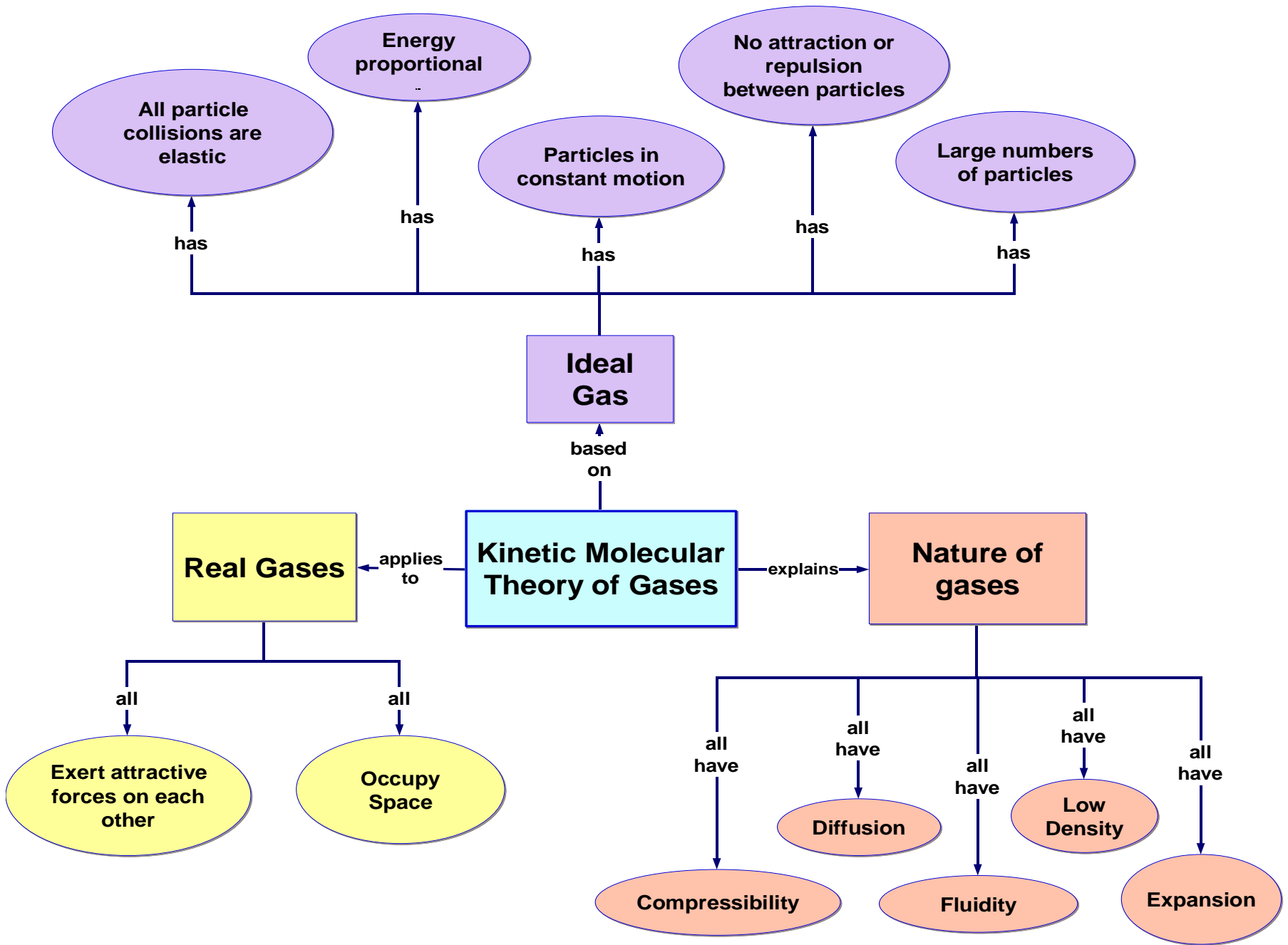
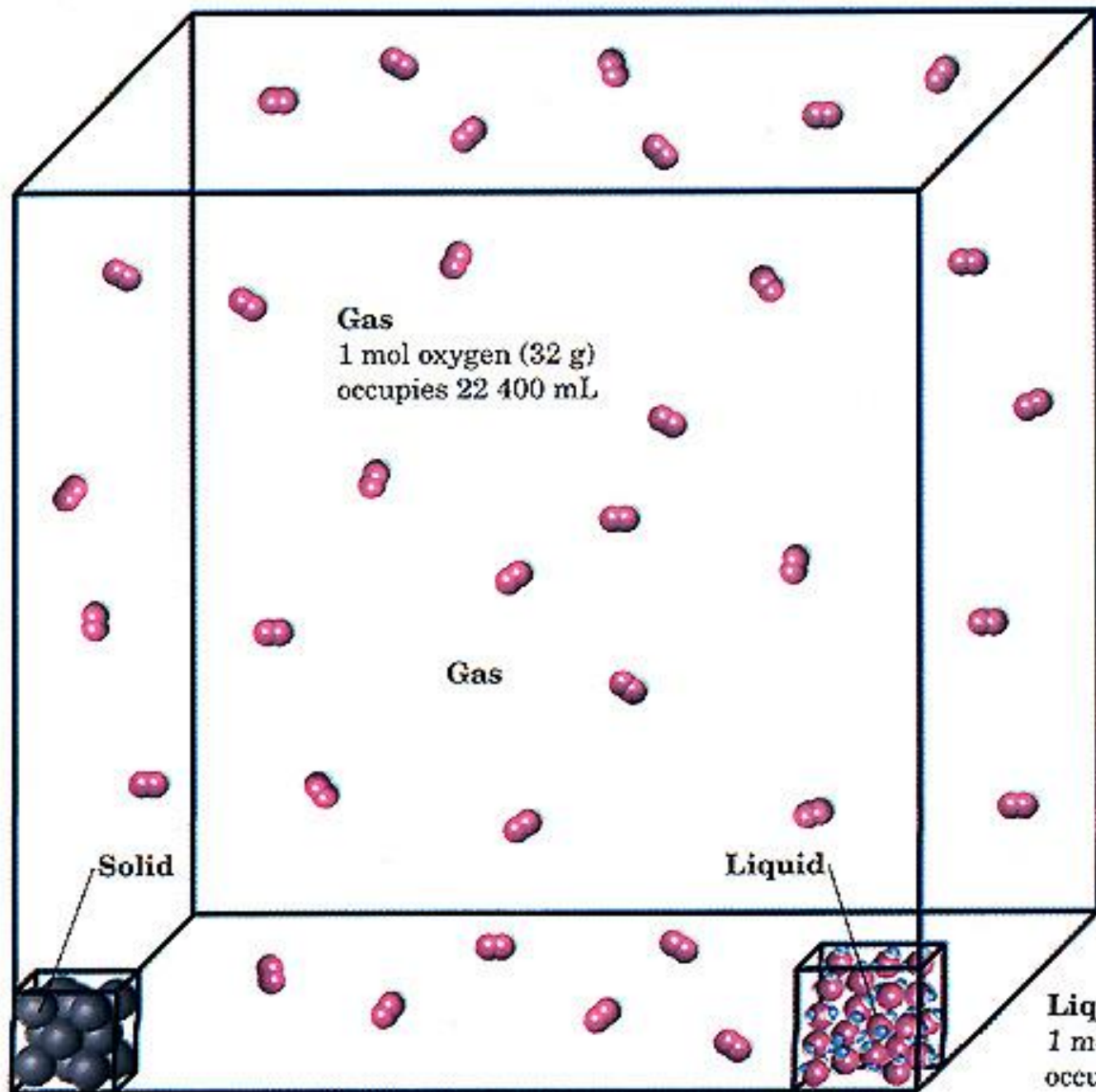


CHAPTER 11:

Gas Laws





Solid
1 mol aluminum
(27 g)
occupies 10 mL

Liquid
1 mol water (18 g)
occupies 18 mL

Kinetic Molecular Theory

For an Ideal Gas:

- The motion of the particles is
 - Random
 - Linear
 - Elastic collisions

Real Gases

- **Exert attractive forces on one another**
- **Occupy space**

How do we define a gas?

- **Volume (in L or mL)**
- **Pressure (atm, kPa, mm)**
- **Temperature (K)**
- **Number of Molecules (moles)**

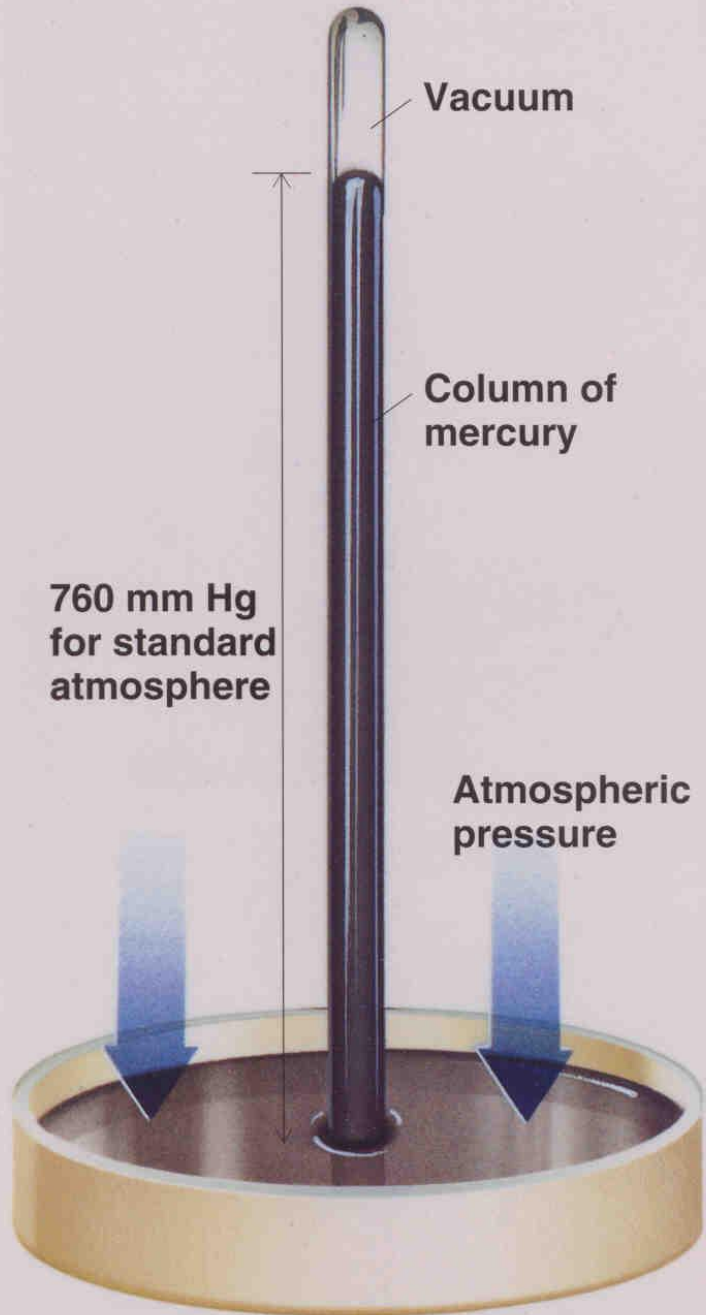
Pressure of a Gas:

- Caused by the elastic collisions in a container
- Is evenly distributed due to the randomness of particle motion

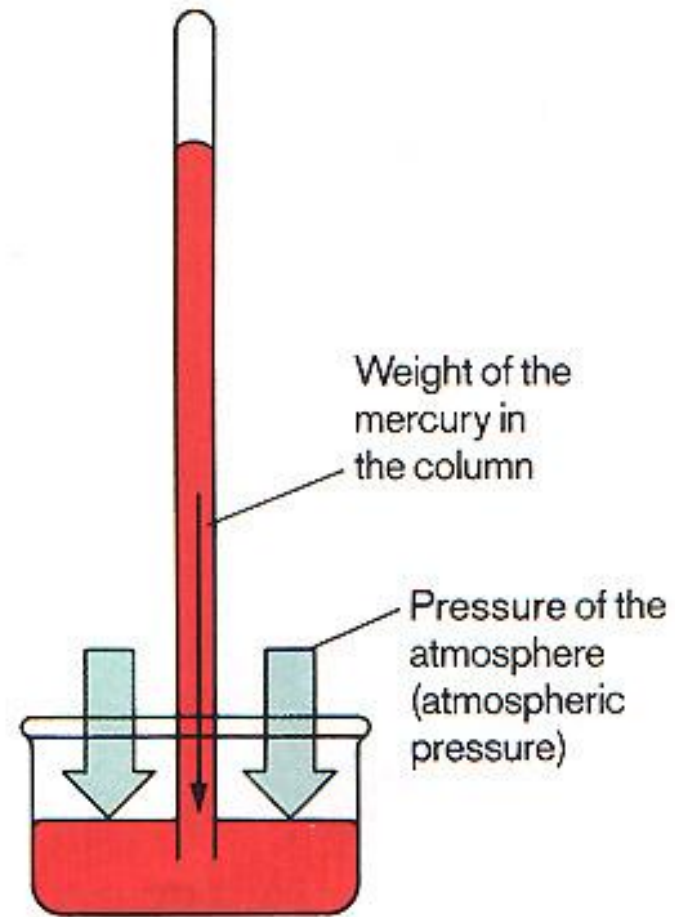
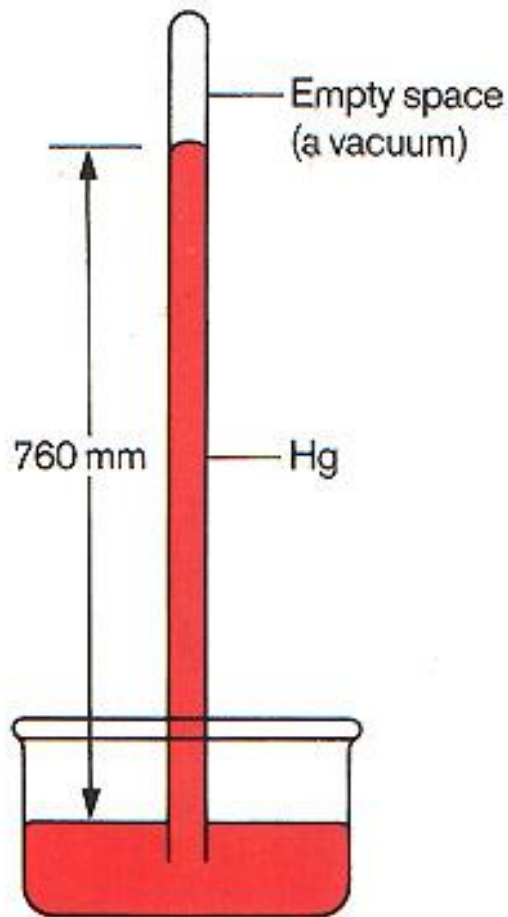
$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

Barometer

- Device used to measure pressure
- Developed by Evangelista Torricelli



Measuring Pressure



Units of Pressure

1 Atmosphere	1 atm
1 mm Hg (torr)	1 atm = 760 mm Hg
Pascal (Pa)	1 atm = 101325 Pa
kilopascal (kPa)	1 atm = 101.325 kPa

Boyle's Law

Robert Boyle experimented with the relationship between pressure and volume of gases.

Boyle's Law

He set-up a J-shaped tube and added mercury to see what it did to the volume of a trapped gas. He found that as pressure increases volume decreases.

pressure of atmosphere

trapped air

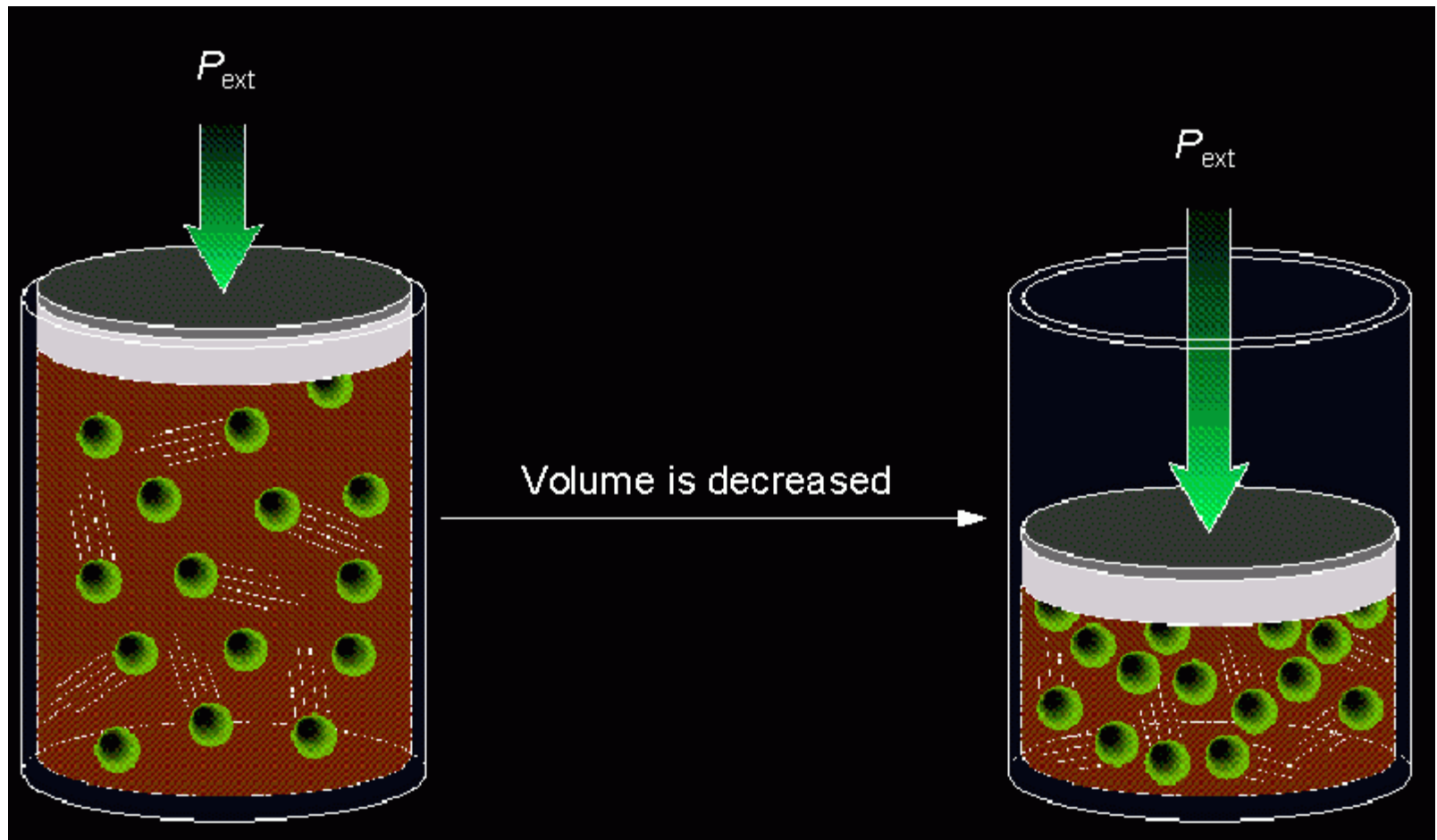


pressure of atmosphere

trapped air



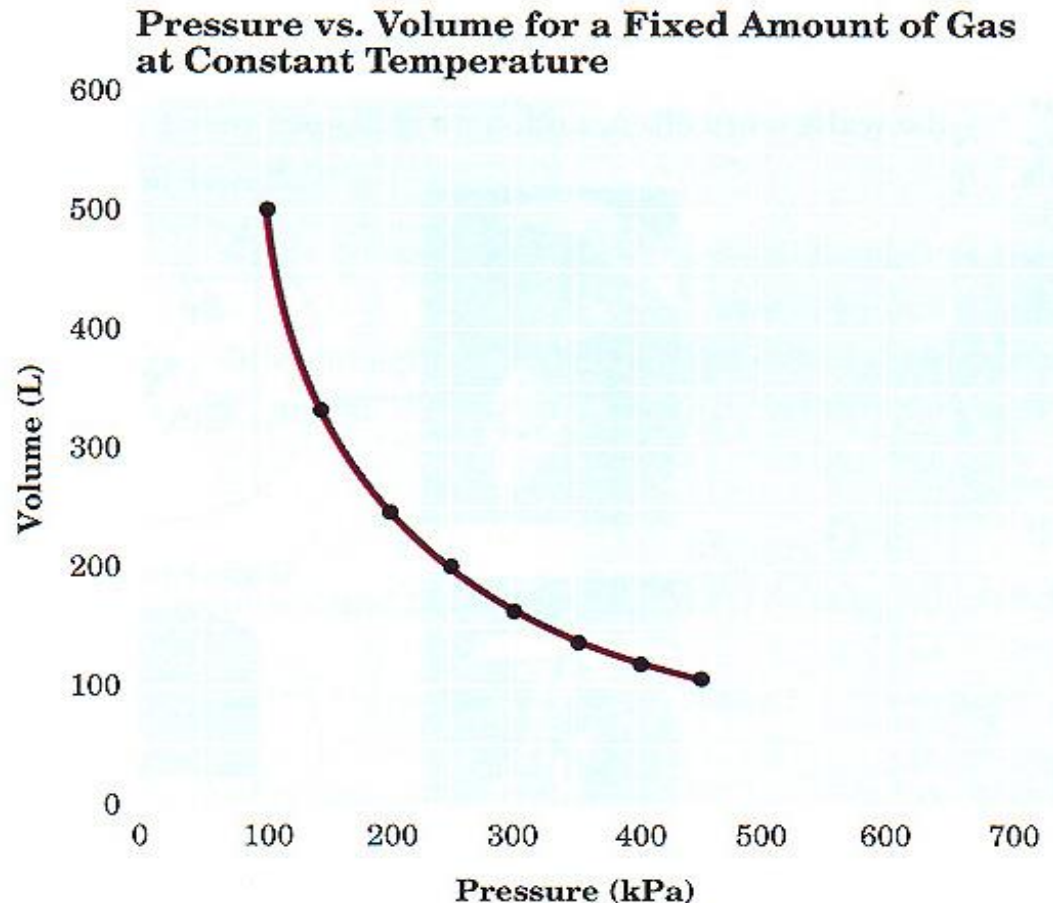
Boyle's Law



Boyles' Experiments:

Table 10-5
Pressure-Volume
Data

Pressure (kPa)	Volume (mL)	PV
100	500	50 000
150	333	49 950
200	250	50 000
250	200	50 000
300	166	49 800
350	143	50 500
400	125	50 000
450	110	49 500



This relationship is inversely proportional, when one increases the other decreases.

Boyle's Law: $PV = k$

$P =$ pressure $V =$ volume $k =$ a constant

At Constant Temperature

$$P_1V_1 = k \text{ and } P_2V_2 = k$$

$$P_1V_1 = k = P_2V_2$$

So:

$$P_1V_1 = P_2V_2$$

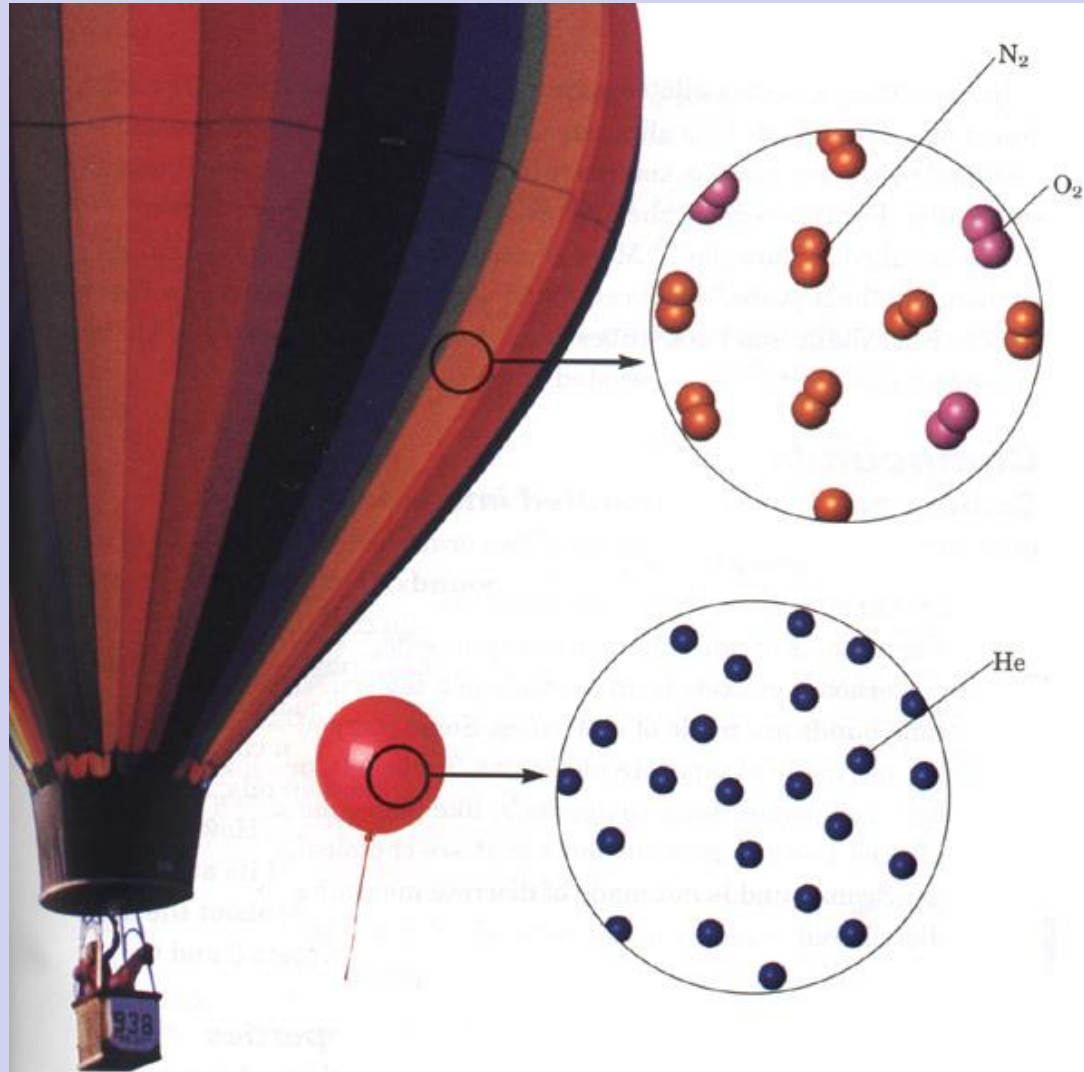
Charles' Law

French physicist Jacques Charles was the first to fill a balloon with hydrogen gas and make a solo flight.

Charles' Law

He showed that the volume of a gas increases when the temperature increases
(at a constant pressure)

Charles' Law: Volume and Temperature

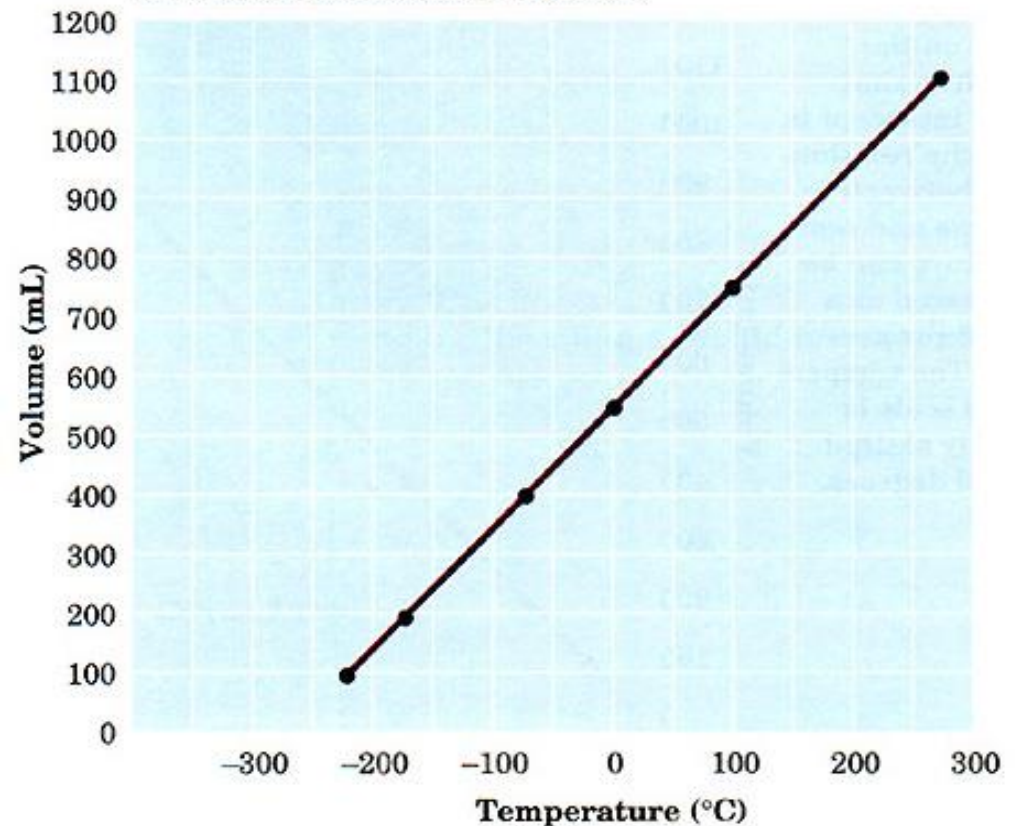


Charles' Law

**Volume–Temperature
Data for a Gas at
Constant Pressure**

Temperature (°C)	Volume (mL)
273	1094
100	747
10	568
1	545
0	545
-1	546
-73	403
-173	199
-223	100

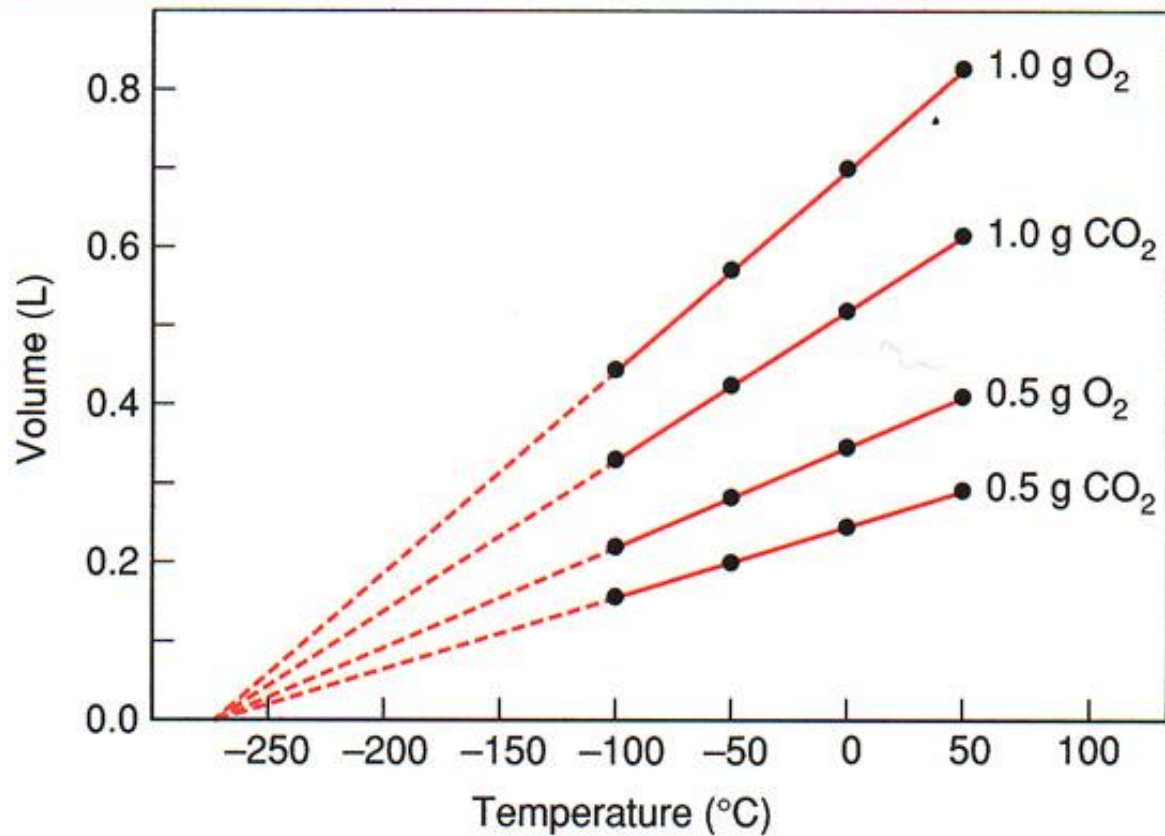
**Volume vs. Temperature for a Fixed Amount
of Gas at Constant Pressure**



As temperature drops, the volume decreases. This is a linear relationship.

Volume vs. Temperature

Volume-Temperature Data



Charles' Law:

The volume of a gas is directly proportional to the temperature

$$V = bT$$

$$\frac{V}{T} = b = \textit{constant}$$

Gay-Lussac's Law

Joseph Gay-Lussac discovered that the pressure of a gas is directly proportional to the Kelvin Temperature if the volume remains constant

Gay-Lussac's Law

The pressure of a gas is directly proportional to the temperature at constant volume

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Combined Gas Law

A single expression that combines the three gas laws:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Avogadro's Law

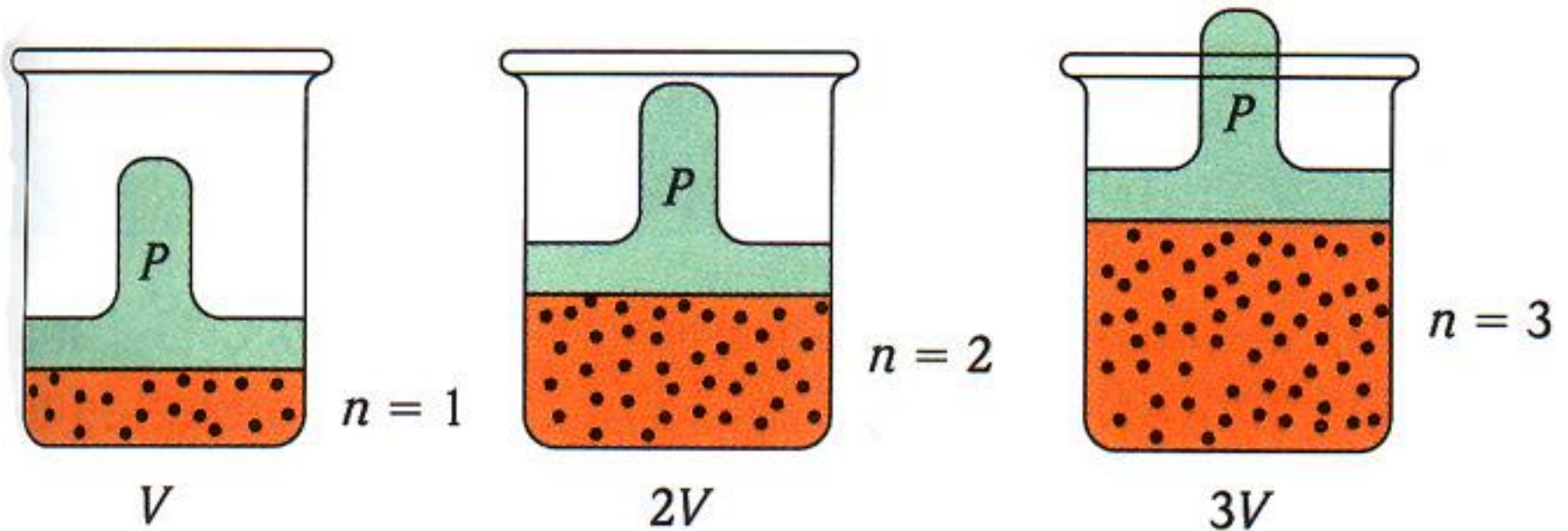
Avogadro investigated the relationship between the volume of a gas and the number of moles present in the gas sample.

Avogadro's Law

He found that as the number of moles is doubled, the volume doubles. (*at constant temperature and pressure*)

$$\frac{V}{n} = a = \textit{constant}$$

Avogadro's Law

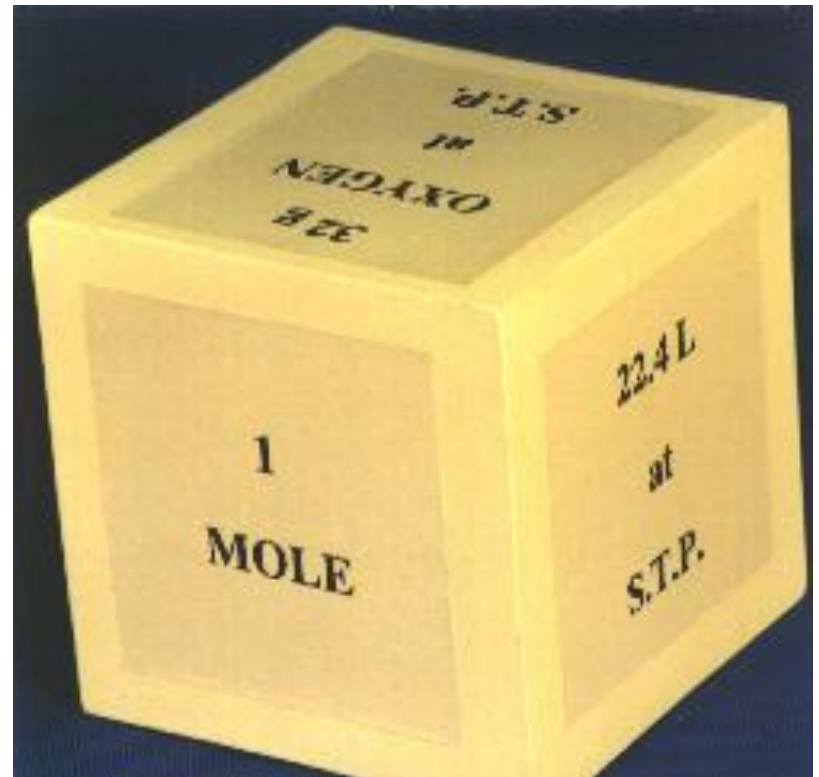


The volume of a gas is directly proportional to the number of moles

Avogadro's Law:

Equal volumes of all gases at the same temperature and pressure contain the same number of molecules.

- Amedeo Avogadro



Ideal Gas Law

$$\frac{PV}{T} = \textit{constant} = nR$$

or

$$PV = nRT$$

Ideal Gas Law

$$PV = nRT$$

R is the ideal gas constant

$$R = 8.31 \frac{\text{L-kPa}}{\text{mol-K}} = .08206 \frac{\text{L-atm}}{\text{mol-K}}$$

Dalton's Law of Partial Pressures

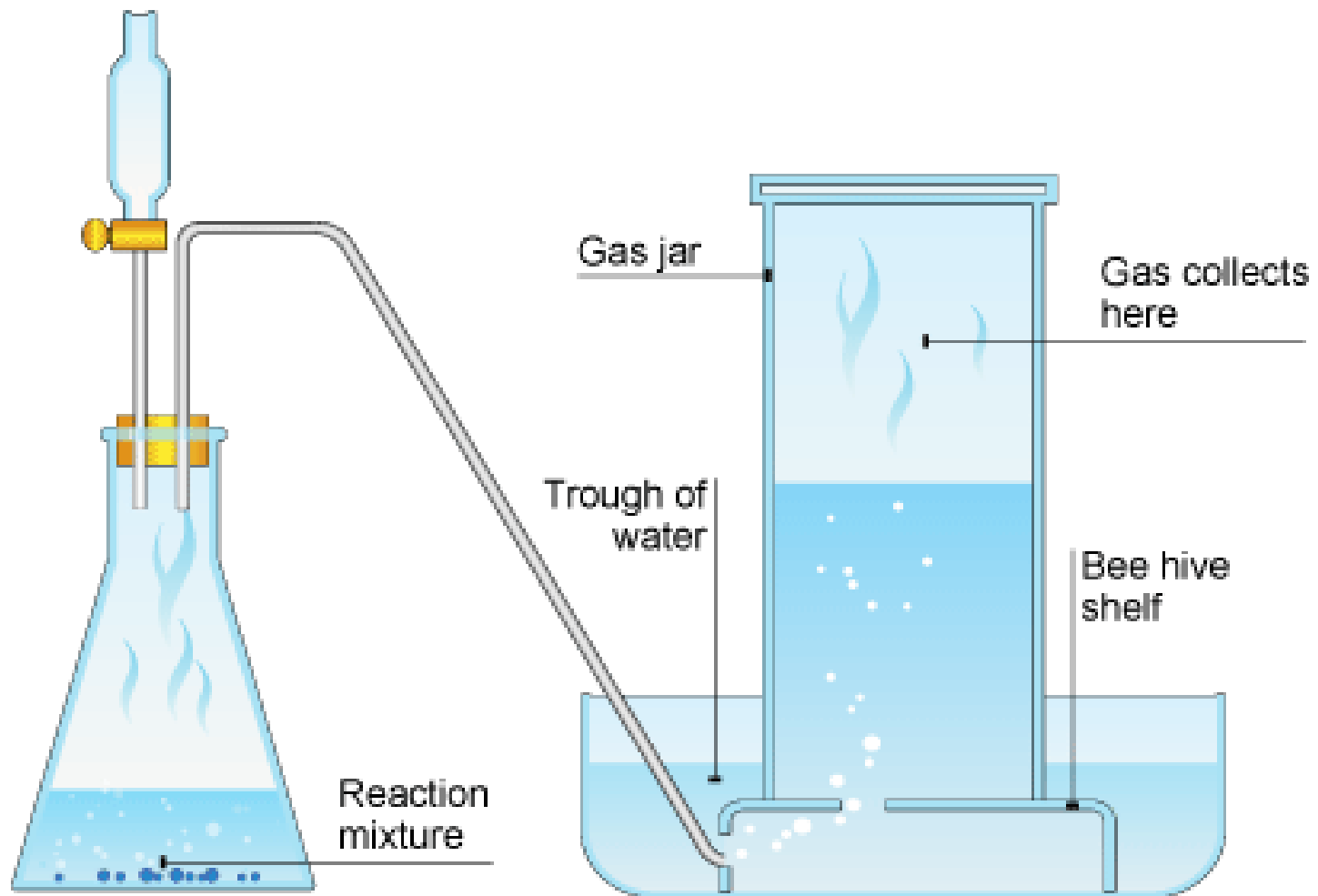
For a mixture of gases in a container

$$P_{\text{Total}} = P_1 + P_2 + P_3 + \dots$$

This is particularly useful in calculating the pressure of gases collected over water.

Dalton's Law of Partial Pressure

Gases are collected over water in the laboratory



Graham's Law of Diffusion

$$\frac{\text{rate of diffusion}_A}{\text{rate of diffusion}_B} = \frac{\sqrt{M_B}}{\sqrt{M_A}} = \frac{\sqrt{\text{density}_B}}{\sqrt{\text{density}_A}}$$

Animations

- Gas Law Animations
- Boyle's Law Animation
- Gas Experiments
- PhET Gas Properties Sim