220.

Problem 24.5 (RHK)

At standard temperature and pressure (0^0C *and* 1.0 atm) *the mean free path in helium gas is* 285 nm. *We have to determine* (a) *the number of molecules per cubic meter and* (b) *the effective diameter of the helium atoms.*

Solution:

(a)

The equation of state of an ideal gas in terms of the total number of molecules N at temperature T, pressure P and volume V is

$$P = \frac{N}{V} kT,$$

or

$$\rho_n = \frac{N}{V} = \frac{P}{kT} = \frac{1.01\times10^5}{1.38\times10^{-23}\times273.16} \text{ molecules. m}^{-3}$$
$$= 2.68\times10^{25} \text{ molecules. m}^{-3}.$$

(b)

The mean free path λ is determined by the number density of molecules ρ_n and the effective molecular diameter *d* by the relation

$$\lambda = \frac{1}{\sqrt{2}\pi d^2 \rho_n},$$

or

$$d = \left(\frac{1}{\sqrt{2}\pi\lambda\rho_n} \right)^{1/2}.$$

We are given that the mean free path in the helium gas at the standard temperature and pressure is

$\lambda = 285\times10^{-9}$ m.

Therefore,

$$d = \left(\frac{1}{\sqrt{2}\pi \times 285\times10^{-9} \times 2.68\times10^{25}} \right)^{1/2} \text{ m} = 1.71\times10^{-10} \text{ m}$$

$$= 0.171 \text{ nm}.$$