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Chapter 1 - Introduction

1.1 A gas at 20°C may be *rarefied* if it contains less than 10^{12} molecules per mm^3 . If Avogadro's number is 6.023×10^{23} molecules per mole, what air pressure does this represent?

Solution: The mass of one molecule of air may be computed as

$$m = \frac{\text{Molecular weight}}{\text{Avogadro's number}} = \frac{28.97 \text{ mol}^{-1}}{6.023 \times 10^{23} \text{ molecules/g-mol}} = 4.81 \times 10^{-23} \text{ g}$$

Then the density of air containing 10^{12} molecules per mm^3 is, in SI units,

$$\rho = \left(10^{12} \frac{\text{molecules}}{\text{mm}^3} \right) \left(4.81 \times 10^{-23} \frac{\text{g}}{\text{molecule}} \right) \\ = 4.81 \times 10^{-11} \frac{\text{g}}{\text{mm}^3} = 4.81 \times 10^{-5} \frac{\text{kg}}{\text{m}^3}$$

Finally, from the perfect gas law, Eq. (1.13), at 20°C = 293 K, we obtain the pressure:

$$p = \rho RT = \left(4.81 \times 10^{-5} \frac{\text{kg}}{\text{m}^3} \right) \left(287 \frac{\text{m}^2}{\text{s}^2 \cdot \text{K}} \right) (293 \text{ K}) = \mathbf{4.0 \text{ Pa}} \quad \text{Ans.}$$

1.2 The earth's atmosphere can be modeled as a uniform layer of air of thickness 20 km and average density 0.6 kg/m^3 (see Table A-6). Use these values to estimate the total mass and total number of molecules of air in the entire atmosphere of the earth.

Solution: Let R_e be the earth's radius = 6377 km. Then the total mass of air in the atmosphere is

$$m_a = \int \rho \, d\text{Vol} = \rho_{\text{air}} (\text{Air Vol}) = \rho_{\text{air}} 4\pi R_e^2 (\text{Air thickness}) \\ = (0.6 \text{ kg/m}^3) 4\pi (6377 \times 10^3 \text{ m})^2 (20 \times 10^3 \text{ m}) = \mathbf{6.1 \times 10^{18} \text{ kg}} \quad \text{Ans.}$$

Dividing by the mass of one molecule = $4.8 \times 10^{-23} \text{ g}$ (see Prob. 1.1 above), we obtain the total number of molecules in the earth's atmosphere:

$$N_{\text{molecules}} = \frac{m(\text{atmosphere})}{m(\text{one molecule})} = \frac{6.1 \times 10^{18} \text{ grams}}{4.8 \times 10^{-23} \text{ gm/molecule}} = \mathbf{1.3 \times 10^{44} \text{ molecules}} \quad \text{Ans.}$$





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