

GASES

In ancient times, Chemistry existed despite the principles not yet being set. It is evident in practice such as the extraction of iron from iron ore. Chemicals such as sulfuric acid, nitric acid, and sodium sulfate are already used in various ways. In the eighteenth century, gases such as nitrogen and oxygen had been isolated. Chemistry began to formalize when the process of combustion had been studied.

Gas Laws (Chemistry 1e (OpenSTAX), 2023)

The Ideal Gas Law is the combination of all simple gas laws. The gas laws are derived from the ideal gas equation which relates pressure, volume, quantity, and temperature.

Boyle's Law

The volume of a given amount of gas is inversely proportional to its pressure at constant temperature. This equation would be ideal when working with a problem asking for the initial or final value of pressure or volume of a certain gas when one of the two factors is missing.

$$P \propto \frac{1}{V} \quad P_1 V_1 = P_2 V_2$$

Charle's Law

The volume of a given amount of gas is directly proportional to its absolute temperature at constant pressure. This equation can be used to solve for the initial or final value of volume or temperature under the given condition that pressure and the number of moles of the gas stay the same.

$$V \propto T \quad \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Gay Lussac's Law

At a fixed volume, the temperature and pressure of a gas are directly proportional to each other.

$$P \propto T \quad \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Avogadro's Law

The volume of a gas at a given temperature pressure is directly proportional to the number of moles contained in the volume. This law can be applied to problems using standard temperature and pressure.

$$V \propto n \quad \frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Combined Gas Law or The Ideal Gas Law

The relationships shared by pressure, volume, and temperature: the variables found in other gas laws, such as Boyle's law, Charles' law, and Gay-Lussac's law

$$PV = nRT \quad \frac{P_1 V_1}{n_1 T_1} = \frac{P_2 V_2}{n_2 T_2}$$

Standard Temperature and Pressure (STP)

The universal value of STP is 1 atm (pressure) and 0°C. Convert into 273 Kelvin when plugging this value into the Ideal Gas equation or any simple gas equation. In STP, 1 mole of gas will take up 22.4 L of the volume of the container.

Factor	Variable	Units
Pressure	P	atm, Torr, Pa, mmHg
Volume	V	L, m ³
moles	n	mol
Temperature	T	K
Gas Constant	R	0.082057 L atm / mol·K 8.3145 J/mol·K, 8.3145 m ³ ·Pa /mol·K

Table 1. Gas Law Units

Dalton's Law

The ideal gas law assumes that all gases behave identically and that their behavior is independent of attractive and repulsive forces. The total pressure exerted by a mixture of gases is the sum of the partial pressures of component gases.

$$P_{tot} = P_1 + P_2 + P_3 + P_4 \dots = \sum_{i=1}^n P_i = \sum_{i=1}^n n_i \left(\frac{RT}{V} \right)$$

Example:

Calculate the total pressure of a mixture containing 1 atm He_(g), 3 atm Ne_(g), 5 atm C₆H_{14(g)} and 0.7 atm UF_{6(g)}

$$P_{tot} = 1 + 3 + 5 + 0.7 = 9.7 \text{ atm}$$

Gas Stoichiometry (Bauer et al., 2024)

The ideal gas law allows us to establish a connection between the quantities of gases (measured in moles) and their respective volumes (expressed in liters). It enables us to compute the stoichiometry of reactions that involve gases, provided we know the pressure and temperature. This capability is crucial for a variety of reasons. In many laboratory reactions, a gas is either produced or consumed. Therefore, chemists need to be able to handle gaseous reactants and products quantitatively, just as they would with solids or solutions.

Example:

Given: $2S_{(s)} + 3O_{2(g)} + 2H_2O_{(l)} \rightarrow 2H_2SO_{4(aq)}$
T = 22°C, P = 745 mmHg, mass = 1 ton = 907.18 kg of H₂SO₄

Required: Volume of gaseous constant

Strategy:

1. Calculate the number of moles of H₂SO₄
2. From stoichiometric coefficients, calculate the moles of O₂ required
3. Use ideal gas law to compute for volume of O₂

Kinetic Molecular Theory (Silberberg & Amateis, 2024)

The Kinetic Molecular Theory is a fundamental concept in chemistry that explains the behavior of matter. It is used to explain the properties of a gas, such as pressure and temperature, in terms of its microscopic components, such as atoms.

Assumptions for Kinetic Model of Gases

1. Gases are made up of particles with no defined volume but with a defined mass. In other words, their volume is very small compared to the distance between themselves and other molecules.
2. Gas particles undergo no intermolecular attractions or repulsions. This assumption implies that the particles possess no potential energy; thus, their total energy is equal to their kinetic energies.
3. Gas particles are in continuous, random motion.
4. Collisions between gas particles are completely elastic. In other words, there is no net loss or gain of kinetic energy when particles collide.
5. The average kinetic energy is the same for all gases at a given temperature, regardless of the identity of the gas. This kinetic energy is proportional to the absolute temperature of the gas.

$$KE = \frac{1}{2}mv^2 = \frac{3}{2}k_B T$$

- k_B = Boltzmann's constant = $1.382 \times 10^{-23} \frac{m^2 kg}{s \cdot K}$
- T = absolute temperature in Kelvin (K)

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