University of Al-Mustaqbal
College of Science
Department of Medical Physics

Thermodynamics and Heat

Second stage

Introduction

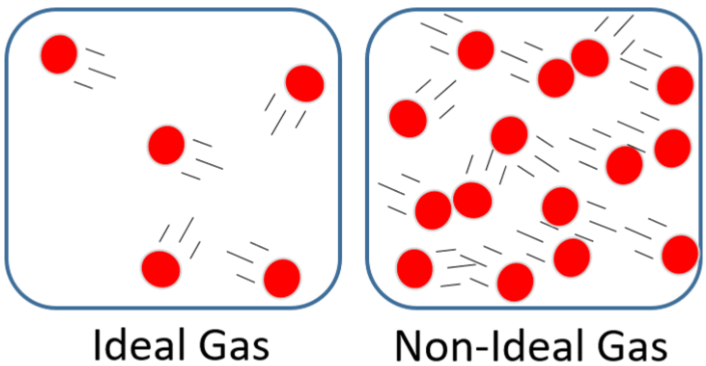
Lecture three

Name of lecturer

Asst .prof .Dr Rusul Abdul Ameer

Ideal Gas

A gas is made of molecules that move around with random motion. In the ideal gas, the molecules may collide but they have no tendency to stick together or repel each other. In reality, there is a slight force of attraction between gas molecules but this is so small that gas laws formulated for an ideal gas work quite well for a real gas.



Equation of State

Any equation that relates the pressure, temperature and volume of a substance is called an equation of state. Property relations that involve other properties of a substance at equilibrium states are also referred to as equations of state. There are several equations of state, some simple and others very complex. The simplest and best known equation of state for substances in the gas phase is the ideal gas equation of state. This equation predicts the (P-V-T) behavior of a gas quite accurately within some properly selected region. The ideal gas equation of state is expressed as:

$$PV = nRT$$

or PV = RT (in terms of specific volume)

where R is the gas constant, which has a different value for each gas. The equation of state can also be expressed in terms of the number of moles instead of the mass as follows:

$$PV = NR_oT$$

where N is the number of moles, and Ro is the universal gas constant which has a constant value for all gases:

$$Ro = 8.314 \text{ kJ/kmol. K}$$

$$Ro = 1545.37 \text{ ft. lbf/kmol. R}$$

$$R = Ro / M \text{ and } M = m\, N$$

where M is the molar mass (also called molecular weight) of the gas.

For a constant mass, the properties of an ideal gas at two different states are related to each other by:

$$P_1V_1 / T_1 = P_2V_2 / T_2$$

Note: in these equations T is the absolute temperature (i.e. substituted in Kelvin or Rankine).

Boyle's law states that the pressure of a given mass of an ideal gas is inversely proportional to its volume at a constant temperature. It is expressed as:

$$PV = C \text{ or } P_1V_1 = P_2V_2$$

Charles's law states that the volume of an ideal gas at constant pressure is directly proportional to the absolute temperature. It is expressed as:

$$V\ T = C \text{ or } V_1\ T_1 = V_2\ T_2$$

Gay-Lussac's law states that, for a given mass and constant volume of an ideal gas, the pressure exerted on the sides of its container is directly proportional to its absolute temperature. It is expressed as:

$$P\ T = C \text{ or } P_1\ T_1 = P_2\ T_2$$

Example

An amount of gas has a pressure of 350 KPa, a volume of 0.03 m^3 and a temperature of 35°C. If R = 0.29 kJ/kg .K, calculate the mass of the gas and the final temperature if the final pressure is 1.05 MPa and the volume remains constant?

Solution:

The absolute temperature: $T_1 = 35 + 273 = 308$ K Applying the equation of state for the initial conditions: $P_1V_1 = mRT_1$

$= 350 \times 0.03 = m \times 0.29 \times 308 \rightarrow m = 350 \times 0.03 / (0.29 \times 308)$

$\boldsymbol{m} = \mathbf{0.12\ kg}$

Applying the equation of state between two conditions at constant volume:

$P_1 / T_1 = P_2 / T_2$

$= 350 / 308 = (1.05 \times 10^3 / T_2) \rightarrow T_2 = (1.05 \times 10^3 \times 308) / 350$

$\boldsymbol{T_2} = \mathbf{924\ K}$

Example

A tank has a volume of 0.5 m^3 and contains 10 kg of an ideal gas having a molecular weight of 24. The temperature is 25°C. What is the pressure of the gas?

Solution:

The absolute temperature:

$T = 25 + 273 = 298$ K

$R = R_o / M = (8.314 / 24) = 0.35$ kJ/kg. K

Applying the equation of state:

$PV = mRT$

$P \times 0.5 = 10 \times 0.35 \times 298 \rightarrow \quad P = (10 \times 0.35 \times 298) / 0.5$

$\boldsymbol{P} = \mathbf{2086\ kPa}$.