Problem 1.57

Breathing Oxygen. The density of air under standard laboratory conditions is 1.29 kg/m^3, and about 20% of that air consists of oxygen. Typically, people breathe about $\frac{1}{2}$ L of air per breath. (a) How many grams of oxygen does a person breathe in a day? (b) If this air is stored uncompressed in a cubical tank, how long is each side of the tank?

Solution

Part (a)

The density of air is given as

$$\rho_{\text{air}} = 1.29\ \frac{\text{kg air}}{\text{m}^3}.$$

Since the air consists of 20% oxygen, the density of oxygen is

$$\rho_{\text{O}_2} = 0.2\rho_{\text{air}} = 0.258\ \frac{\text{kg O}_2}{\text{m}^3}.$$

Multiply the oxygen density by $\frac{1}{2}$ L per breath to get the mass of O_2 inhaled per breath. Use the conversion factor in Appendix E on page A-6.

$$m_{\text{O}_2} = \rho_{\text{O}_2} \times \frac{1}{2}\ \frac{\text{L}}{\text{breath}} = 0.258\ \frac{\cancel{\text{kg O}_2}}{\cancel{\text{m}^3}} \times \frac{1}{2}\ \frac{\cancel{\text{L}}}{\text{breath}} \times \frac{1000\ \text{g}}{1\ \cancel{\text{kg}}} \times \frac{10^{-3}\ \cancel{\text{m}^3}}{1\ \cancel{\text{L}}} = 0.129\ \frac{\text{g O}_2}{\text{breath}}$$

Assume a person inhales once every five seconds on average.

$$0.129\ \frac{\text{g O}_2}{\cancel{\text{breath}}} \times \frac{1\ \cancel{\text{breath}}}{5\ \cancel{\text{sec}}} \times \frac{60\ \cancel{\text{sec}}}{1\ \cancel{\text{min}}} \times \frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{hr}}} \times \frac{24\ \cancel{\text{hr}}}{1\ \text{day}} \approx 2.23 \times 10^3\ \frac{\text{g O}_2}{\text{day}}$$

Part (b)

In one day a person breathes in 2.23×10^3 g O_2, or 2.23 kg O_2. Invert the density of oxygen and multiply it by this result to get the volume this oxygen occupies in cubic meters.

$$\frac{1}{\rho_{\text{O}_2}} \times 2.23\ \text{kg} = \frac{1}{0.258}\ \frac{\text{m}^3}{\cancel{\text{kg O}_2}} \times 2.23\ \cancel{\text{kg O}_2} \approx 8.64\ \text{m}^3$$

Take the cube root to get the length of the cube's side.

$$\sqrt[3]{8.64\ \text{m}^3} \approx 2.05\ \text{m}$$