(2) Let's define "the top of the atmosphere" as the height at which a nitrogen molecule moving upward with more than escape velocity has a probability 0.5 of leaving the Earth for good. About how high is that?

Ignoring any difference between nitrogen and oxygen, let σ be the N_2-N_2 collision cross section (the cross section that would be $4\pi a^2$ for hard spheres of radius a). At the height h that we seek to determine, the number of molecules above unit area must be about $0.5/\sigma$. The mass above unit area is then $(0.5/\sigma)\times 28\times 1.6\times 10^{-24}$ g. Let's assume a value of 10^{-15} cm^2 for σ, corresponding roughly to $a = 1$ Å. Then the mass above 1 cm^2 at height h is 2×10^{-8} g, which is 2×10^{-11} of the mass above 1 cm^2 at sea level. The ratio is approximately e^{-24}, so h would be 24 scale heights in a uniformly exponential atmosphere. If the scale height in the lower atmosphere, approximately 8 km, persisted to extreme altitudes, h would be around 200 km. In fact, the scale height itself begins to increase rapidly above 100 km, owing to the increasing temperature above the stratosphere, and the height h above which the sky is "half-clear" of molecules is actually close to 400 km, rather than 200 km.