

GASES

A. PROPERTIES OF GASES

1. Compressible
2. Adjust to volume and shape of container
3. Diffuse and flow rapidly
4. Low density
5. Expand greatly when heated

B. MEASUREMENTS OF GASES

The physical behavior of a gas is nearly independent of its chemical composition, therefore, the behavior of a gas is controlled by four variables: P, V, n, T

1. Pressure (P)

a. Pressure =

b. Units of pressure: mm Hg, torr, atm, pascal

1 mm Hg = 1 torr

760 mm Hg = 1 atm

1 atm = 101,325 Pa

2. Volume (V)

a. Volume =

b. Units of volume =

c. The volume of each component of a mixture of gases is the same as the volume occupied by the entire mixture.

3. Temperature (T)

a. Temperature =

b. Units of temperature =

4. Moles (n)

5. Standard Temperature and Pressure (STP)

a. Standard temperature =

b. Standard pressure =

C. GAS LAWS

1. Boyle's Law: the volume occupied by a fixed quantity of a gas is inversely proportional to its pressure at constant temperature.
2. Charles' Law: the volume occupied by a fixed quantity of gas is directly proportional to its temperature at constant pressure.
3. Gay-Lussac's Law the pressure of a fixed quantity of a gas in a fixed volume is directly proportional to its temperature.
4. Combined Gas Laws

$$\frac{P \cdot V}{T} = \text{constant}$$

5. Dalton's Law of Partial Pressures: when two or more gases that do not react are placed in the same container, the pressure exerted by each gas is the same as it would be if it were the only gas in the container.

GAS LAW PROBLEM #1: 1150 mL O₂ were collected by displacement of water at 23°C and 762 torr. What is the volume of the gas at STP? (vapor pressure of water at 23°C is 21 torr)

6. Ideal Gas Law: equation of state for an ideal gas

$$PV = nRT$$

R = universal gas constant (Boltzman's Constant)

$$\text{Value of R depends on pressure unit used: } \left\{ \begin{array}{l} R = 0.082057 \frac{\text{liter atm}}{\text{K mole}} \\ R = 62.37 \frac{\text{liter torr}}{\text{K mole}} \end{array} \right.$$

GAS LAW PROBLEM #2: At what pressure (in atm) will 0.250 mole of $\text{N}_2(\text{g})$ occupy 10.0 liters at 100°C ?

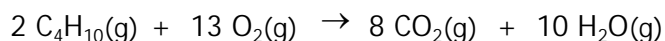
GAS LAW PROBLEM #3: What volume will 10.0 g of $\text{CO}_2(\text{g})$ occupy at 27°C and 2.00 atm?
(molar mass $\text{CO}_2 = 44.0 \text{ g/mole}$)

GAS LAW PROBLEM #4: What is the density of $\text{NH}_3(\text{g})$ at 100°C and 825 torr?
(molar mass $\text{NH}_3 = 17.0 \text{ g/mole}$)

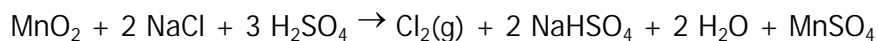
7. Gay-Lussac's Law of Combining Volumes: the volumes of gaseous substances that are consumed and produced in a chemical reaction are in ratios of small whole numbers, provided the volumes are measured under the same conditions of temperature and pressure.
8. Avogadro's Principle: equal volumes of different gases contain equal numbers of molecules at same temperature and pressure.

Molar Volume at STP: one mole of an ideal gas occupies a volume of 22.4136 liters at STP

GAS LAW PROBLEM #5: Calculate the volume of CO₂ produced by reacting 5.00 L of butane (C₄H₁₀) and 30.0 L of O₂ at 400°C and 950 torr.



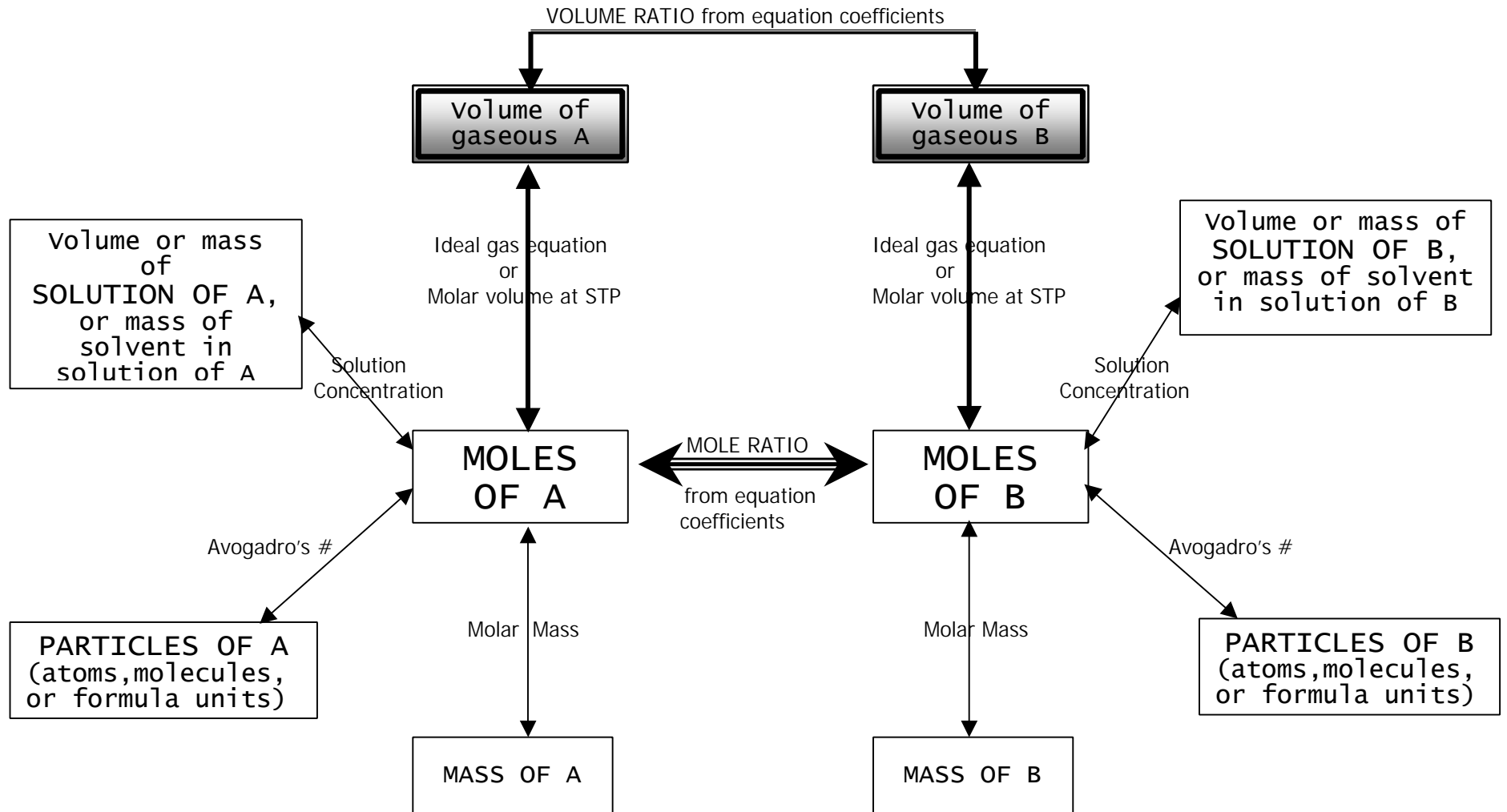
GAS LAW PROBLEM #6: Chlorine can be prepared in the lab according to the following reaction:



Calculate the volume of chlorine produced at STP from 25.0 g NaCl and an excess of MnO₂ and H₂SO₄. (molar mass NaCl = 58.5 g/mole)

STOICHIOMETRY

A = reactant or product in a given chemical reaction B = reactant or product in a given chemical reaction



D. KINETIC MOLECULAR THEORY OF GASES

1. Gases are composed of tiny particles: atoms or molecules.
2. The average distance between the particles is very large relative to the size of the particles themselves. Therefore, the volume of the particles is considered to be negligible.
3. The particles are in constant, rapid, random, straight-line motion, colliding often with each other and the walls of their container. (Collisions with the walls of the container are the cause of pressure exerted by gas.)
4. Collisions between particles are completely elastic (frictionless collisions). Although energy may be transferred from one molecule to another during a collision, no kinetic energy (energy of motion) is lost.
5. Particles exert no forces on each other; they neither attract nor repel.
6. The average kinetic energy of particles of a gas is directly proportional to the absolute temperature. At a given temperature the particles of all gases have the same average kinetic energy.

E. Dalton's Law of Partial Pressures

Ideal gas particles have no attraction for each other, therefore they are not aware of each other until they collide. Each gas behaves independently in a mixture. The partial pressure of a gas is related to its mole fraction in the mixture - that is:

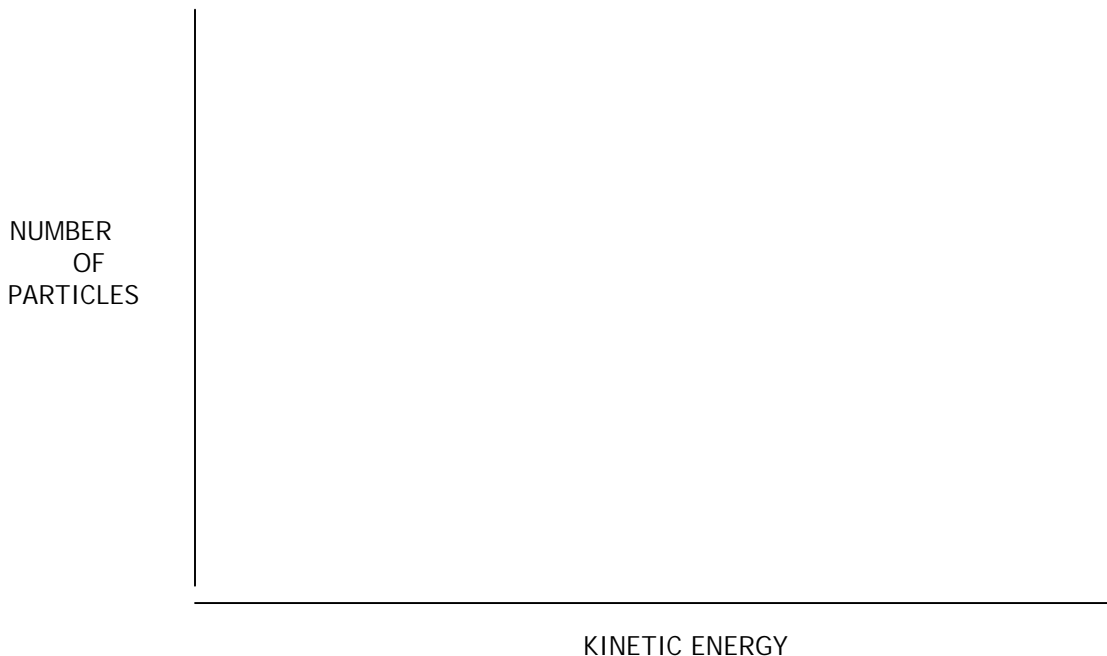
$$p_A = \chi_A \cdot P_{\text{total}} \quad \text{where} \quad \chi_A = \text{mole fraction A in the mixture (this is a concentration term, which is calculated by dividing moles A by total moles of all components in the mixture)}$$

$$p_A = \text{partial pressure of gas A in the mixture}$$

$$P_{\text{total}} = \text{total pressure exerted by gases in the mixture}$$

PROBLEM: A mixture of 6.0 mole of gas A and 8.0 mole of gas B exerts a pressure of 785 torr. What is the partial pressure of gas A in the mixture?

F. DISTRIBUTION OF PARTICLE SPEEDS



G. Graham's Law of Effusion

1. Effusion = process by which a gas under pressure escapes from a vessel by passing through a very small opening.
2. For gases A and B, both at the same temperature and pressure, in separate containers:

$$KE_A = KE_B \quad \text{where } KE = \text{kinetic energy}$$

$$\frac{1}{2} m_A v_A^2 = \frac{1}{2} m_B v_B^2 \quad \text{where } m = \text{mass}$$

$$v = \text{velocity}$$

$$\frac{v_A}{v_B} = \left[\frac{m_B}{m_A} \right]^{1/2}$$

$$1 \quad \frac{v_A}{v_B} = \left[\frac{M_B}{M_A} \right]^{1/2} \quad \text{where } M = \text{molar mass}$$

Since molecules with larger velocities effuse at a faster rate, then:

$$2 \quad \frac{r_A}{r_B} = \left[\frac{M_B}{M_A} \right]^{1/2} \quad \text{where } r = \text{rate of effusion}$$

$$3 \quad \frac{r_A}{r_B} = \left[\frac{\rho_B}{\rho_A} \right]^{1/2} \quad \text{where } \rho = \text{density}$$

Since rate = distance/time, $r = \frac{d}{t}$ d = distance

$$4 \quad \frac{t_B}{t_A} = \left[\frac{M_B}{M_A} \right]^{1/2} \quad \text{where } t = \text{time of effusion}$$

GRAHAM'S LAW PROBLEM: What is the molar mass of gas X if it effuses 0.876 times as rapidly as N₂ gas? (N₂ = 28.0 g/mole)

