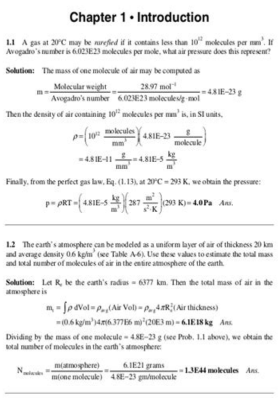

Chapter 1 • Introduction

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 6.023E23 molecules per mole, what air pressure does this represent?

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

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

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

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

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

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

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

$$m_t = \int \rho\, d\text{Vol} = \rho_{avg}(\text{Air Vol}) \approx \rho_{avg} 4\pi R_e^2(\text{Air thickness}) = (0.6\ \text{kg/m}^3)4\pi(6.377\text{E}6\ \text{m})^2(20\text{E}3\ \text{m}) \approx \mathbf{6.1E18\ kg} \quad \textit{Ans.}$$

Dividing by the mass of one molecule ≈ 4.8E−23 g (see Prob. 1.1 above), we obtain the total number of molecules in the earth's atmosphere:

$$N_{molecules} = \frac{\text{m(atmosphere)}}{\text{m(one molecule)}} = \frac{6.1\text{E}21\ \text{grams}}{4.8\text{E}{-23}\ \text{gm/molecule}} \approx \mathbf{1.3E44\ molecules} \quad \textit{Ans.}$$

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