(2) Is it likely or unlikely that your next breath will contain an atom of nitrogen that was in your first breath?

Many readers will have heard this problem before in one version or another, sometimes with one of the breaths that of Julius Caesar. There are 800 g of nitrogen atoms over each cm^2 of the Earth's surface, or 4×10^{21} g in the entire atmosphere, with negligible amounts anywhere else. Let n_0 be the number of nitrogen atoms in the atmosphere; it is 1.7×10^{44}. Let n_1 and n_2 be the number of atoms in the two breaths. The probability that a certain atom in breath 1 is not in breath 2 is $1 - n_2/n_0$. The probability that no atom in breath 1 is in breath 2 is then $(1 - n_2/n_0)^{n_1} \approx e^{-n_1 n_2/n_0}$, which has the value 0.5 if $n_1 n_2/n_0 = 0.69$. One liter of air contains 5×10^{22} nitrogen atoms. If v_1 and v_2 are the two breath volumes in liters, "likely" is the correct answer if the product $v_1 v_2 > (1.7\times10^{44}\times0.69)/(5\times10^{22})^2 = 0.05$ liter^2. Make your own estimate of the breath volumes. *Molecule* cannot be substituted for *atom* in this problem without examination of atmospheric chemical processes which could result in atoms changing partners.