Thermodynamics
Professor Anand T N C
Department of Mechanical Engineering,
Indian Institute of Technology Madras
Lecture 38
Tutorial problem - Part 1

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Figure 1.

Solution of the problem given in Fig. 1:

$m_{O_2} = 70\ g = 0.07\ kg, m_{He} = 0.3\ kg, V = 10\ L = 10 \times 10^{-3} m^3, T = 298\ K$

Partial pressure of gases, $p_{O_2} = x_{O_2} p_{mix}$ and $p_{He} = x_{He} p_{mix}$ where x and p$_{mix}$ represent the mole fraction and mixture pressure. Also, $V_{O_2} = x_{O_2} V$ and $V_{He} = x_{He} V$.

We can find mole fraction using molecular weight of the mixture which in turn needs mass fractions.

$$y_{O_2} = \frac{m_{O_2}}{m_{O_2} + m_{He}} = \frac{0.07}{0.07 + 0.03} = 0.18, y_{He} = 1 - y_{O_2} = 0.82$$

Molecular weight of the mixture, $M_{mix} = \frac{1}{\Sigma y_i/M_i} = \frac{1}{\frac{y_{O_2}}{M_{O_2}} + \frac{y_{He}}{M_{He}}} = \frac{1}{\frac{0.18}{32} + \frac{0.82}{4}} = 4.74\ kg/kmol$

Now, $x_{O_2} = \frac{y_{O_2}}{M_{O_2}} M_{mix} = \frac{0.18}{32} \times 4.74 = 0.026$ and $x_{He} = 1 - x_{O_2} = 0.974$

Hence, $V_{O_2} = x_{O_2} V = 0.026 \times 10 = 0.26\ L$ and $V_{He} = x_{He} V = 0.974 \times 10 = 9.74\ L.$

To calculate partial pressures, we need mixture pressure.

Assume that both the gases are ideal gases. Hence, the mixture is also an ideal gas.

Now, $m_{mix} = 0.37\ kg, T_{mix} = 298\ K, V_{mix} = 10^{-2}\ m^3, R_{mix} = \dfrac{\bar{R}}{M_{mix}} = \dfrac{8314.5\ \frac{kJ}{kmol \cdot K}}{4.74\ \frac{kg}{kmol}} = 1754.1\ \dfrac{kJ}{kg \cdot K}$.

Hence, $p_{mix}V_{mix} = m_{mix}R_{mix}T_{mix}\quad \rightarrow\quad p_{mix} = 193\ bar$

Hence, $p_{O_2} = x_{O_2}p_{mix} = 5\ bar,\ \ p_{He} = x_{He}p_{mix} = 187.2\ bar$

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