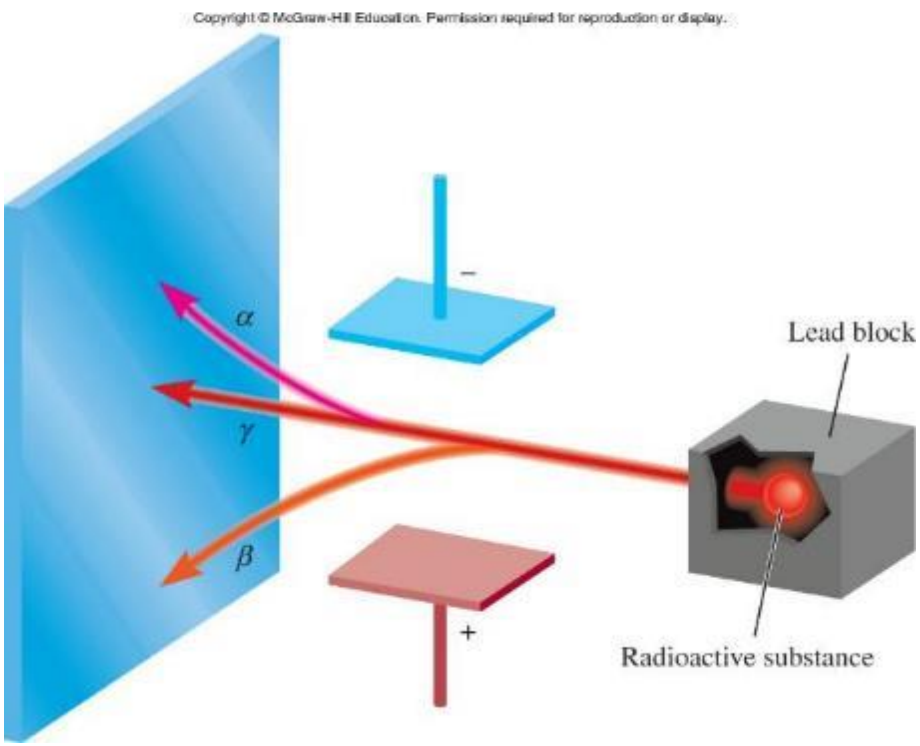
Dalton's Atomic Theory (1808)

1. Elements are composed of extremely small particles called ***atoms***.
2. All ***atoms*** of a given element are identical, having the same size, mass and chemical properties.
3. ***Compounds*** are composed of atoms of more than one element.
4. A ***chemical reaction*** involves only the separation, combination, or rearrangement of atoms; it does not result in their creation or destruction.

Types of Radioactivity



(uranium compound)

Wilhelm Rontgen (1895) discovered:

Alpha particles α
Beta particles β
Gamma rays γ

All radioactive substances emit one or more of these particles/ray.

Ernest Rutherford’s Experiment

(1908 Nobel Prize in Chemistry)

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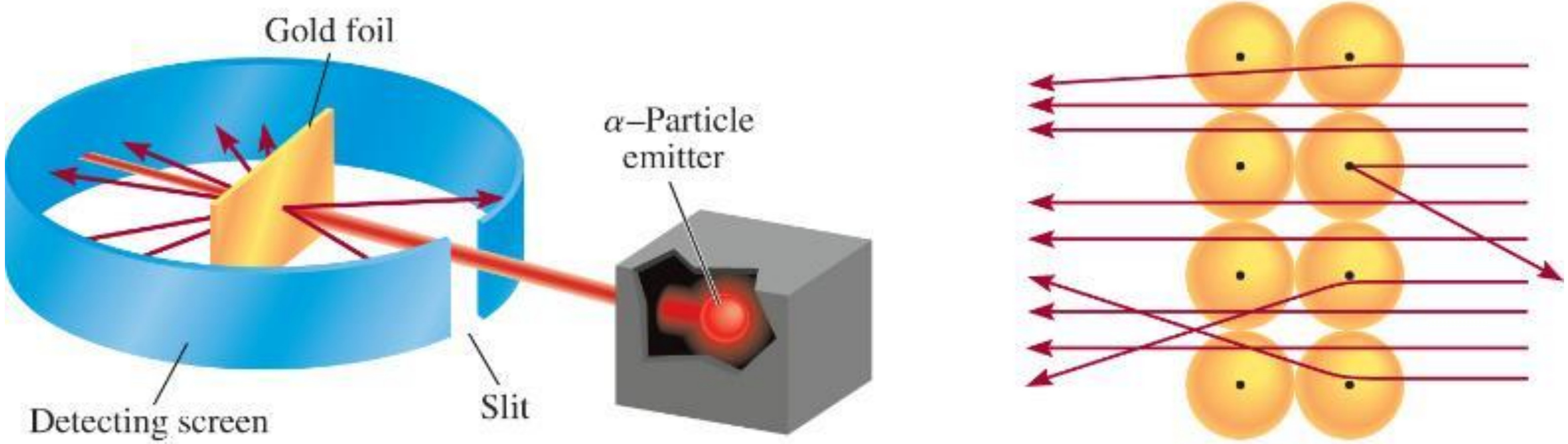

(a) (b)

1. Atoms’ positive charge is concentrated in the nucleus
2. proton (p) has opposite (+) charge of electron (-)

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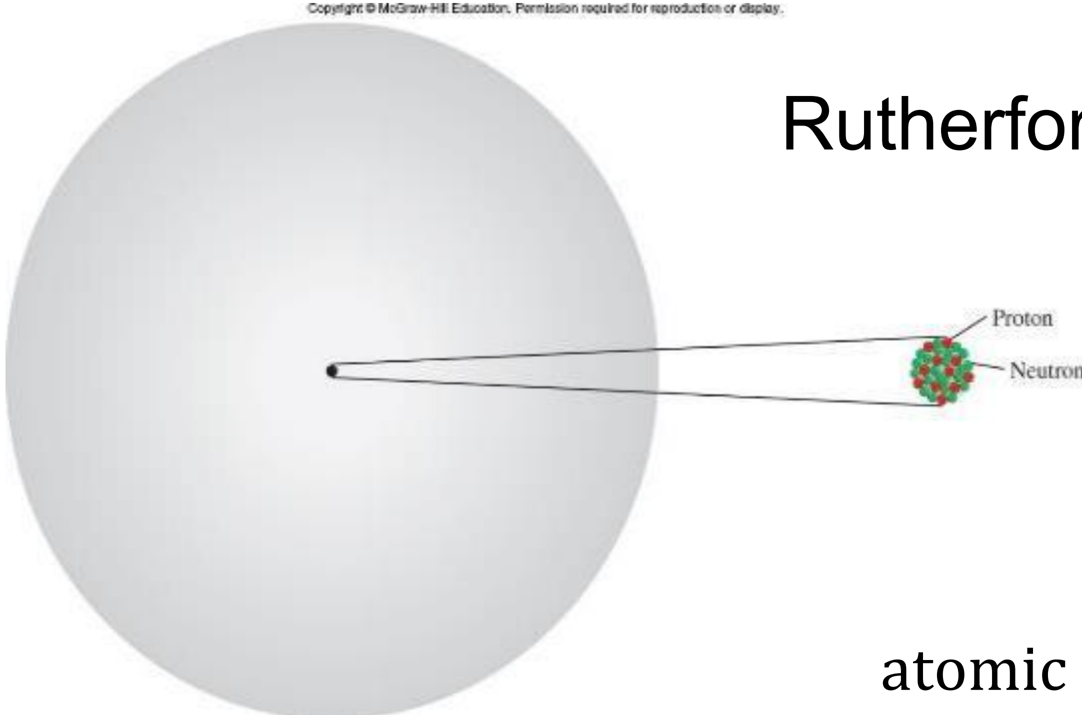

Rutherford's Model of the Atom

$$\text{atomic radius} \sim 100\ \text{pm}$$

$$\text{nuclear radius} \sim 5 \times 10^{-3}\text{pm}$$

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"If the atom is a domed stadium, then the nucleus is a marble on the 50-yard line."

Chadwick’s Experiment (1932)
(1935 Noble Prize in Physics)

Chadwick discovered neutrons within atoms:

1. Neutrons have no charge
2. Neutrons are almost identical in mass to protons
3. Neutrons are concentrated in the atom’s nucleus along with protons

Thus, nucleus is very dense but rest of atom is largely empty space (just a few electrons).

Properties of Subatomic Particles

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Table 2.1 Mass and Charge of Subatomic Particles

Particle	Mass (g)	Coulomb *Charge*	Charge Unit *Charge*
Electron*	9.10938×10^{-28}	-1.6022×10^{-19}	-1
Proton	1.67262×10^{-24}	$+1.6022 \times 10^{-19}$	$+1$
Neutron	1.67493×10^{-24}	0	0

*More refined measurements have given us a more accurate value of an electron's mass than Millikan's.

Protons and neutrons are both 1840 *times more massive than electrons.*

Atomic Number, Mass Number, and 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

Mass Number → $^{A}_{Z}\mathrm{X}$ ← Element Symbol
Atomic Number →

$^{1}_{1}\mathrm{H}$ $^{2}_{1}\mathrm{H}$ $^{3}_{1}\mathrm{H}$

$^{235}_{92}\mathrm{U}$ $^{238}_{92}\mathrm{U}$

The Isotopes of Hydrogen

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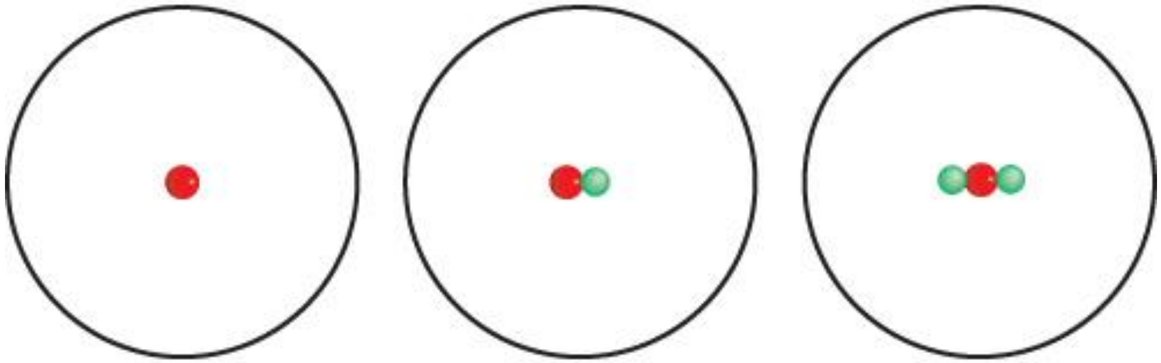

$^{1}_{1}H$ $^{2}_{1}H$ $^{3}_{1}H$

Example 2.1

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

(a) $^{20}_{11}Na$ — $11\ p^+$, $9\ n$, $11\ e^-$

(b) $^{22}_{11}Na$ — $11\ p^+$, $11\ n$, $11\ e^-$

(c) ^{17}O — $8\ p^+$, $9\ n$, $8\ e^-$

(d) carbon-14 — $6\ p^+$, $8\ n$, $6\ e^-$

(e) ^{108}Pd — $46\ p^+$, $62\ n$, $46\ e^-$

Balancing Nuclear Reactions

	proton	neutron	electron	positron	∝ particle
	${}^{1}_{1}\mathrm{p}$ or ${}^{1}_{1}\mathrm{H}$	${}^{1}_{0}\mathrm{n}$	${}^{0}_{-1}e$ or ${}^{0}_{-1}\beta$	${}^{0}_{+1}e$ or ${}^{0}_{+1}\beta$	${}^{4}_{2}\mathrm{He}$ or ${}^{4}_{2}\propto$
Mass	1	1	0	0	4
Charge	1	0	-1	+1	2

Balancing Nuclear Equations

1. Conserve mass number (A).

The sum of protons plus neutrons in the products must equal the sum of protons plus neutrons in the reactants.

2. Conserve atomic number (Z) or nuclear charge.

The sum of nuclear charges in the products must equal the sum of nuclear charges in the reactants.

Example 19.1

Balance the following nuclear equations (that is, identify the product X):

(a) $^{212}_{84}\text{Po} \rightarrow {}^{208}_{82}\text{Pb} + \text{X}$

(b) $^{137}_{55}\text{Cs} \rightarrow {}^{137}_{56}\text{Ba} + \text{X}$

Comparing Nuclear and Chemical Equations

Comparison of Chemical Reactions and Nuclear Reactions

Chemical Reactions	Nuclear Reactions
1. Atoms are rearranged by the breaking and forming of chemical bonds.	1. Elements (or isotopes of the same elements) are converted from one to another.
2. Only electrons in atomic or molecular orbitals are involved in the breaking and forming of bonds.	2. Protons, neutrons, electrons, and other elementary particles may be involved.
3. Reactions are accompanied by absorption or release of relatively small amounts of energy.	3. Reactions are accompanied by absorption or release of tremendous amounts of energy.
4. Rates of reaction are influenced by temperature, pressure, concentration, and catalysts.	4. Rates of reaction normally are not affected by temperature, pressure, and catalysts.

The Modern Periodic Table

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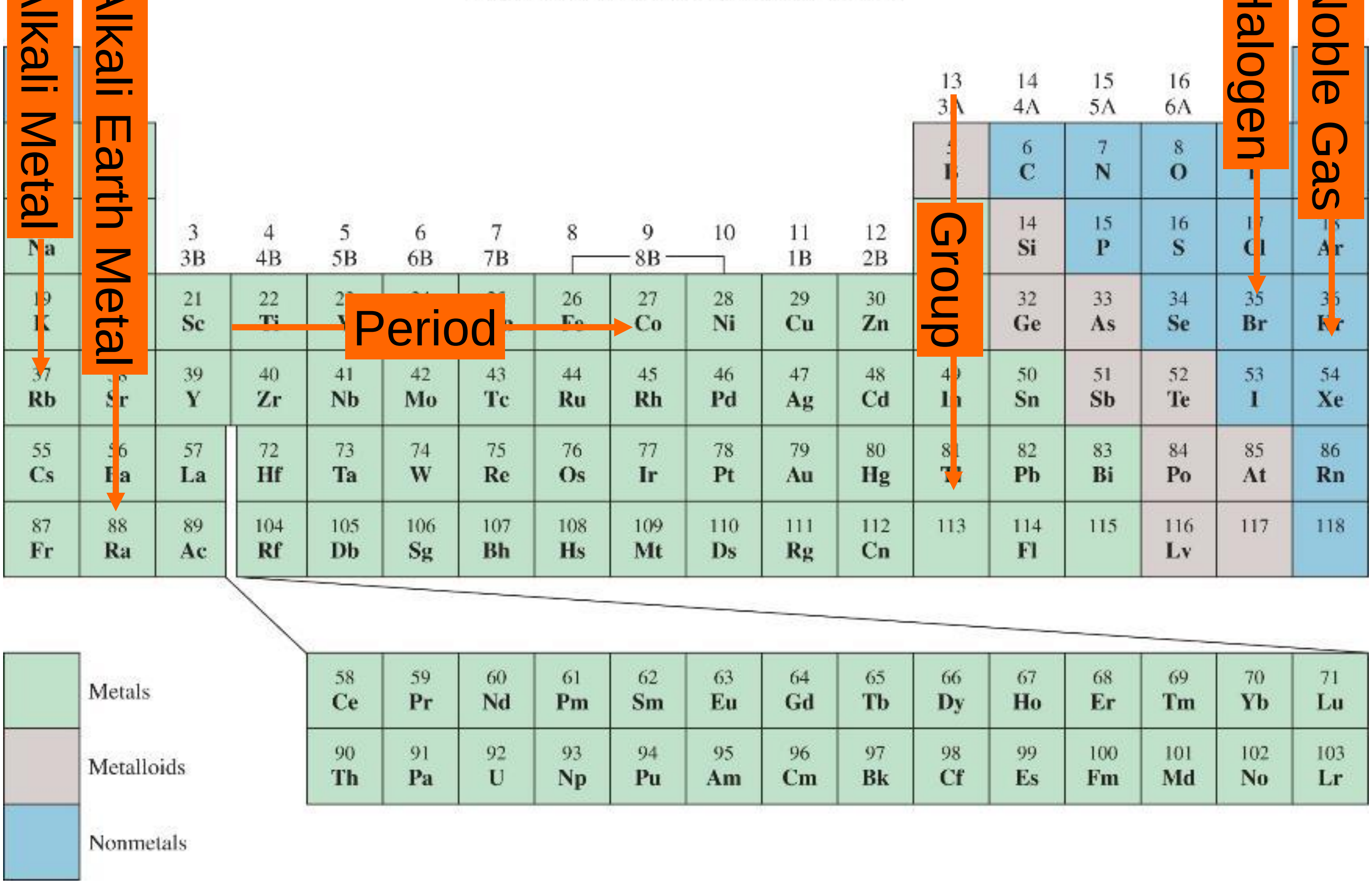
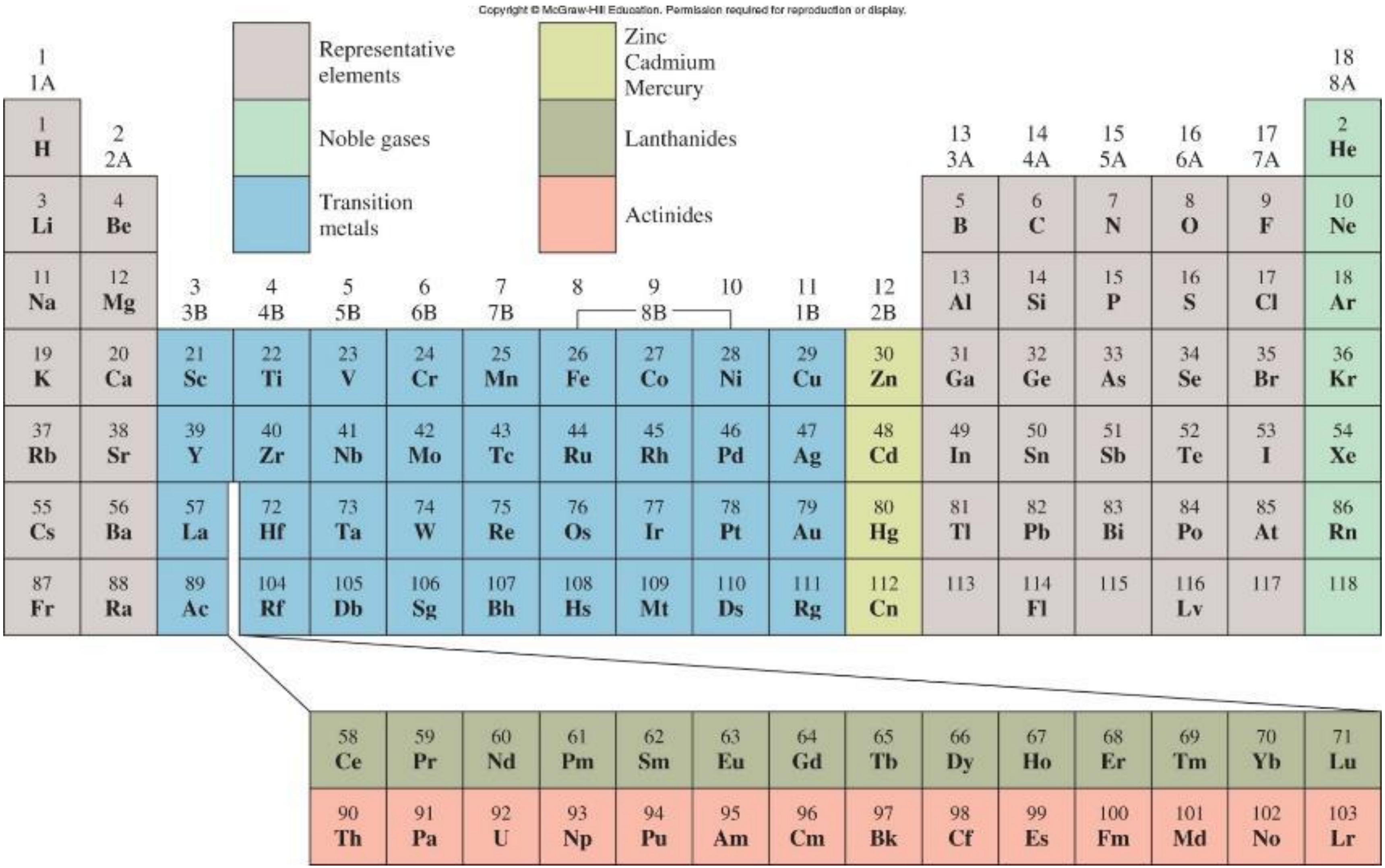


Classification of the Elements



Molecules

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

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

$H_2, N_2, O_2, Br_2, HCl, CO$

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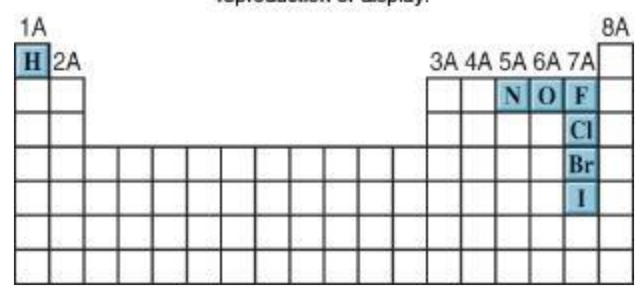

diatomic elements

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

O_3, H_2O, NH_3, CH_4

Ions

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.

Na

11 protons
11 electrons

Na^{+}

11 protons
10 electrons

anion – ion with a 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

Common Ions Shown on the Periodic Table

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1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
Li^{+}													C^{4-}	N^{3-}	O^{2-}	F^{-}	
Na^{+}	Mg^{2+}											Al^{3+}		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+}				

Ionic Compounds

Ionic compounds consist of a combination of cations and anions.

- The formula is usually 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

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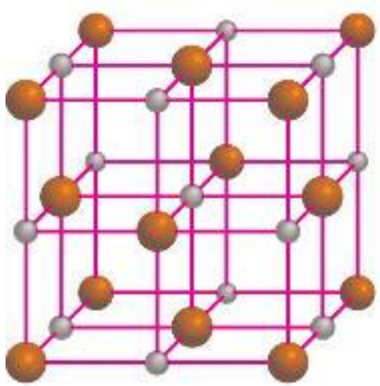

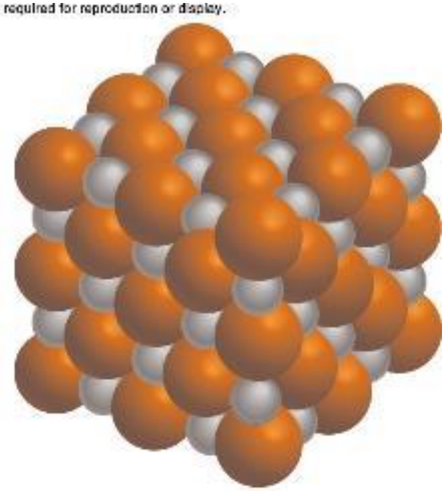

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Molecular Compounds

- **Molecular compounds**
  - Nonmetals or nonmetals + metalloids
  - Common names
    - H_2O, NH_3, CH_4

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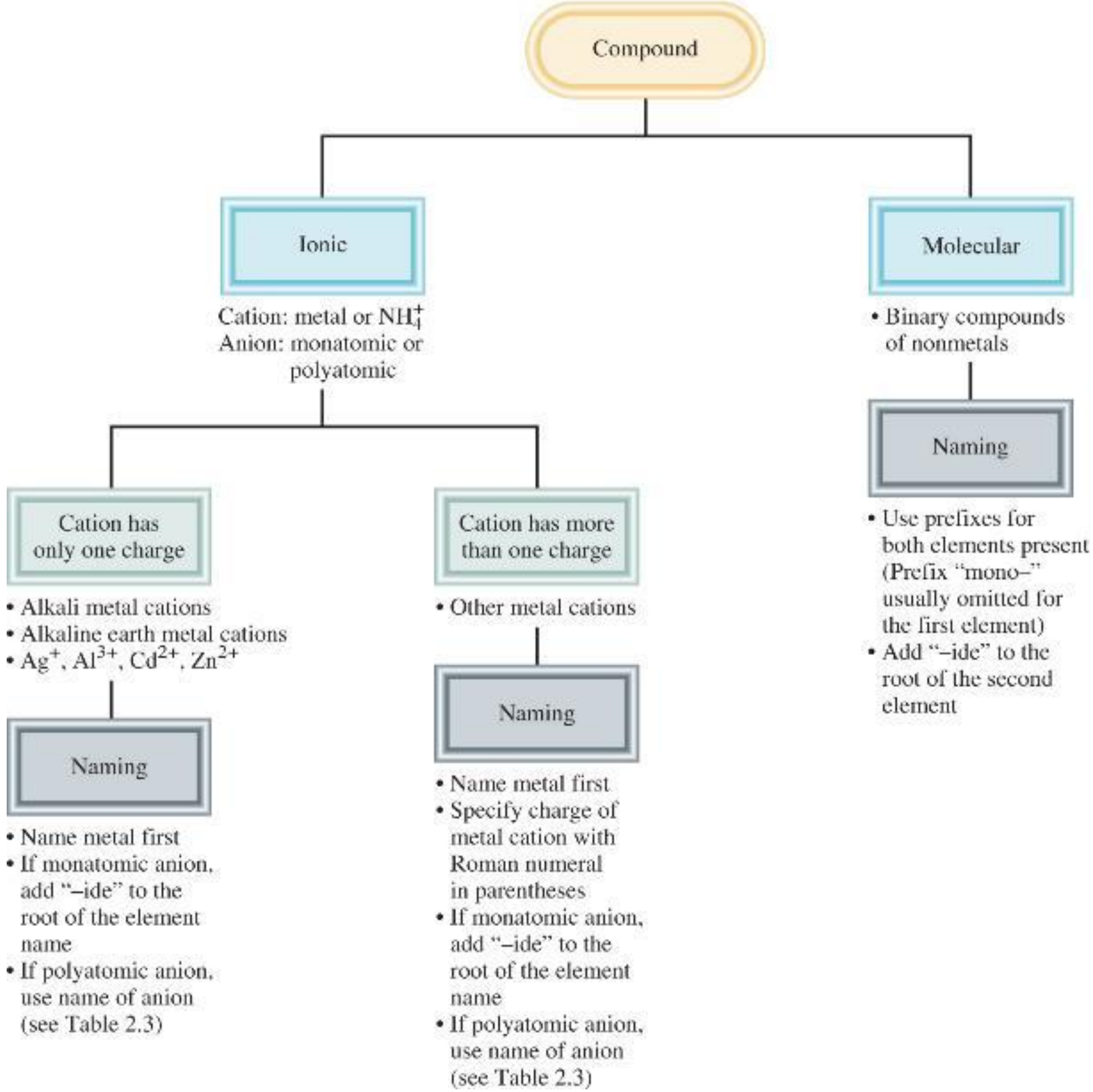
Table 2.4
Greek Prefixes Used in Naming Molecular Compounds

Prefix	Meaning
mono-	1
di-	2
tri-	3
tetra-	4
penta-	5
hexa-	6
hepta-	7
octa-	8
nona-	9
deca-	10

Examples of 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

Flowchart for Naming Compounds



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Organic Chemistry

Organic chemistry is the branch of chemistry that deals with carbon compounds.

Organic compounds are comprised of:
Carbon & hydrogen

May also contain: O, S, N, P, etc..

The first four hydrocarbons:

methane	CH_4
ethane	C_2H_6
propane	C_3H_8
butane	C_4H_{10}

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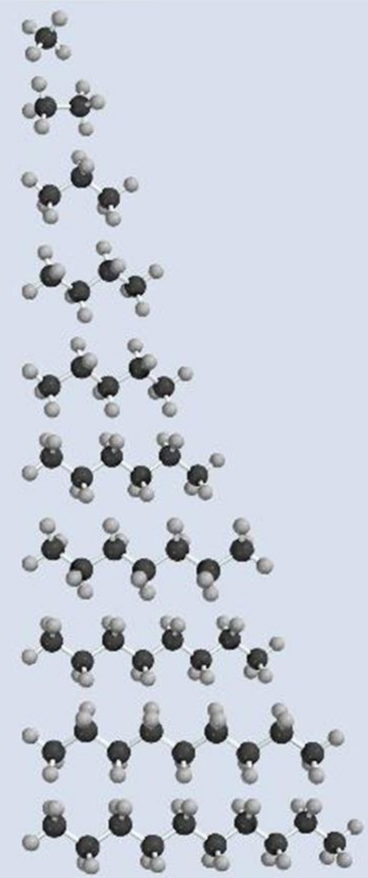
Table 2.8 The First Ten Straight-Chain Alkanes

Name	Formula	Molecular Model
Methane	CH_4	
Ethane	C_2H_6	
Propane	C_3H_8	
Butane	C_4H_{10}	
Pentane	C_5H_{12}	
Hexane	C_6H_{14}	
Heptane	C_7H_{16}	
Octane	C_8H_{18}	
Nonane	C_9H_{20}	
Decane	$C_{10}H_{22}$	



Elemental Gases

Elements that exist as gases at 25° C and 1 atmosphere

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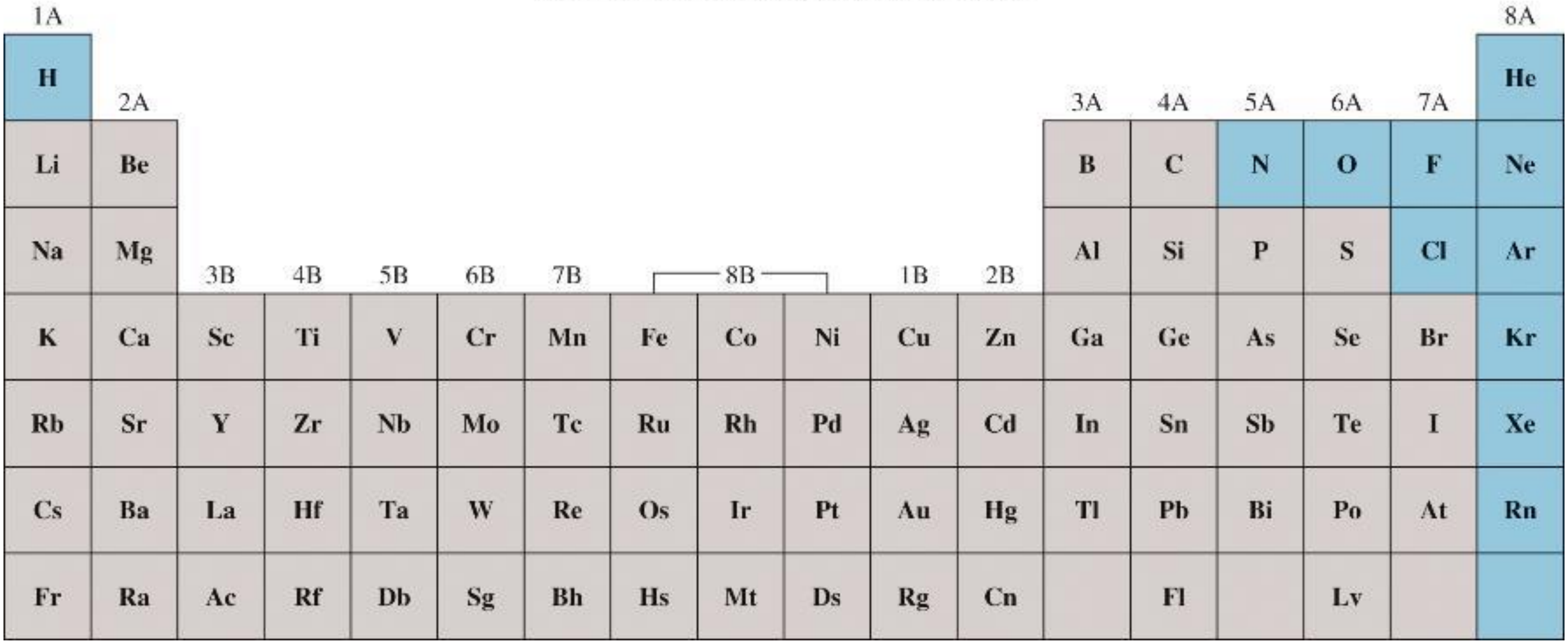

Common Gases

Table 5.1 Some Substances Found as Gases at 1 atm and 25°C

Elements	
H_2 (molecular hydrogen)	N_2 (molecular nitrogen)
O_2 (molecular oxygen)	O_3 (ozone)
F_2 (molecular fluorine)	Cl_2 (molecular chlorine)
He (helium)	Ne (neon)
Ar (argon)	Kr (krypton)
Xe (xenon)	Rn (radon)
Compounds	
HF (hydrogen fluoride)	HCI (hydrogen chloride)
HBr (hydrogen bromide)	HI (hydrogen iodide)
CO (carbon monoxide)	CO_2 (carbon dioxide)
CH_4 (methane)	C_2H_2 (acetylene)
NH_3 (ammonia)	NO (nitric oxide)
NO_2 (nitrogen dioxide)	N_2O (nitrous oxide)
SO_2 (sulfur dioxide)	SF_6 (sulfur hexafluoride)
H_2S (hydrogen sulfide)	HCN (hydrogen cyanide)*

Physical Characteristics of Gases

- Gases assume the volume and shape of their containers.
- Gases are the most compressible state of matter.
- Gases will mix evenly and completely when confined to the same container.
- Gases have much lower densities than liquids and solids.

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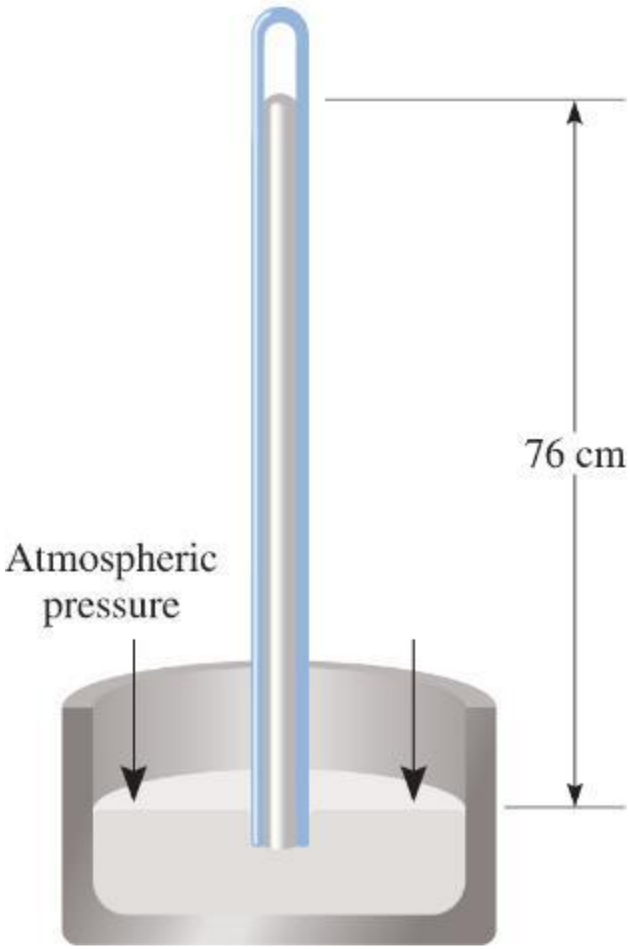
NO_2 gas

Pressure

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

(force = mass × acceleration)



Units of Pressure

1 pascal (pa) = 1 N/m^2

1 atm = 760 mmHg = 760 torr

1 atm = 101,325 Pa

Pressure (1)

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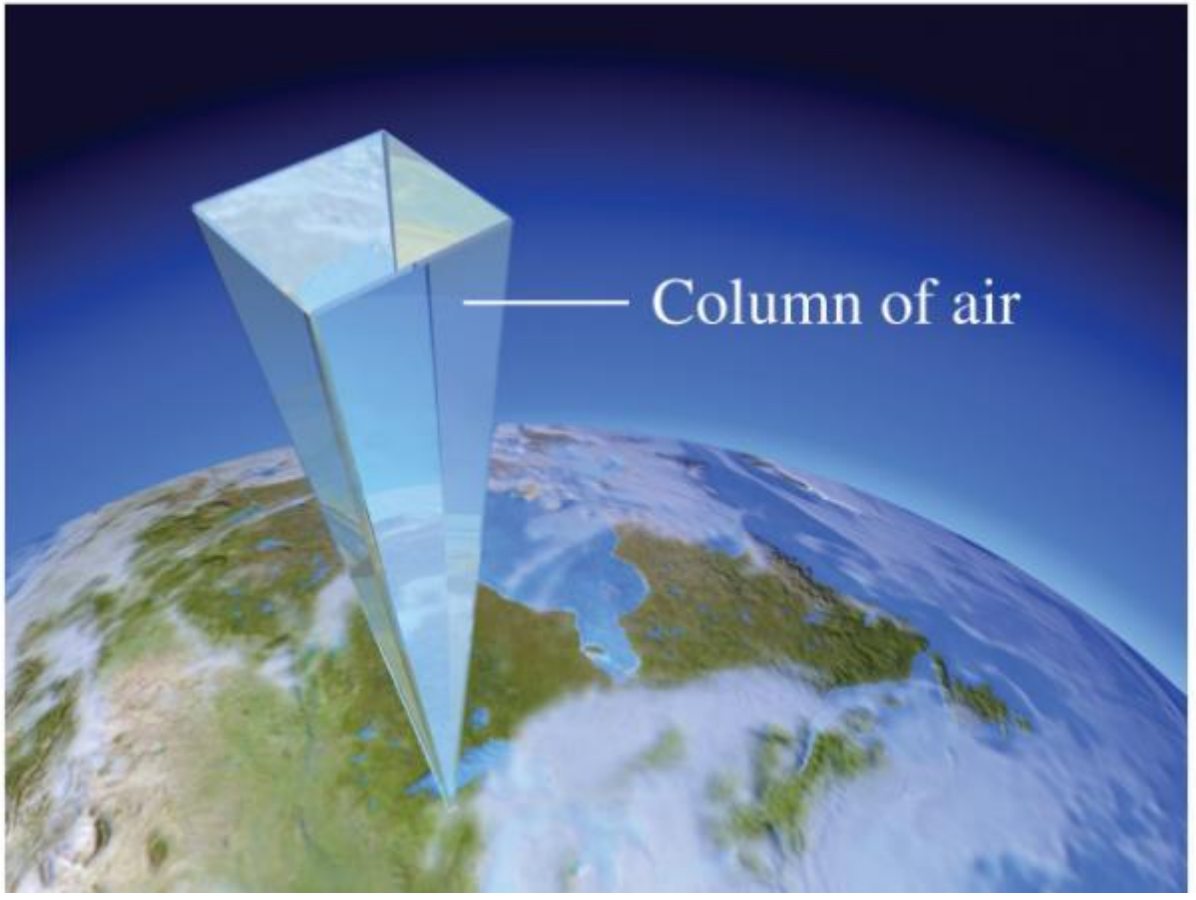

Ideal Gas Equation

$$\boxed{PV = nRT}$$

Standard Temperature and Pressure

The conditions $0\ ^\circ\mathrm{C}$ and 1 atm are called **standard temperature and pressure (STP).**

Experiments show that at STP, 1 mole of an ideal gas occupies 22.414 L.

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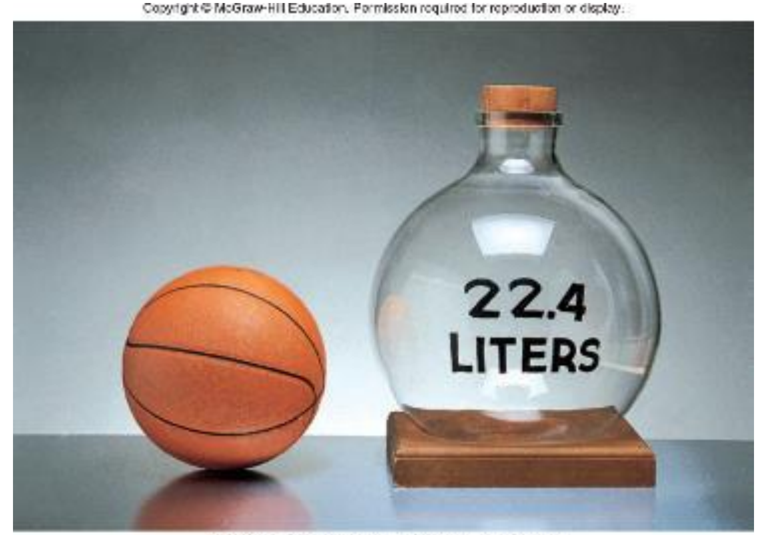

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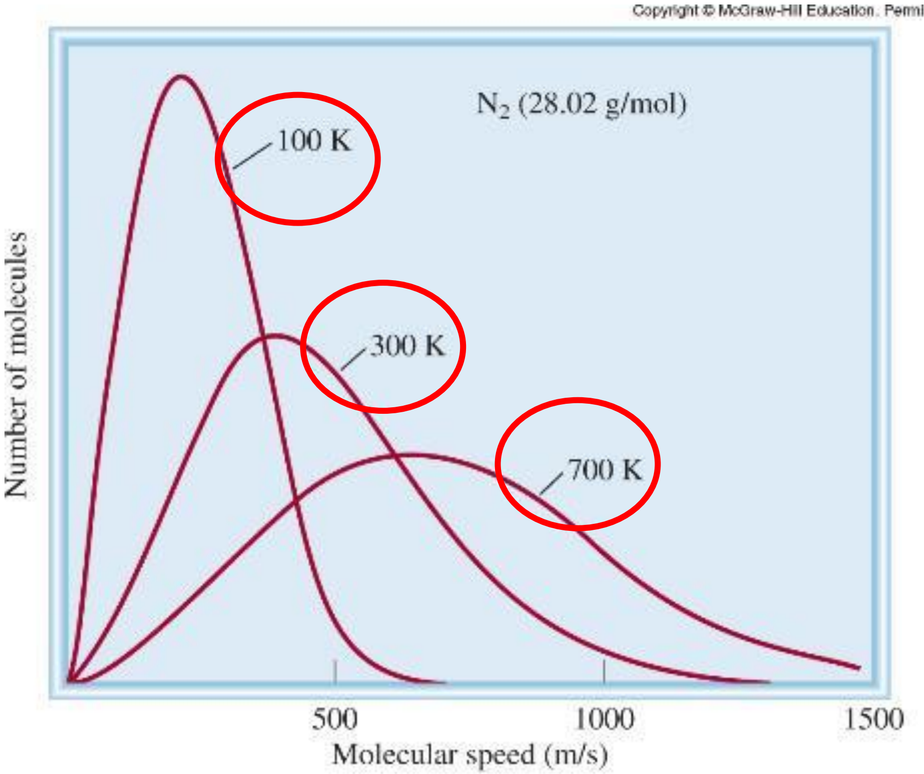
$$PV = nRT$$

$$R = \frac{PV}{nT} = \frac{(1\ \mathrm{atm})(22.414\mathrm{L})}{(1\ \mathrm{mol})(273.15\ \mathrm{K})}$$

$$R = 0.082057\,\mathrm{L}\cdot\mathrm{atm}/(\mathrm{mol}\cdot\mathrm{K})$$

Distribution of Gas Speeds



The distribution of speeds for nitrogen gas molecules at three different temperatures

$$u_{\text{rms}} = \sqrt{\frac{3RT}{\mathcal{M}}}$$

The distribution of speeds of three different gases at the same temperature