39. (a) The rms speed of molecules in a gas is given by $v_{\text{rms}} = \sqrt{3RT/M}$, where $T$ is the temperature and $M$ is the molar mass of the gas. See Eq. 20–34. The speed required for escape from Earth's gravitational pull is $v = \sqrt{2gr_e}$, where $g$ is the acceleration due to gravity at Earth's surface and $r_e$ $(= 6.37 \times 10^6\,\text{m})$ is the radius of Earth. To derive this expression, take the zero of gravitational potential energy to be at infinity. Then, the gravitational potential energy of a particle with mass $m$ at Earth's surface is $U = -GMm/r_e^2 = -mgr_e$, where $g = GM/r_e^2$ was used. If $v$ is the speed of the particle, then its total energy is $E = -mgr_e + \frac{1}{2}mv^2$. If the particle is just able to travel far away, its kinetic energy must tend toward zero as its distance from Earth becomes large without bound. This means $E = 0$ and $v = \sqrt{2gr_e}$. We equate the expressions for the speeds to obtain $\sqrt{3RT/M} = \sqrt{2gr_e}$. The solution for $T$ is $T = 2gr_eM/3R$. The molar mass of hydrogen is $2.02 \times 10^{-3}\,\text{kg/mol}$, so for that gas

$$T = \frac{2(9.8\,\text{m/s}^2)(6.37 \times 10^6\,\text{m})(2.02 \times 10^{-3}\,\text{kg/mol})}{3(8.31\,\text{J/mol}\cdot\text{K})} = 1.0 \times 10^4\ \text{K}\ .$$

(b) The molar mass of oxygen is $32.0 \times 10^{-3}\,\text{kg/mol}$, so for that gas

$$T = \frac{2(9.8\,\text{m/s}^2)(6.37 \times 10^6\,\text{m})(32.0 \times 10^{-3}\,\text{kg/mol})}{3(8.31\,\text{J/mol}\cdot\text{K})} = 1.6 \times 10^5\ \text{K}\ .$$

(c) Now, $T = 2g_mr_mM/3R$, where $r_m$ $(= 1.74 \times 10^6\,\text{m})$ is the radius of the Moon and $g_m$ $(= 0.16g)$ is the acceleration due to gravity at the Moon's surface. For hydrogen

$$T = \frac{2(0.16)(9.8\,\text{m/s}^2)(1.74 \times 10^6\,\text{m})(2.02 \times 10^{-3}\,\text{kg/mol})}{3(8.31\,\text{J/mol}\cdot\text{K})} = 4.4 \times 10^2\,\text{K}\ .$$

For oxygen

$$T = \frac{2(0.16)(9.8\,\text{m/s}^2)(1.74 \times 10^6\,\text{m})(32.0 \times 10^{-3}\,\text{kg/mol})}{3(8.31\,\text{J/mol}\cdot\text{K})} = 7.0 \times 10^3\ \text{K}\ .$$

(d) The temperature high in Earth's atmosphere is great enough for a significant number of hydrogen atoms in the tail of the Maxwellian distribution to escape. As a result the atmosphere is depleted of hydrogen. On the other hand, very few oxygen atoms escape.