A 5-liter vessel contains nitrogen gas at a temperature of 27°C and a pressure of 3 atm. Find:

A) the average kinetic energy per molecule

B) the average velocity of a molecule, and

C) the total kinetic energy of the gas.

A) $$\overline{K}_m = \frac{3}{2}kT = \frac{3}{2}\left(1.38 \times 10^{-23}\,\frac{J}{K}\right)(300\,K) = 6.21 \times 10^{-21}\,J = .0034\,eV$$

To put this number in perspective, note that typical excitation energies of the elements tend to be on the order of an eV. This says that thermal energies don't lead to excitation of the gas.

B) The mass of a single nitrogen atom is

$$\begin{aligned} m_N &= (\text{atomic mass})(\text{proton mass}) \\ &= (14)\left(1.67 \times 10^{-27}\,kg\right) = 2.34 \times 10^{-26}\,kg \end{aligned}$$

But nitrogen is diatomic as a gas, i.e. N_2, thus $m_{N_2} = 4.68 \times 10^{-26}\,kg$

$$v_{RMS} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{2\overline{K}_m}{m}} = \sqrt{\frac{2\left(6.21 \times 10^{-21}\,J\right)}{4.68 \times 10^{-26}\,kg}} = 515\,\frac{m}{s}$$

This value compares well with the book value of $v_{RMS}(20^oC)$=511 m/s.

C) $$\overline{K} = N\overline{K}_m$$

Note that the Ideal Gas Law says that PV=NkT, thus

$$N = \frac{PV}{kT} = \frac{\left(3 \times 1.01 \times 10^{5}\,Pa\right)\left(5 \times 10^{-3}\,m^3\right)}{\left(1.38 \times 10^{-23}\right)(300\,K)} = 3.66 \times 10^{23}$$

$$\Rightarrow \overline{K} = \left(3.66 \times 10^{23}\,N_2\right)\left(6.21 \times 10^{-21}\,\frac{J}{N_2}\right) = 2.27\,kJ$$

Of course this energy is distributed amongst the many atoms.