Question #78604

The temperature in a vessel is 36 degree C and the proportion by mass of air to dry saturated steam is 0.1. What is the pressure in the vessel in bar and in mm of mercury vacuum? The barometric pressure is 760mm Hg?

Answer:

The pressure in the vessel is the sum of the partial pressure of the air and steam:

$$P = P_{air} + P_{steam}. \quad (1)$$

The pressure of the saturated steam at 36°C equals to 0.06 bar (see https://www.engineeringtoolbox.com/saturated-steam-properties-d_457.html).

Consider the steam and the air are ideal gases. So, the equation of their state is given by:

$$PV = nRT = \frac{M}{m}RT, \quad (2)$$

where *P*, *V* and *T* are the pressure, volume and absolute temperature, respectively,

R is the universal gas constant,

n is the number of moles,

M is the mass,

m is the molecular mass (m_{air} = 28.966 kg/kmol, m_{H2O} = 18.02 kg/kmol – see https://www.engineeringtoolbox.com/molecular-weight-gas-vapor-d_1156.html).

Thus, (2) gives us the mass of the air and the steam in the vessel as follow:

$$M_{air} = m_{air}P_{air}\frac{V}{RT}, \quad (3)$$

$$M_{steam} = m_{steam}P_{steam}\frac{V}{RT}. \quad (4)$$

Using (1), (3) and (4) we can derive the following equation:

$$\frac{M_{air}}{M_{steam}} = \frac{m_{air}P_{air}\frac{V}{RT}}{m_{steam}P_{steam}\frac{V}{RT}} = \frac{m_{air}(P - P_{steam})}{m_{steam}P_{steam}},$$

$$P = P_{steam}\left(1 + \frac{M_{air}}{M_{steam}} \cdot \frac{m_{steam}}{m_{air}}\right). \quad (5)$$

Substitute into (5):

$$P = 0.06\left(1 + 0.1 \cdot \frac{18.02}{28.966}\right) = 0.064 \text{ bar}.$$

Converting into mm of mercury: *P* = 48.0 mm Hg. Thus the vacuum in mm of mercury is:

$$P_{vac} = 760 - 48 = 712 \text{ mm Hg}.$$