Model Solutions

To

Numerical Problems Appearing in

Fuels, Energy and the Environment

By

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6.6.1.-

Air is considered to contain 20.9% by volume oxygen and the remainder nitrogen. Calculate the composition of air on mass basis. What is the effective molecular weight of air? Assume air to behave as an ideal gas.

Given:

Volumetric composition of normal air to be oxygen20.9% and nitrogen 79.1%

Consider one kmol of air, then: mass of oxygen = $(Mwt \times Vol)_{oxygen}$ = 32 x 0.209

= 6.69 kg/kmol

Similarly, mass of nitrogen = 28 x 0.791 = 22.15 kg/kmol

% oxygen by mass = 6.69 x 100 / (6.69 + 22.15) = 23.20

% nitrogen by mass = 22.15 x 100 / (6.69 + 22.15) = 76.80

Effective molecular weight of air = mass / molar volume

= (6.69 + 22.15 / 1.0 = 28.84 kg/kmol

6.6.2 –

A natural gas has the following composition by volume: CH_4: 88.7%, C_2H_6: 4.3%: H_2S: 1.5% and N_2: 5. 5%. Calculate the density of the gas at a temperature of 310K and a pressure of 103.5kPa. What would be the density of the gas if it were diluted by mixing with carbon dioxide so that the combustible components represent 85% by volume of the resulting mixture? Assume ideal gas behaviour,

The composition of the gas by volume is:

CH_4 : 88.7%, C_2H_6 : 4.3%, H_2S : 1.5% and N_2 : 5.5%

The combustible components are: $CH_{4,}$ $C_2H_{6,}$ and H_2S .

Assume ideal gas applies to all components of the gas.

P/V = m.R.T/ M, i.e. Density, ρ = P.M / R.T

Find the effective molecular weight of the gas, M_g:

M_g = 0.887 x 16 + 0.043 x 30 + 0.015 x 34 + 0.55 x 28 = 17.532 kg/kmol

ρ_1 = 103.5 x 17.532 / 8.316 x 310 = 0.7039 kg/m^3

Per 100 moles of the original gas the addition of CO2 will make the fraction of the total combustible components equal to :

$(n_{CO2} + n_{C2H6} + n_{H2S}) / (100 + n_{CO2}) = 0.85$

i.e. (0.887 + 0.043 + 0.015) / (1.00 + nCO2) = 0.945 / (1.00 +n_{CO2})

When the value of this fraction equals 0.85 then:

n_{CO2} = (0.945 – 0.85) / 0.85 = o.118

The molecular weight of the new gas = Σ ni Mi / Σ ni

= (0.887 x16 + 0.43 x 30 + 0.15 x 34 + 0.055 x 28 + 0.1118 x 44) / 1.1118

= 20.194 kg/kmol

$\rho_2 = \rho_1 \times Mgas2/ Mgas1$

$\rho_2 = 0.7039 \times 20.194 / 17.532 = 0.8107\ kg/m^3$

6.6.3. –

A high pressure tank of 0.75 m^3 capacity contains pure hydrogen. What is the mass of the gas if at a temperature of 287K the pressure is found to be 1.45MPa?
After discharging some gas, the pressure became 0.7 MPa and the temperature 279K. How much hydrogen gas was discharged?

For an ideal gas mass is given as:

m= P.V/ R.T For hydrogen R= 8.315 / 2.0 kJ/kg.K

m=1.45 x 1000 x 0.75 x 2 / 8.314 x 287 = 0.9115 kg

After the gas discharge the mass becomes: = 0.78 x 1000 x 0.75 x 2 / 8.314 x

279

= 0.5043kg

Mass of gas discharged = 0.9115 – 0.5043 = 0.4072kg

6.6.4 -

An ideal gas mixture has a molecular weight of 40 kg/kmol and a specific heat at constant pressure of 0.523kJ/kg.K. At a gauge pressure of 380kPa and 422K the volume was measured to be 14.5m^3. Determine: a) the gas constant, b) the specific heat at constant volume and the mass of the gas.

An ideal gas with molecular weight of 40kg/kmol has a Cp of 0.523kJ/kg.K

Its volume at a gauge pressure of 380kPa and 422 K is 14.5m^3

a) The gas Constant = 8.3146/ M.Wt = 8.3146/ 40 = 0.2078 kJ/kg.K

b)For an ideal gas : Cp – Cv = R