207.

Problem 23.19 (RHK)

At $0\,^{0}\mathrm{C}$ *and* 1.00 atm *pressure the densities of air, oxygen, and nitrogen are, respectively,* $1.29\ \mathrm{kg\ m^{-3}}, 1.429\ \mathrm{kg\ m^{-3}}$*, and* $1.250\ \mathrm{kg\ m^{-3}}$. *We have to calculate the fraction by mass of nitrogen in the air from these data, assuming only these two gases to be present.*

Solution:

In the ideal gas approximation at the same temperature and pressure all the three gaseous substances air, oxygen and nitrogen will have the same number of molecules. Let this number be N. Let m_{O_2} be the mass of an oxygen molecule and m_{N_2} be the mass of a nitrogen molecule. Let V be the volume of the three gaseous substances at $0\,^{0}\mathrm{C}$ and at 1.00 atm pressure containing N molecules. The densities of the oxygen gas and nitrogen gas at $0\,^{0}\mathrm{C}$ and at 1.00 atm pressure are $1.429\ \mathrm{kg\ m^{-3}}$, and $1.250\ \mathrm{kg\ m^{-3}}$, respectively. Therefore,

$$\frac{m_{O_2}N}{V}=1.429\text{ kg m}^{-3},$$

and

$$\frac{m_{N_2}N}{V}=1.250\text{ kg m}^{-3}.$$

Let the number of oxygen and nitrogen molecules in air be N_{O_2}, and N_{N_2}, respectively. As the density of air is 1.29 kg m^{-3}, we have

$$\frac{m_{O_2}N_{O_2}+m_{N_2}N_{N_2}}{V}=1.293\text{ kg m}^{-3}.$$

Substituting

$$N_{O_2}=N-N_{N_2},$$

we find

$$\frac{N_{N_2}}{N}=0.7597.$$

And

$$\frac{m_{N_2}N_{N_2}}{\left(m_{N_2}N_{N_2}+m_{O_2}N_{O_2}\right)}=\frac{\frac{N_{N_2}}{N}\times\frac{m_{N_2}N}{V}}{1.293}=\frac{0.7597\times1.250}{1.293}$$

$$=0.73.$$

Therefore, fraction by mass of nitrogen in air is 0.73.