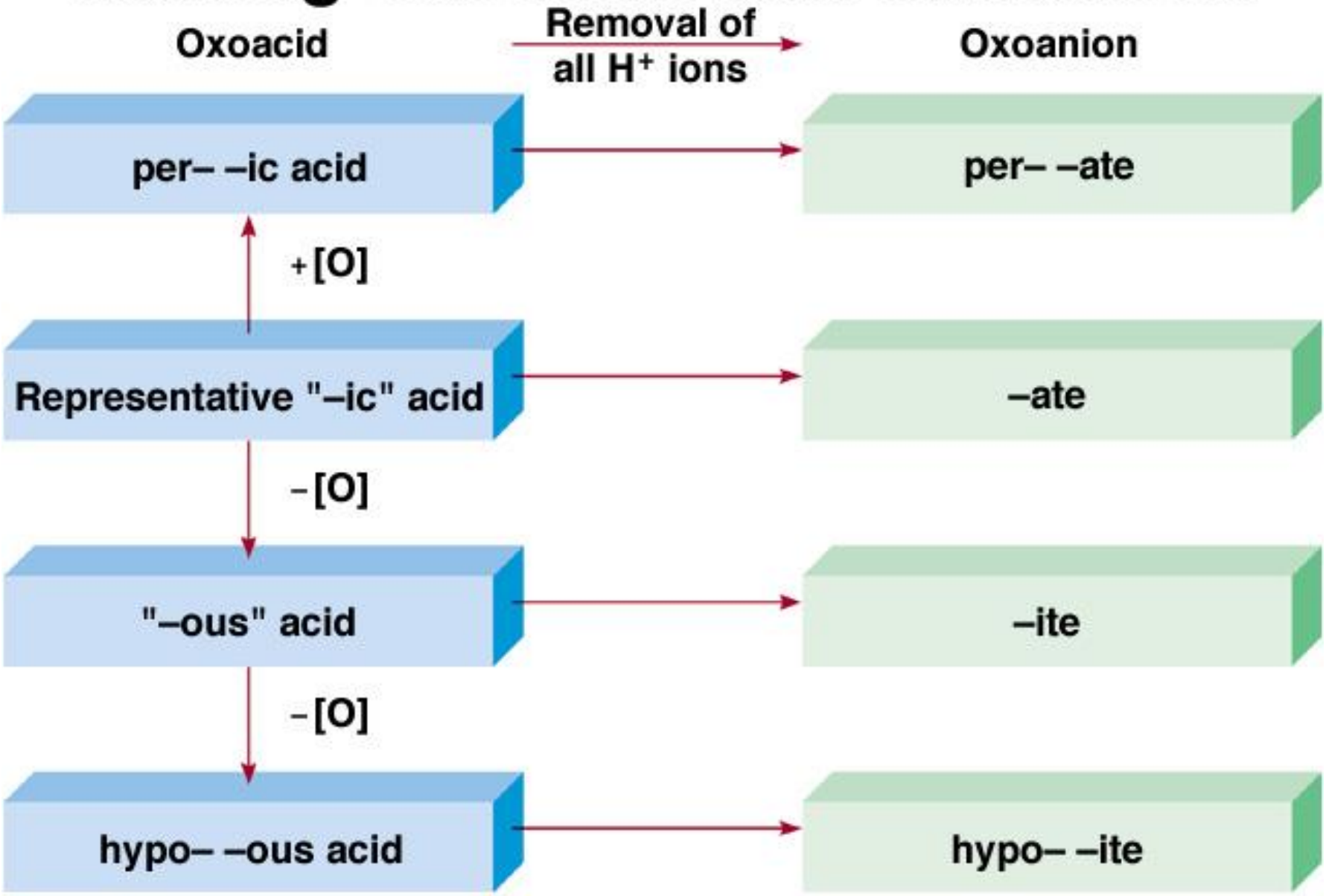


TABLE 2.6

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

TABLE 2.7

Common and Systematic Names of Some Compounds

Formula	Common Name	Systematic Name
H_2O	Water	Dihydrogen monoxide
NH_3	Ammonia	Trihydrogen nitride
CO_2	Dry ice	Solid carbon dioxide
NaCl	Table salt	Sodium chloride
N_2O	Laughing gas	Dinitrogen monoxide
$CaCO_3$	Marble, chalk, limestone	Calcium carbonate
CaO	Quicklime	Calcium oxide
$Ca(OH)_2$	Slaked lime	Calcium hydroxide
$NaHCO_3$	Baking soda	Sodium hydrogen carbonate
$Na_2CO_3 \cdot 10H_2O$	Washing soda	Sodium carbonate decahydrate
$MgSO_4 \cdot 7H_2O$	Epsom salt	Magnesium sulfate heptahydrate
$Mg(OH)_2$	Milk of magnesia	Magnesium hydroxide
$CaSO_4 \cdot 2H_2O$	Gypsum	Calcium sulfate dihydrate