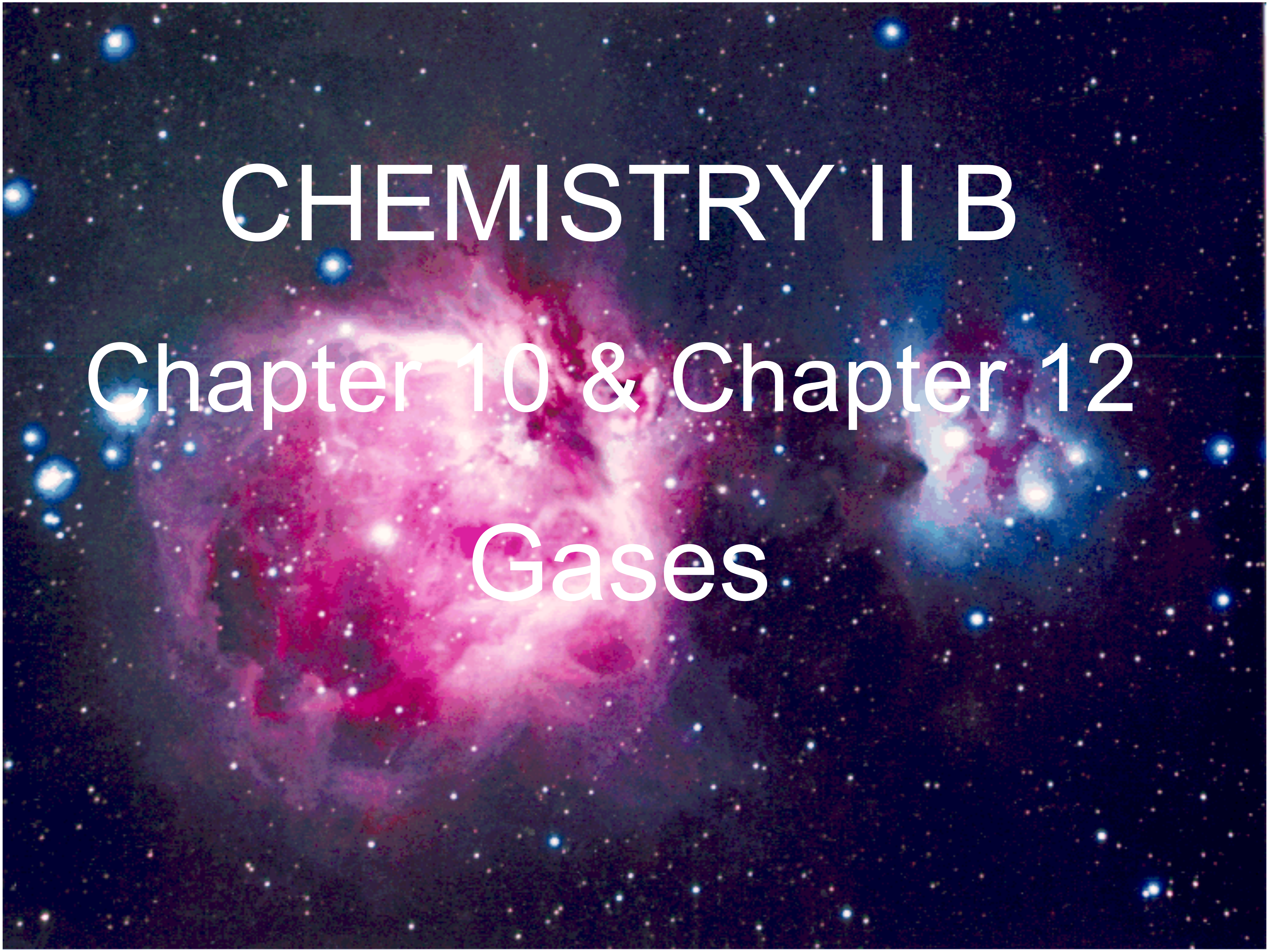

CHEMISTRY II B
Chapter 10 & Chapter 12
Gases

Think to yourself

- How do gas particles move/behavior?
- What is the Kinetic Molecular Theory?
  - Gases are mostly empty space
  - Particles have no attractive or repulsive forces
  - Rapid constant random motion (really fast)
  - Elastic collision (no lost energy)

- Nature abhors a vacuum

  Aristotle 384 - 322 B.C.

- We live submerged at the bottom of an ocean of air.

  Evangelista Torricelli 1644

1. Gases

substances that exist in the gaseous phase under normal atmospheric conditions

T = 25^{o}C p = 1 atm

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	0
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.70	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 * La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226.0)	89 ** Ac (227)	104 Rf	105 Ha	106 Unh	107 Uns	108	109 Une									

HF, HCl, HBr, HI

CO, CO_2

CH_4, NH_3, H_2S, PH_3

NO, NO_2, N_2O

SO_2

Jupiter

(H_2, He)

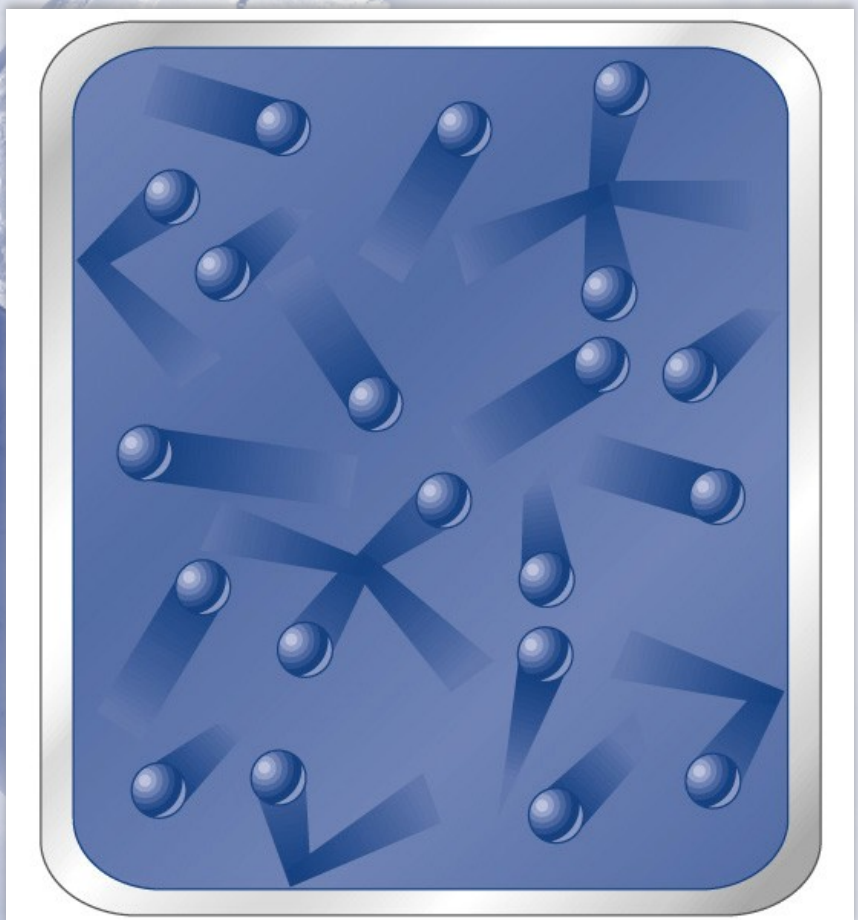
Io

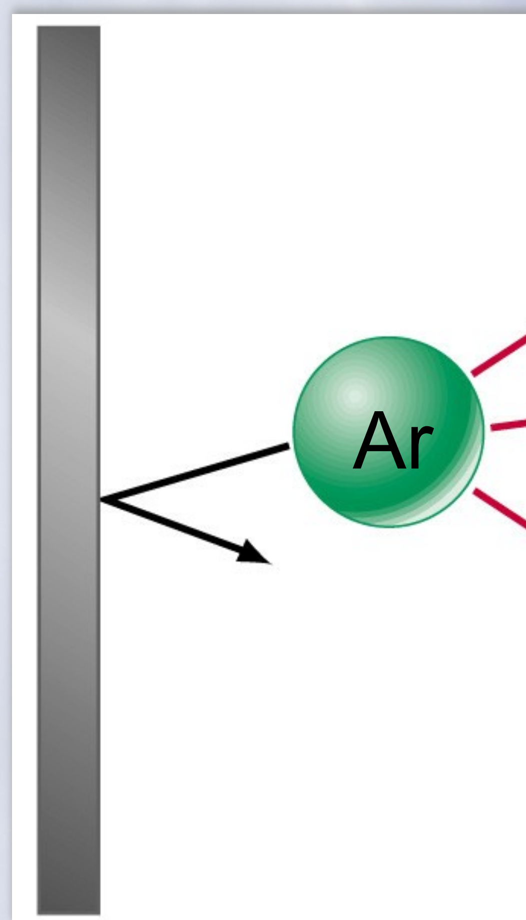
(SO_2)

Helix Nebula

Orion Nebula

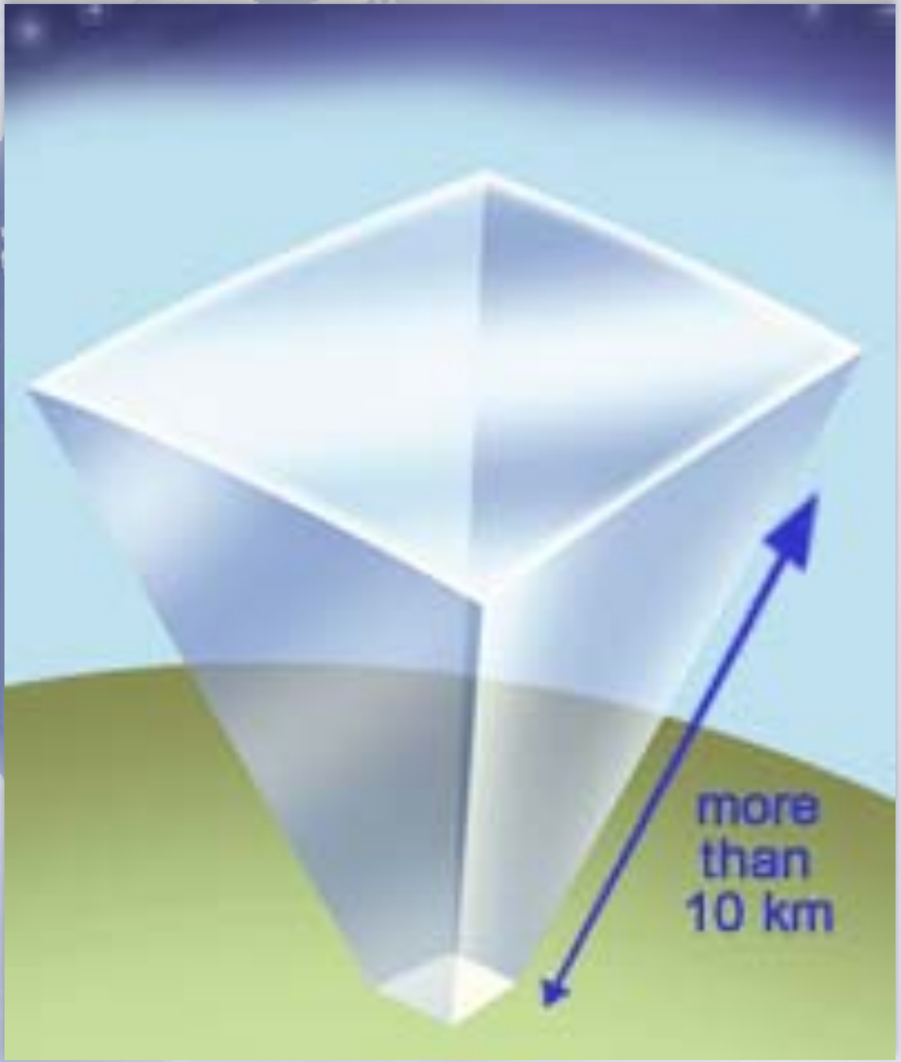
2. Pressure

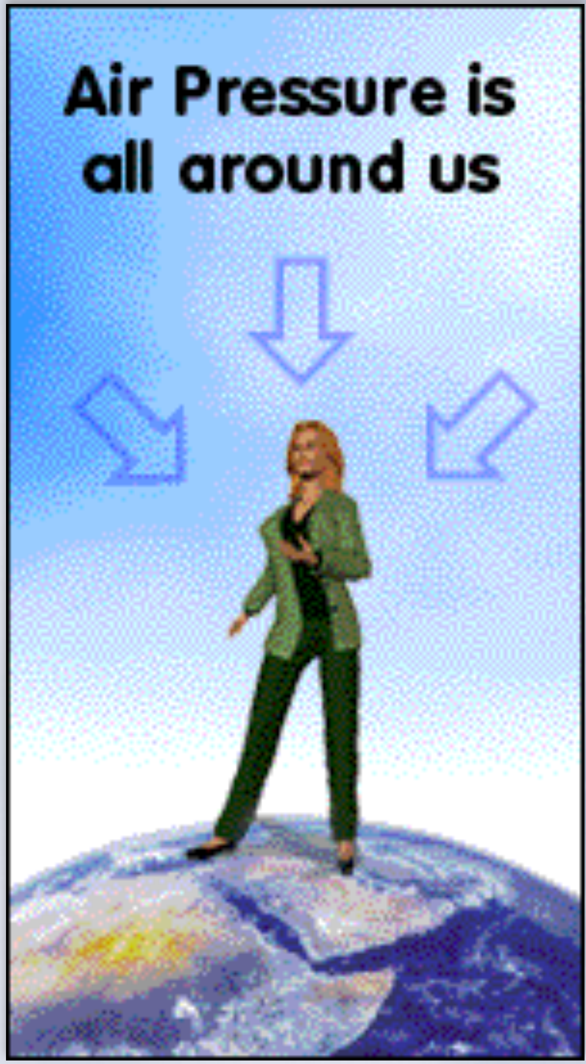




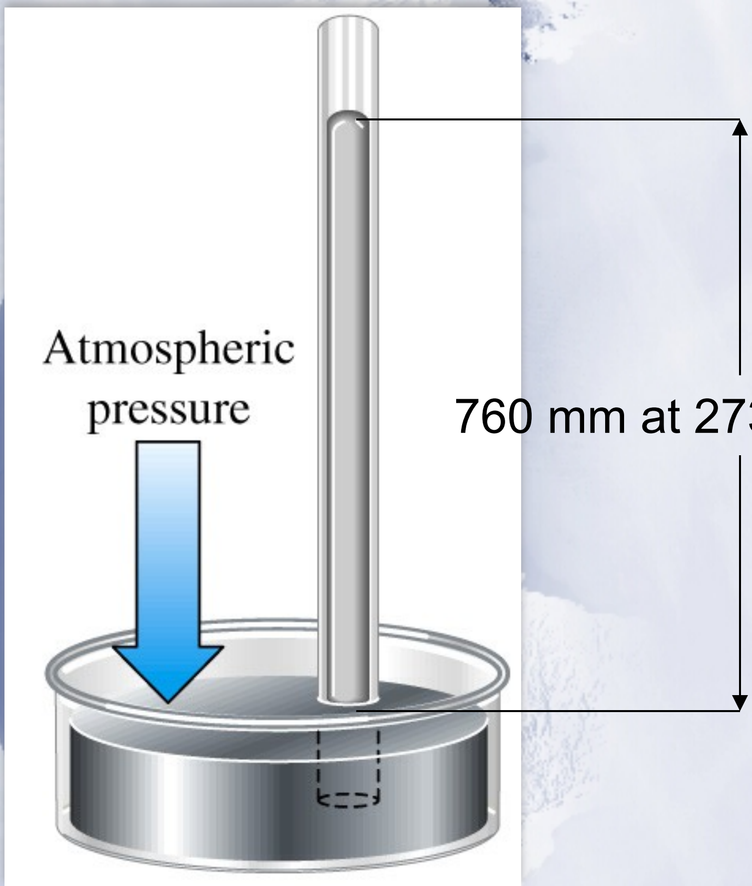
molecules/atoms of gas are constantly in motion

Atmospheric Pressure

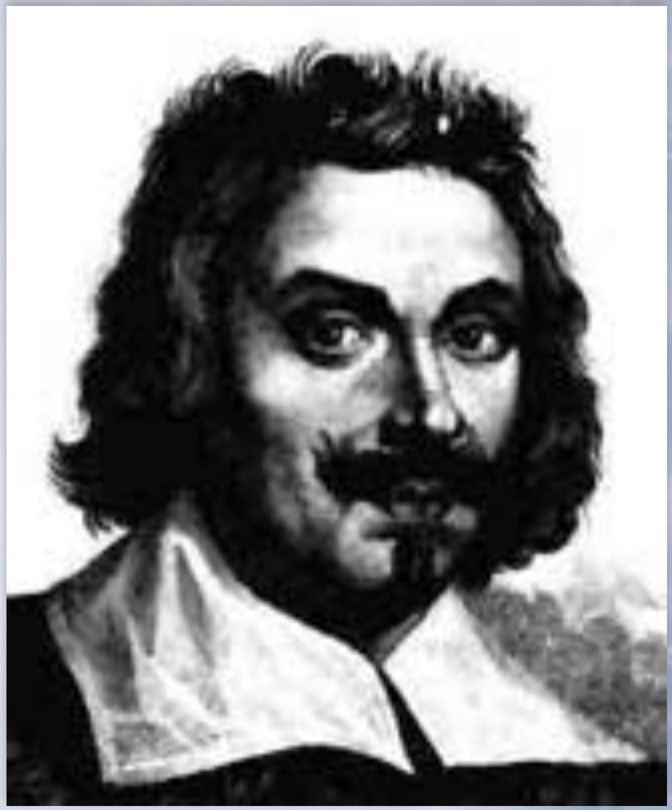




Standard Atmospheric Pressure



barometer



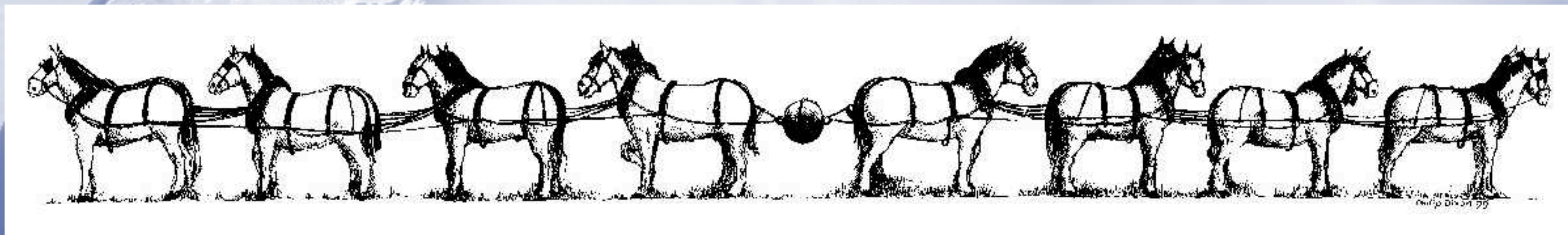
Torricelli

1 atm = 760 mm Hg = 760 torr

Temperature = 0 °C

pressure of the atmosphere is balanced by pressure exerted by mercury

Otto Von Guericke experiment



In 1654 he designed a vacuum pump to withdraw air from vessels.

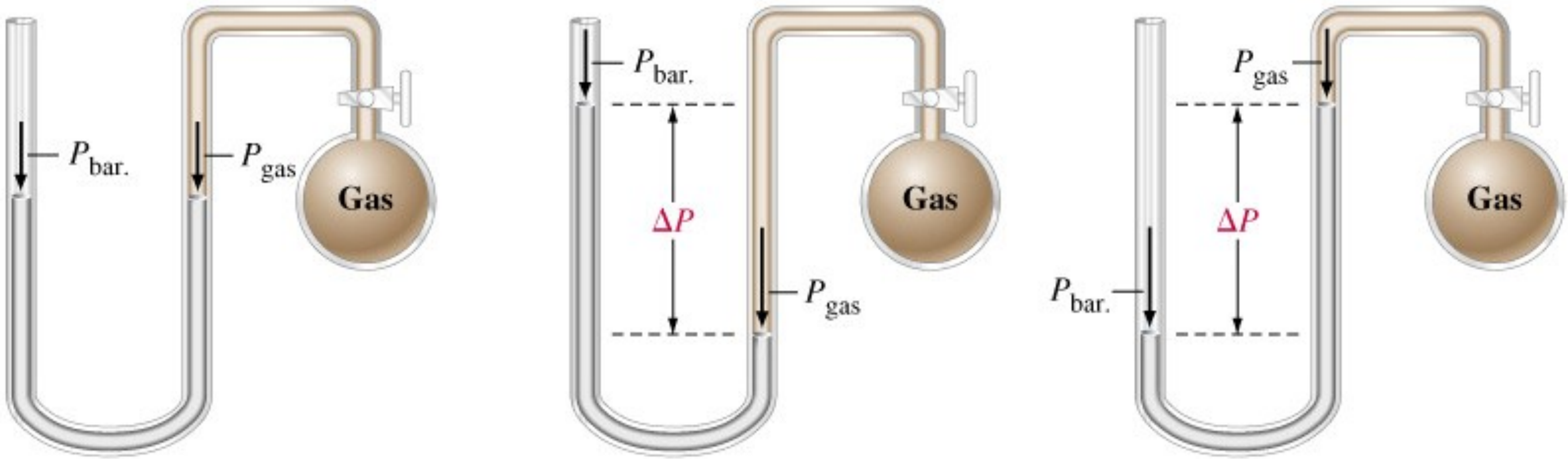
SI units

$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

$$p = F / A$$

Atmosphere (atm)	
Millimeter of mercury (mmHg)	1 atm = 760 mmHg
Torr (Torr)	= 760 Torr
Newton per square meter (N/m^2)	= 101,325 N/m^2
Pascal (Pa)	= 101,325 Pa
Kilopascal (kPa)	= 101.325 kPa
Bar (bar)	= 1.01325 bar
Millibar (mb)	= 1013.25 mb

pressure measurement



$P_{gas} = P_{bar.}$

(a) Gas pressure equal to barometric pressure

$P_{gas} = P_{bar.} + \Delta P$
$(\Delta P > 0)$

(b) Gas pressure greater than barometric pressure

$P_{gas} = P_{bar.} + \Delta P$
$(\Delta P < 0)$

(c) Gas pressure less than barometric pressure

manometer

Factors that influence gases

1. Pressure
2. Volume
3. Temperature
4. Number of particles (moles)

p, V, T, n

Boyle's Law

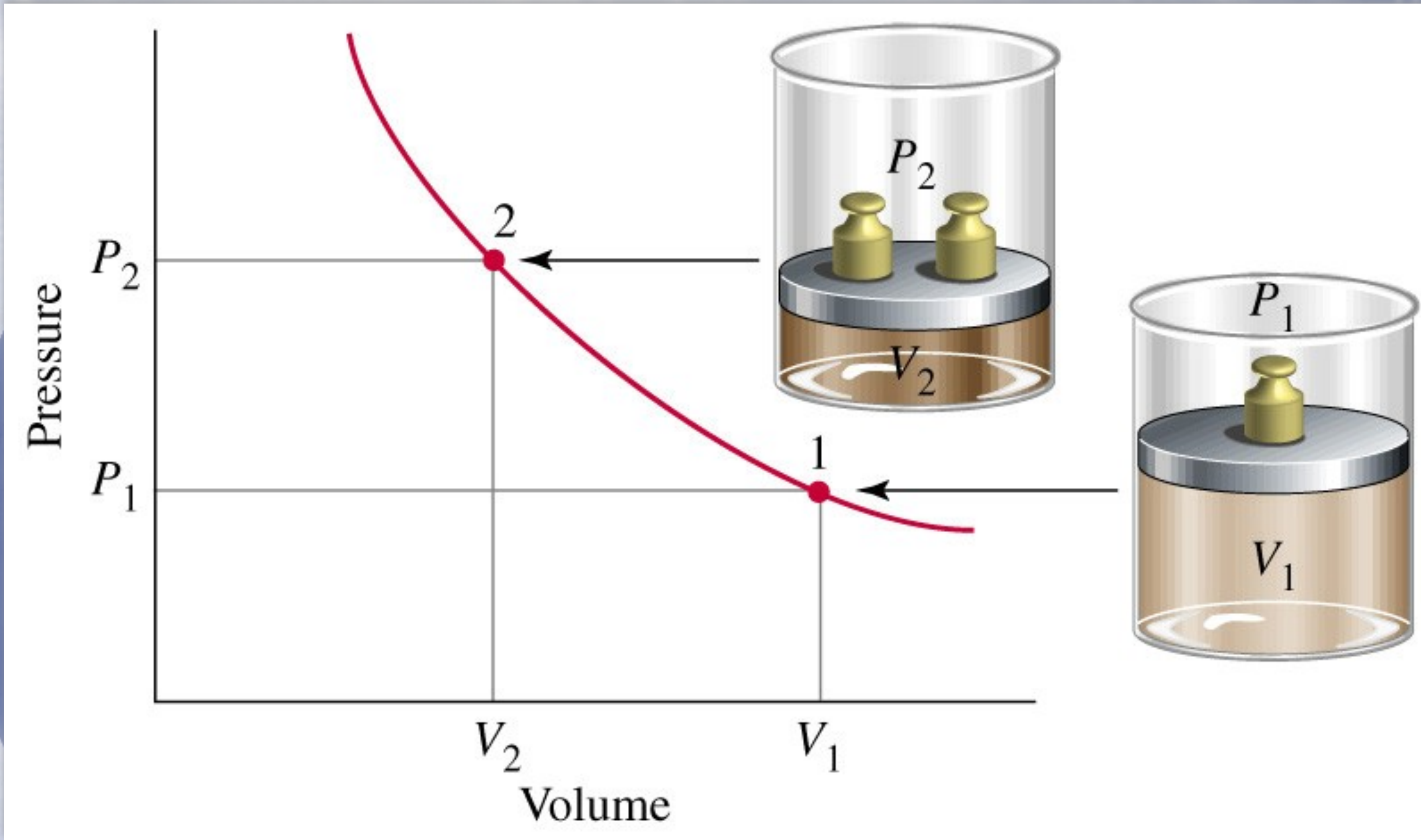
Boyle

(1627-1691)

pressure – volume

relationship

(temperature is constant)



$P \propto 1/V$

$$P \propto 1/V$$

$$p = \text{constant}/V$$

$$P \times V = \text{constant}$$

$$P_1 \times V_1 = \text{constant}$$

$$P_2 \times V_2 = \text{constant}$$

$$P_1 \times V_1 = P_2 \times V_2$$

Sample Problems

A gas at 750 mm Hg pressure and a volume of 2.56 L is compressed to a new pressure 820 mm Hg. Find the new volume

A mole of gas @ STP is changed to a volume of 17.8 L. Find its new pressure in mm Hg

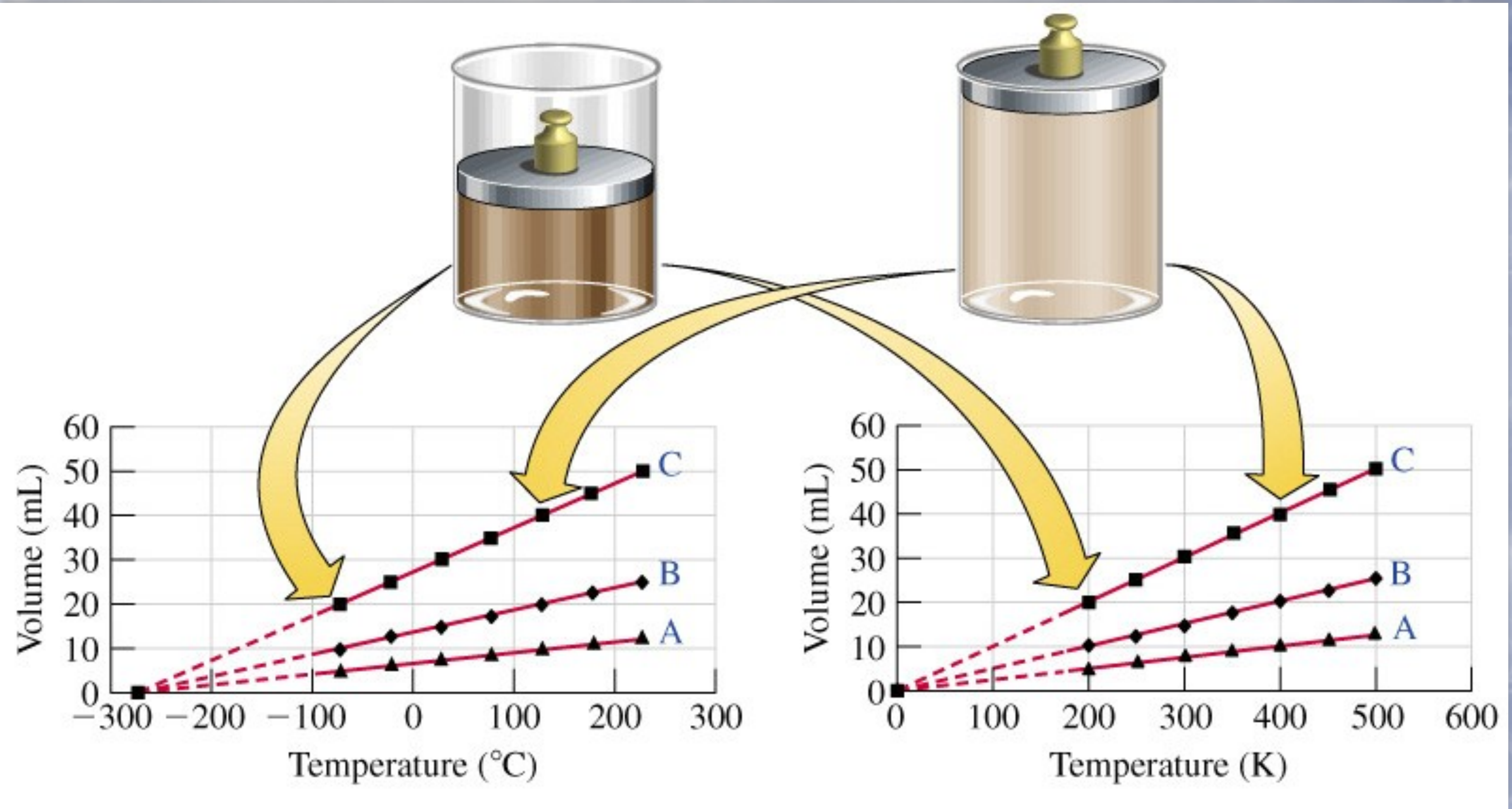
Charle’s Law

1746 - 1823

temperature – volume

relationship

(pressure is constant)


60
50
40
30
20
10
0
Volume (mL)
−300 −200 −100 0 100 200 300
Temperature (°C)
C
B
A
60
50
40
30
20
10
0
Volume (mL)
0 100 200 300 400 500 600
Temperature (K)
C
B
A

$V \propto T$

$$V \propto T$$

$$V = \text{constant } T$$

$$V/T = \text{constant}$$

$$V_1 / T_1 = \text{constant} \qquad V_2 / T_2 = \text{constant}$$

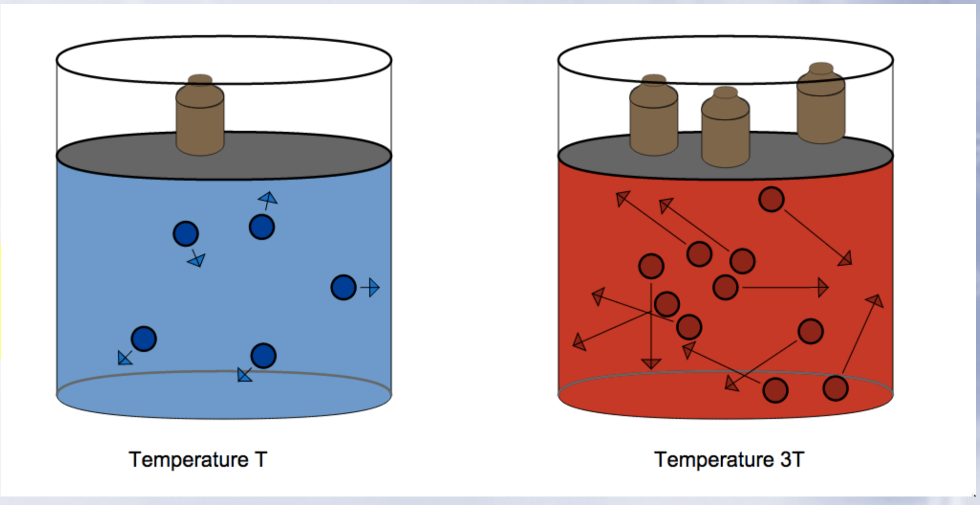
$$V_1 / T_1 = V_2 / T_2$$

Gay-Luassac's Law

- Pressure – temperature relationship
  - Also known as Amonton's Law of Pressure-Temperature

$$P \propto T$$

$$P_1 / T_1 = P_2 / T_2$$



Avogadro's Law

Avogadro

(1776-1856)

amount – volume

relationship

(pressure and temperature

are constant)

$$n \propto V$$

$$n = \text{constant} \times V$$

$$n/V = \text{constant}$$

$$n_1 / V_1 = \text{constant}$$

$$n_2 / V_2 = \text{constant}$$

$$n_1 / V_1 = n_2 / V_2$$

SUMMARY

Boyle's Law

$P \propto 1/V$

Charles's Law

$V \propto T$

Gay-Luassac's Law

$P \propto T$

Avogadro's Law

$n \propto V$

@ a constant pressure find the new volume if a gas with an initial volume of 2.8 L @ a temperature of 22°C if the gas is cooled to 0°C

@ a constant volume of 1.0 L the pressure of a gas is 2.4 atm @ 0°C. Find the new temperature if the pressure is increased to 4.0 atm.

1. IDEAL GAS EQUATION

(1) $p \propto 1/V$	→	$V \propto 1/p$
(2) $V \propto T$	→	$V \propto T$
(3) $n \propto V$	→	$V \propto n$

$$V \propto T \times n / p$$

$$p \times V = \text{const} \times n \times T$$

$$p \times V = \text{const} \times n \times T$$

↓

$$p \times V = R \times n \times T$$

↓

$$p \times V = n \times R \times T$$

ideal gas equation

$$p \times V = n \times R \times T$$

$$[R] = [p] \times [V] \;/\; [n] \text{ x } [T]$$

atm L mol K

$$[R] = \text{atm} \times \text{L} \;/\; \text{mol x K}$$

$$[R] = \text{atm x L} / \text{mol x K}$$

[R] = atm x L / mol x K

R = 0.0821atm x L / mol x K

ideal gas constant

2. MOLAR VOLUME

What is the volume of 1 mol of a gas at

273.15 K (0^oC) and 1 atm (760 mmHg)?

standard temperature and pressure

(STP)

$$p \times V = n \times R \times T$$

$$V = 22.4\ L$$

$$p \times V = n \times R \times T$$

$$V = 22.4\ L$$

$$V_m = 22.4\ L$$

the molar volume at standard pressure and temperature is independent on the gas type

5. DALTON’S LAW

Dalton

(1801)

pure gases

↓

gas mixtures

(atmospheres)

DALTON'S LAW

the total pressure of a gas mixture, p, is the sum of the pressures of the individual gases (partial pressures) at a constant temperature and volume

$$p = p_A + p_B + p_C + \ldots.$$

$$p \times V = n \times R \times T$$

$$p_A \times V = n_A \times R \times T \rightarrow p_A = n_A \times R \times T / V$$

$$p_B \times V = n_B \times R \times T \rightarrow p_B = n_B \times R \times T / V$$

$$p = p_A + p_B$$

$$p = (n_A + n_B) \times R \times T / V$$

$$p \times V = n \times R \times T$$

$$p \times V = (n_A + n_B) \times R \times T$$

$$p_A = n_A \times R \times T / V$$

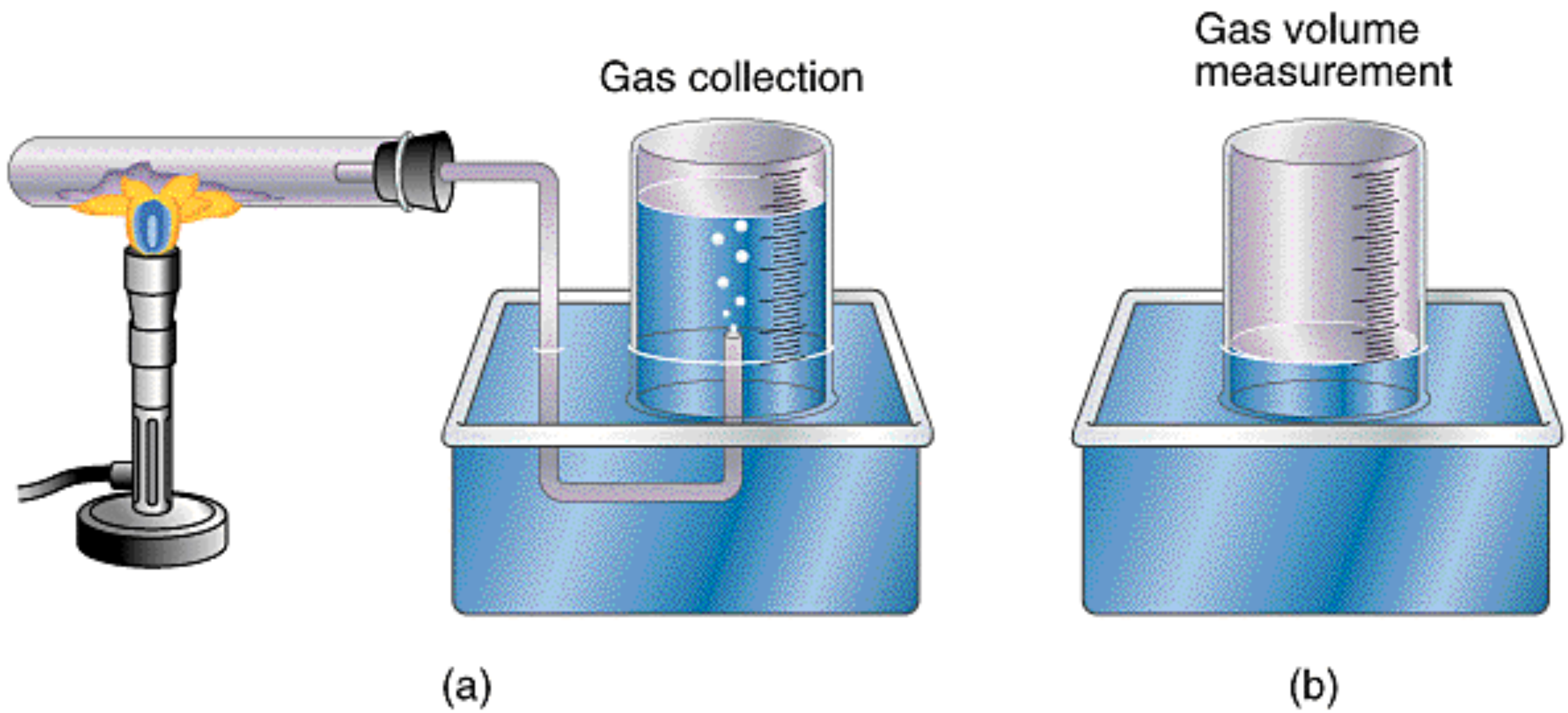
$$p_A / p = n_A / (n_A + n_B) = x_A$$

mole fraction

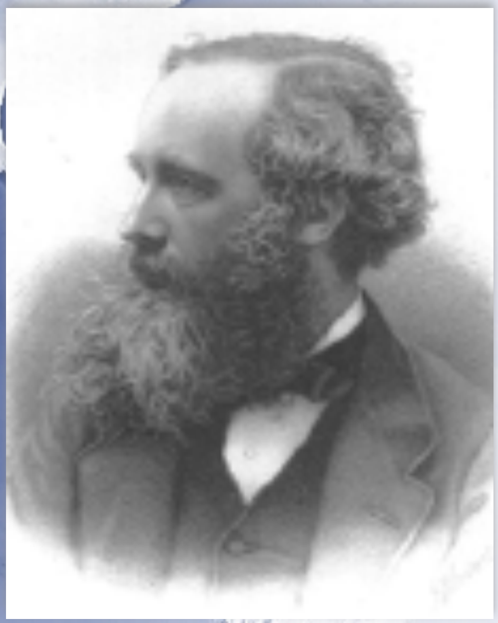
$x < 1$

$$p_A = x_A \times p$$

$$2\ KClO_3 \rightarrow 2\ KCl + 3\ O_2$$



1. Kinetic Molecular Theory of Gases



Maxwell

(1831-1879)

macroscopic

(gas cylinder)

↓

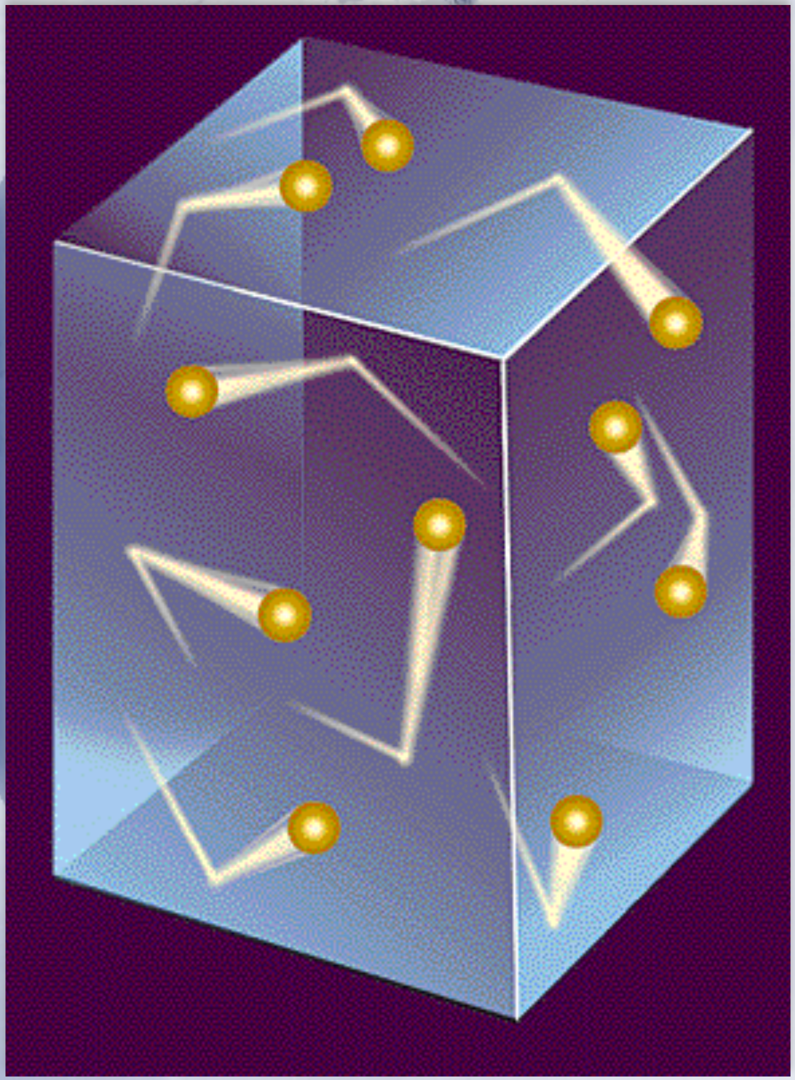
microscopic

(atoms/molecules)

Boltzmann

(1844-1906)

Kinetic Energy of Gases

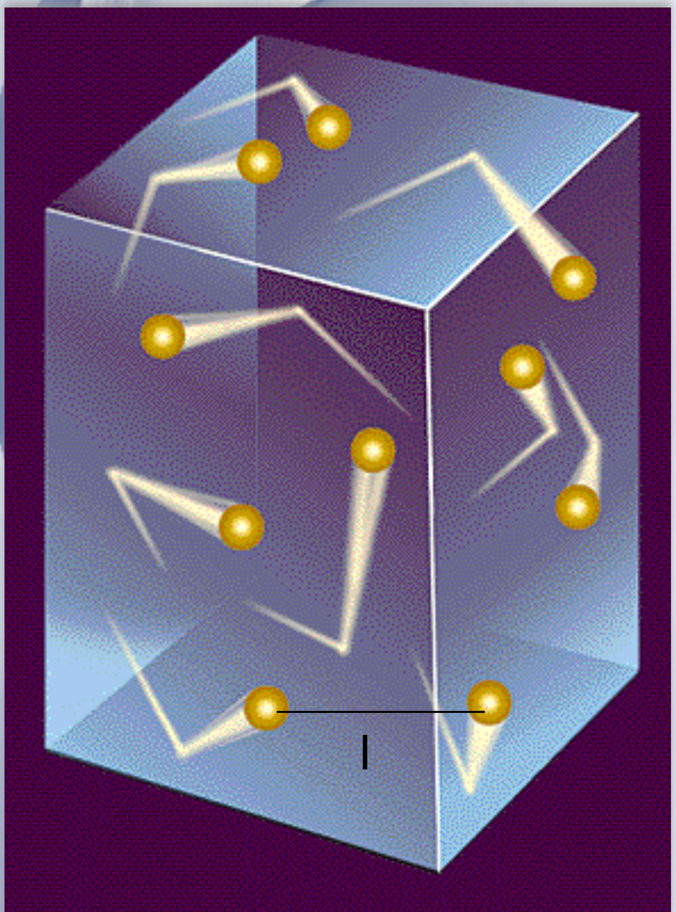


physical properties of gases can be described by motion of individual gas atoms/molecules

each macroscopic and microscopic particle in motion holds an energy (kinetic energy)

Assumptions of the Kinetic Theory of Gases

1. gases are composed of atoms/molecules which are separated from each other by a distance l much more than their own diameter d



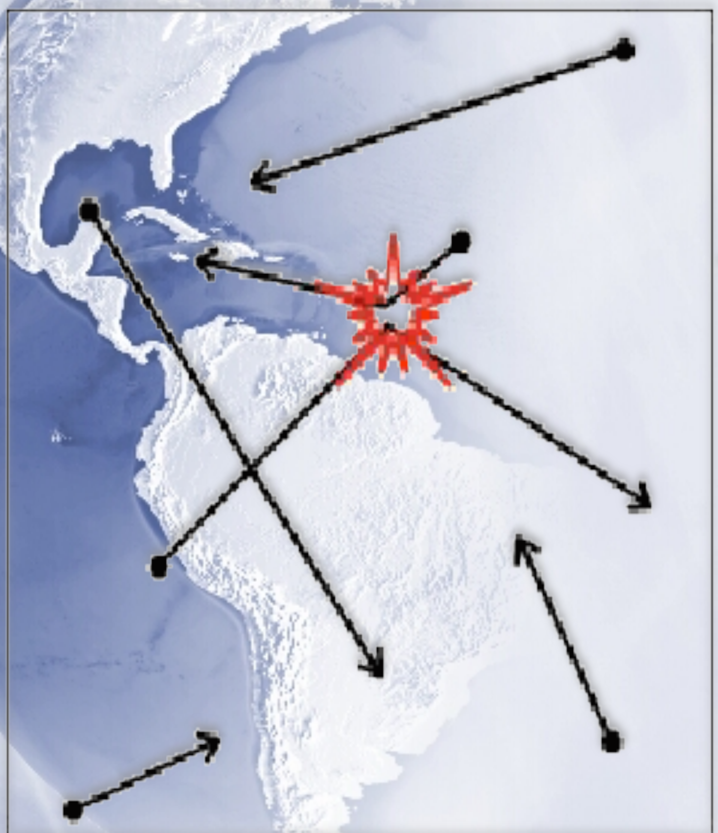
$d = 10^{-10}$ m

$l = 10^{-3}$ m….. few m

↓

molecules are mass points with negligible volume

2. gases are constantly in motion in random reactions and hold a kinetic energy



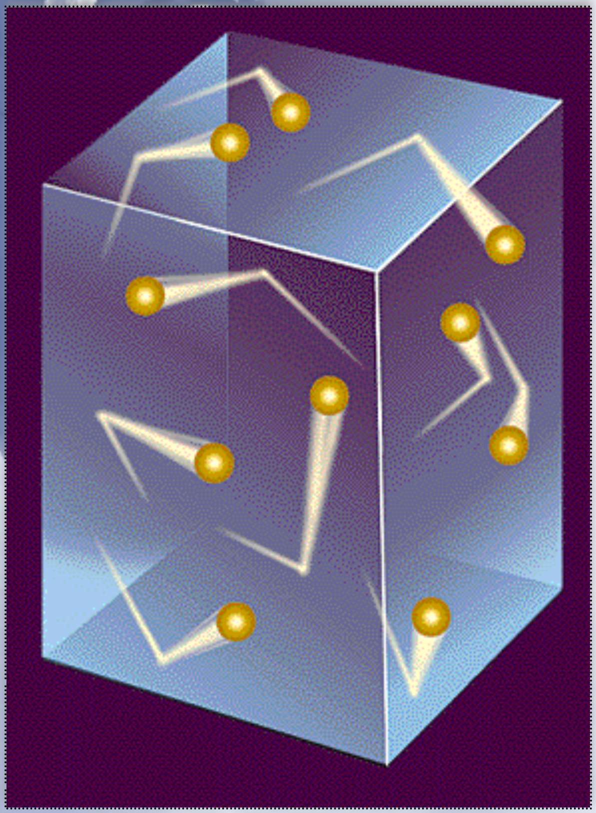
gases collide and transfer energy

(billiard ball model)

3. gases atoms/molecules

do not exert forces on each other

(absence of intermolecular interactions)

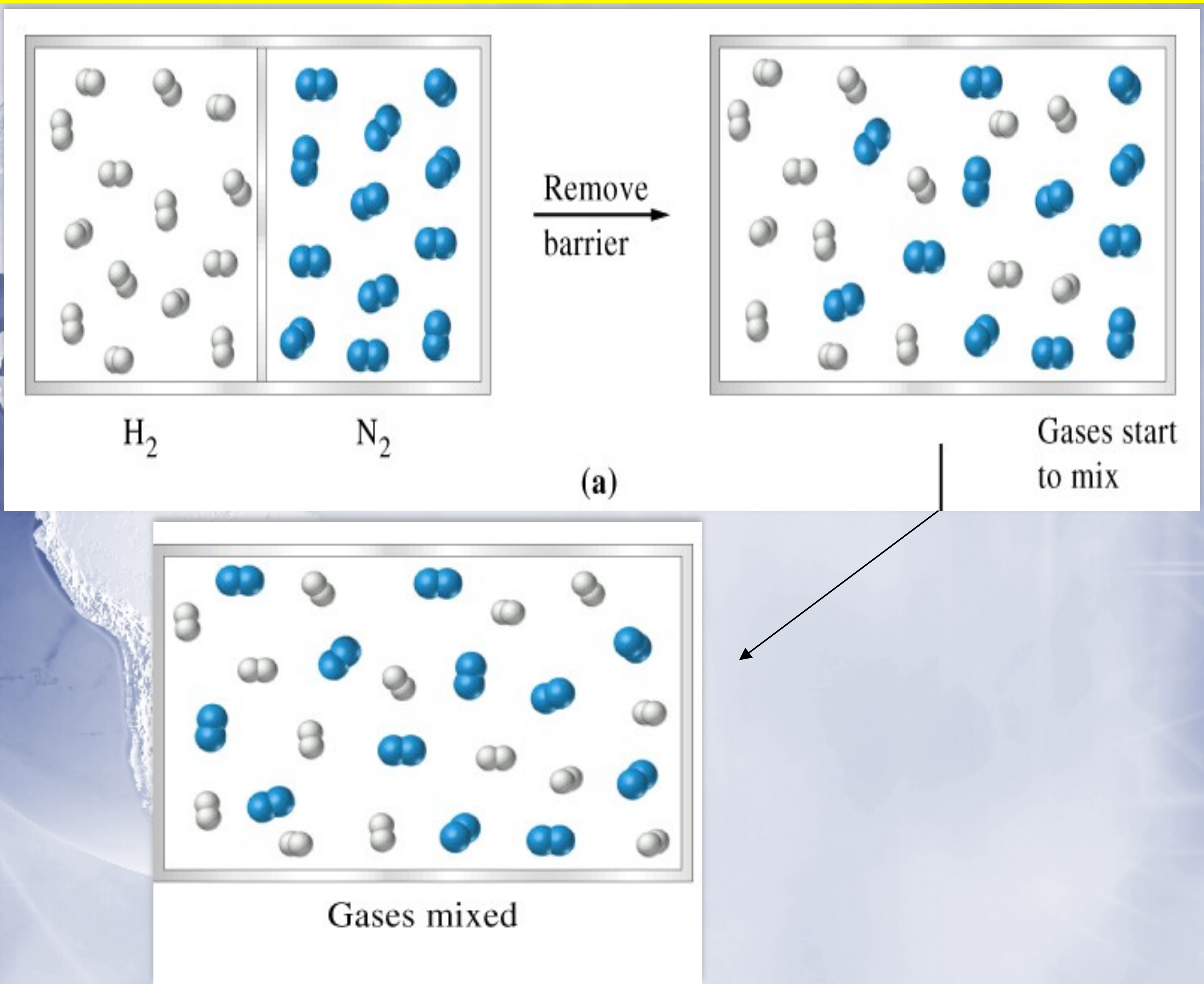


$$F_{(inter)} = 0$$

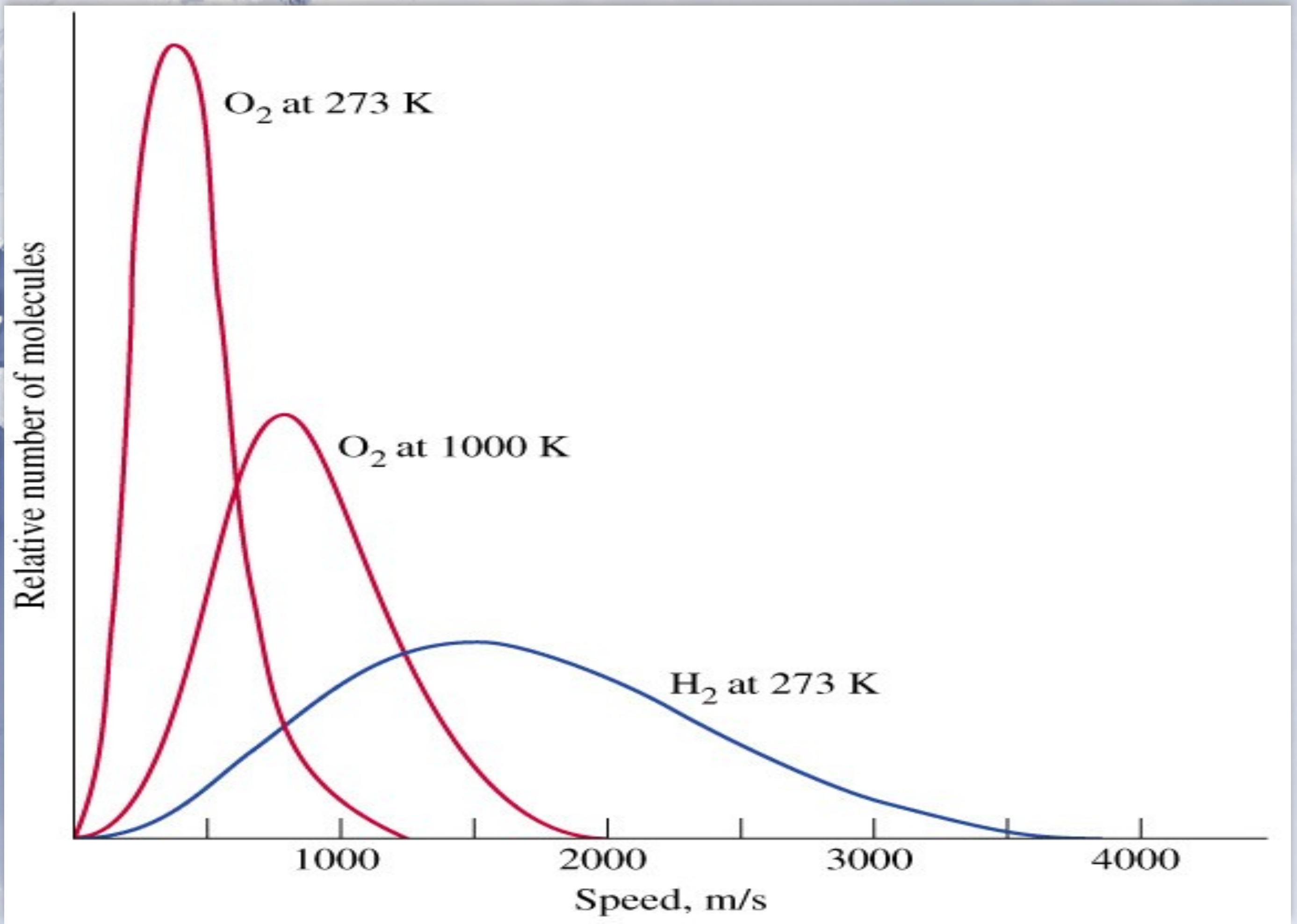
↓

$$p_{(inter)} = 0$$

Gas Diffusion



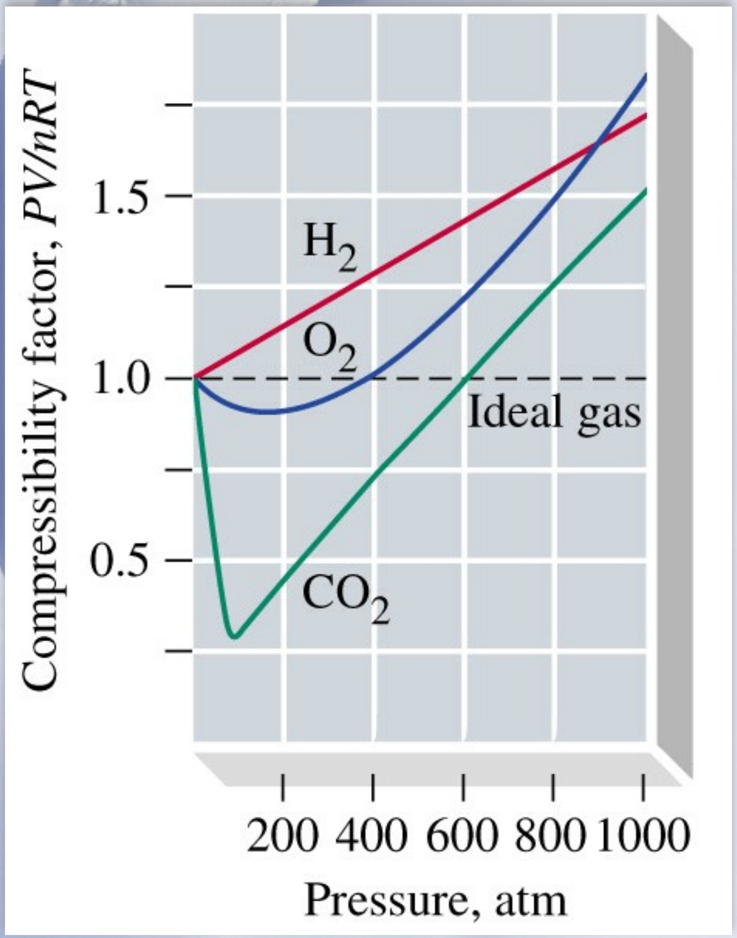
2. Distribution of Molecular Speeds



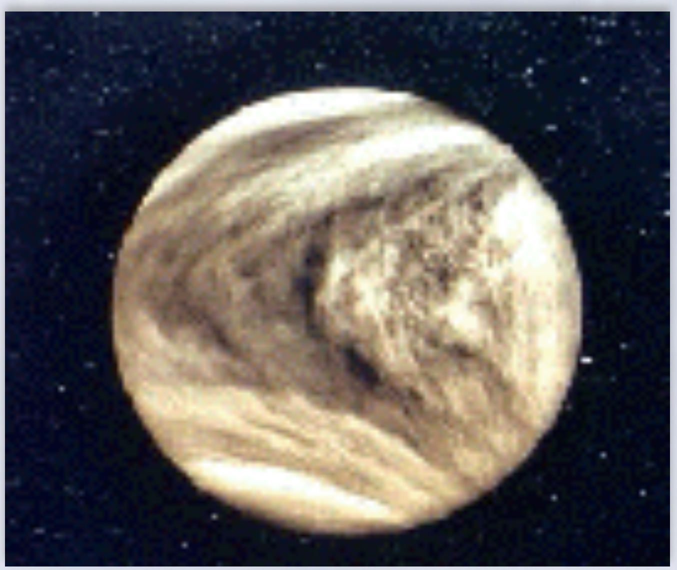
Maxwell-Boltzmann distribution

3. Real Gases

p × V = n × R × T   (n = 1)



deviation of ideal gas law
at high pressures



p ≈ 90 atm