Ministry of Higher Education and Scientific Research
Al-Mustaqbal University College
Chemical Engineering and Petroleum Industries Departement

Physical Chemistry I
Second Stage
Lecture No.1

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Chemistry : is the scientific discipline involved with compounds composed of atoms, i.e. elements, and molecules, i.e. combinations of atoms: their composition, structure, properties, behavior and the changes they undergo during a reaction with other compounds.

Physical chemistry : is the study of the fundamental physical principles that govern the way that atoms, molecules, and other chemical systems behave. Physical chemists study a wide array of topics such as the rates of reactions (kinetics), the way that light and matter interact (spectroscopy), how electrons are arranged in atoms and molecules (quantum mechanics), and the stabilities and reactivities of different compounds and processes (thermodynamics).

References:

1. ATKINS' Physical Chemistry, Eight Edition, Peter Atkins, Julio de Paula.
2. Lectures.

Ideal gas equation

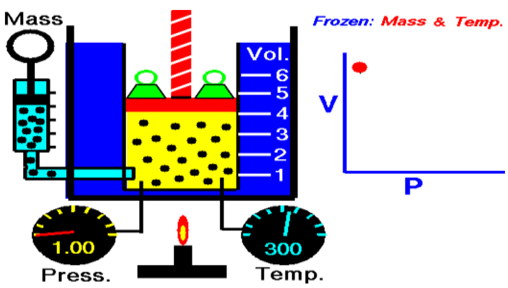
The equation of ideal gas can be written as below:

$$PV = nRT$$

Boyle's Law

According to Boyle's Law, the pressure (P) of a given mass of gas is inversely proportional to its volume (V), provided that the temperature of the gas remains constant.

$$V \propto \frac{1}{P}$$
$$PV = \text{constant}$$
$$P_1V_1 = P_2V_2$$



Example: In an industrial process, a gas confined to a volume of 1 L at a pressure of 20 atm is allowed to flow into a 12 L container by opening the valve that connects the two containers. What is the final pressure of the gas?

solution

Set up the problem by setting up the known and unknown variables. In this case, the initial pressure is 20 atm (P_1), the initial volume is 1 L (V_1), and the new volume is 1L + 12 L = 13 L (V_2), since the two containers are connected.

The new pressure (P_2) remains unknown.

$P_1V_1 = P_2V_2$

(20 atm)(1 L) = (P_2)(13 L)

20 atom = (13) P_2

P_2 = 1.54 atm.

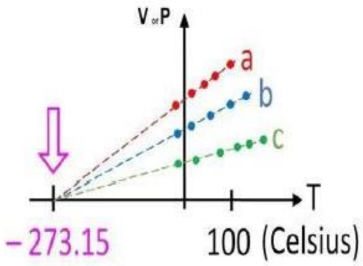
The final pressure of the gas is 1.54 atm.

Charles' Law

Describes the relationship between volume and temperature of gases at constant pressure and mass. With the same amount of gas he found that as the volume increases the temperature also increases.

$$V \propto T$$

$$\frac{V1}{T1} = \frac{V2}{T2}$$

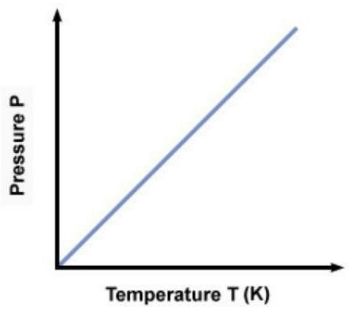


Gay-Lussac's Law

The pressure and absolute temperature (K) of a gas are directly related at constant mass & volume.

$$P \propto T$$

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



Example: A balloon is filled to a volume of 2.2 L at a temperature of 22^{O}C. The balloon is then heated to a temperature of 71^{O}C. Find the new volume of the balloon.

Solution

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \rightarrow \therefore V_2 = \frac{V_1 \times T_2}{T_1}$$

$$V_2 = \frac{2.20L \times 344K}{295K} \rightarrow \therefore V_2 = 2.57\ L$$

Example: The gas in an aerosol can is under a pressure of 3 atm at a temperature of 25^{O}C. It is dangerous to dispose of an aerosol can by incineration. What would the pressure in the aerosol can be at a temperature of 845^{O}C?

Solution

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \rightarrow \therefore\ P_2 = \frac{P_1 \times T_2}{T_1}$$

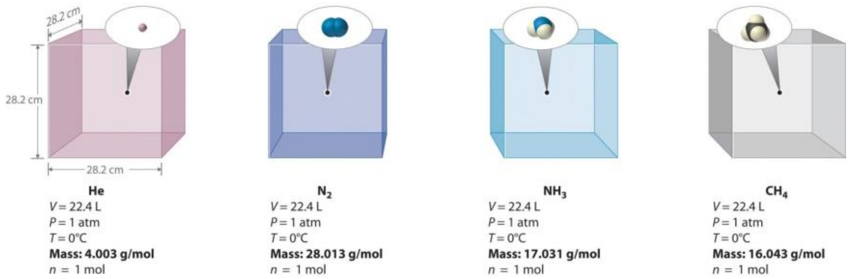
$$P_2 = \frac{3\ atm \times 1118K}{298K} \rightarrow\ \therefore P_2 = 11.3atm$$

Avogadro's Principle

Equal volumes of gases contain equal numbers of moles at constant temp & pressure its true for any ideal gas.

$$V\ \alpha\ n$$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$



So $V\alpha\frac{nT}{P}$

$$PV = nRT \text{......... } ideal\ gas$$

$$\therefore V = \frac{nRT}{P}$$

$$n = m/M_{wt} \qquad \rightarrow \therefore PM_{wt} = (m/V)RT$$

$$\therefore M_{wt} = \frac{\rho RT}{P}$$

Example: A balloon has been filled to a volume of 1.9 L with 0.092 mol of helium gas. If 0.021 mol of additional helium is added to the balloon while the temperature and pressure are held constant, what is the new volume of the balloon?

Solution

Note that the final number of moles has to be calculated by adding the original number ofmoles to the moles of added helium.

$$n_2 = 0.0920 + 0.0210 = 0.1130\,mol$$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} \rightarrow \therefore V_2 = \frac{V_1 \times n_2}{n_1}$$

$$V_2 = \frac{1.90L \times 0.1130\,mol}{0.0920\,mol} \rightarrow \therefore V_2 = 2.33L$$

Dalton’s Law of Partial Pressures

Dalton’s Law, or the Law of Partial Pressures, states that the total pressure exerted by a mixture of gases is equal to the sum of the partial pressures of the gases in the mixture.

$$\boldsymbol{PV = nRT}$$

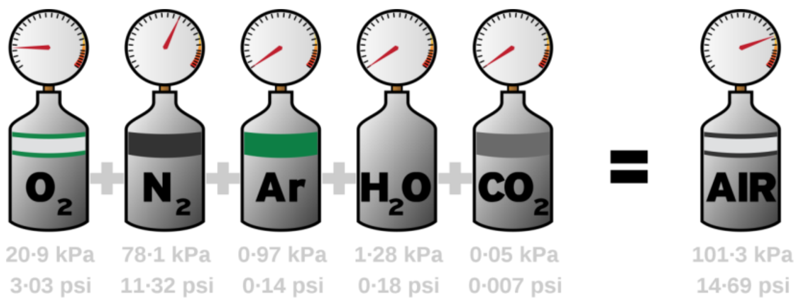
$$\boldsymbol{P_{total} = P_A + P_B + \cdots}$$

$$\boldsymbol{n_{total} = n_A + n_B + \cdots}$$

$$\boldsymbol{P_{tot}V = n_{tot}RT}$$

$$\boldsymbol{\frac{P_A}{P_{tot}} = \frac{n_A}{n_{tot}}}$$

$$\boldsymbol{\frac{P_B}{P_{tot}} = \frac{n_B}{n_{tot}}}$$



Example: 24.0 L of nitrogen gas at 2 atm and 12.0 L of oxygen gas at 2 atm are added to a 10 L container at 273 K. Find the partial pressure of nitrogen and oxygen and then find the total pressure.

Solution

Find the number of moles of oxygen and nitrogen using PV=nRT which is n=PV/RT

- oxygen: ((2 atm)(12L))/(0.08206 atm L mol^{-1} K^{-1})(273 K)=1.071 moles oxygen
- nitrogen: ((2 atm)(24.0L))/(0.08206 atm L mol^{-1} K^{-1})(273 K)=2.143 moles ofNitrogen
- add to get n_{tot}: 1.071 mol_{Oxygen}+2.143 $mol_{Nitrogen}$=3.214 moles total

- Use PV=nRT or P=(nRT)/V to find the total pressure
  - P_{tot}=((3.214 mol_{total})(0.08206 atm L mol^{-1} K^{-1})(273 K))/(10.0 L)=7.200 atm

- $P_A/P_{tot}=n_A/N_{tot}$ can be rearranged to $P_{A}=(P_{tot})(n_A/N_{tot})$ to find the partial pressures
  - P_{oxygen}=(7.200 atm_{total})(1.071mol_{Oxygen}/3.214 mol_{total})=2.399 atm_{Oxygen}
  - $P_{nitrogen}$=7.200 atm_{total}-2.399 atm_{Oxygen}=4.801 $atm_{Nitrogen}$