Problem Solving and Estimation
Concept Questions

Question 1 What is your best estimate of the volume of one breath?

1) between 1/10 and 1 liter

2) between 1 and 10 liters

3) between 10 and 100 liters

4) between 100 and 1000 liters

Answer 2. I estimate the volume of the lungs by estimating the volume of an average sized person's upper body with dimensions 0.3 meters by 0.2 meters by 0.2 meters which is approximately $10 \times 10^{-3}\ \mathrm{m}^3$. One liter is $10^3\ \mathrm{cm}^3 = 10^{-3}\ \mathrm{m}^3$. So this volume is approximately $10\ \text{liters}$. A typical breath occupies half this volume so between 1 and 10 liters.

Question 2 What is your best estimate for the volume of the earth's atmosphere?

1) between 10^1 and 10^5 cubic meters

2) between 10^5 and 10^{10} cubic meters

3) between 10^{10} and 10^{15} cubic meters

4) between 10^{15} and 10^{20} cubic meters

5) between 10^{20} and 10^{25} cubic meters

6) between 10^{25} and 10^{30} cubic meters

Answer 4. The volume is a scalar quantity. Approximate the volume of the atmosphere by a spherical shell of radius r and thickness t with volume $V_e \cong 4\pi r^2 t$ where the thickness of shell is approximately $t \cong 10\,\mathrm{km} = 10^4\,\mathrm{m}$ and the radius of shell equals the radius of the earth, $R_e \cong 6\times 10^3\,\mathrm{km} = 6\times 10^6\,\mathrm{m}$. So the volume is approximately

$$V_e \cong 4\pi r^2 t = 4\pi\left(6\times 10^6\,\mathrm{m}\right)^2\left(10^4\,\mathrm{m}\right) = 4\times 10^{18}\,\mathrm{m}^3.$$

Question 3 What is your best estimate for the number of molecules in the earth's atmosphere?

1. Less than 10^{1} molecules.
2. Between 10^{10} and 10^{20} molecules.
3. Between 10^{20} and 10^{30} molecules.
4. Between 10^{30} and 10^{40} molecules.
5. Between 10^{40} and 10^{50} molecules.
6. Between 10^{50} and 10^{60} molecules.
7. Between 10^{60} and 10^{70} molecules.
8. Between 10^{70} and 10^{80} molecules.
9. More than 10^{80} molecules.

Answer 5. One mole of an ideal gas STP (Standard Temperature and Pressure) occupies $22.4\,\mathrm{L} \cong 20\times10^{-3}\,\mathrm{m}^{-3}$, so the number of moles of air in the atmosphere is approximately

$$4\times10^{18}\,\mathrm{m}^{3}\,/\,20\times10^{-3}\,\mathrm{m}^{-3} \cong 2\times10^{20}\,\mathrm{moles}\,.$$

There are approximately $6\times10^{23}\,\mathrm{molecules/mole}$. Therefore there are approximately

$$(2\times10^{20}\,\mathrm{moles})(6\times10^{23}\,\mathrm{molecules/mole}) \cong 10^{44}\,\mathrm{molecules}$$