7. From your physics courses, you know that a molecule’s thermal energy is given by \( E = \frac{3}{2} kT \), where \( k \) is the Boltzmann constant and \( T \) is the temperature in Kelvin.

- What is the energy in a mole of gas at 273 K?

\[
R^* = k \text{ Návágadro} = 8.3 \text{ J} \text{ deg}^{-1} \text{ mole}^{-1} \quad E = \frac{3}{2} (8.3)(273) = 3.4 \times 10^3 \text{ J/mole}
\]

- How many moles of gas are in a m\(^3\) of space if \( T = 273 \text{ K} \) and \( p = 1013 \text{ hPa} \)?

\[
\rho_{\text{STP}} = 1.28 \text{ kg m}^{-3}. \text{ Each mole has a mass of 0.029 kg/mole}
\]

\[
\text{moles} = \left( \frac{1.28 \text{ kg m}^{-3}}{0.029 \text{ kg/mole}} \right) = 44.6 \text{ moles m}^{-3}
\]

- What is the thermal energy of a m\(^3\) of air at STP (\( T = 273 \text{ K} \) and \( p = 1013 \text{ hPa} \))?

\[
E = 44.6 \text{ mole}^{-1} \times 3.4 \times 10^3 \frac{\text{J}}{\text{mole}} = 1.5 \times 10^5 \text{ J}
\]

- Assuming an average temperature for the atmosphere of 250 K, what is the thermal energy in the atmosphere?

\[
\text{Atmosphere has } 1.7 \times 10^{20} \text{ moles. } E_{\text{atm}} = \left( 1.7 \times 10^{20} \right) \frac{3}{2} (8.3)(250) = 5.3 \times 10^{23} \text{ J}
\]

- A stiff wind at Earth’s surface is 30 m s\(^{-1}\). What is the energy associated with one m\(^3\) of air that is traveling at this speed?

\[
E = \frac{1}{2} m v^2 = \frac{1}{2} \rho v^2 = \frac{1}{2} (1.28 \text{ kg m}^{-3})(1 \text{ m}^3)(30 \text{ m s}^{-1})^2 = 5800 \text{ J}
\]

- How does this compare to your answer for the amount of thermal energy in 1 m\(^3\) of air?

\[
\text{It is } (1.5 \times 10^5)/5800 = 130 \text{ times less}.
\]

8. Consider a small fair-weather cumulus cloud (like those you see on a nice summer’s day). If the liquid water content (LWC) is 0.3 g m\(^{-3}\), what is the total liquid water mass in the cloud? State your estimate of the cloud’s size.

A good size fair weather cumulus cloud is about equivalent to a 100 m radius sphere.

\[
\text{Total liquid water} = \frac{4}{3} \pi (r^3) \cdot \text{LWC} = \frac{4}{3} \pi (100^3) \cdot 0.3 = 1.7 \times 10^3 \text{ kg}
\]

\[
\approx 1.2 \text{ ton}
\]

9. Satellites often fly a few hundred kilometers above Earth’s surface. Why don’t they burn up during an active sun period?

During an active sun, \( T \sim 2000 \text{ K} \)! But what is the total energy encountered during 1 orbit?

\[
E = \frac{3}{2} (\text{#molecules}) kT = \frac{3}{2} \left( 10^{15} \text{ mole} \right) \left( \frac{1 \text{ mole}}{\text{mole}} \right) (1 \text{ m}^2 \cdot 2\pi (6,800 \times 10^6 \text{ m})^T)
\]

\[
\text{from Fig 1.5 satellite size orbit path}
\]

\[
1.4 \times 10^{-23} \text{ J deg}^{-1} \text{ mole}^{-1} \cdot 2000 \sim 2000 \text{ J}. \text{ An orbit takes about 1 hour, so the watts of heating is } .5 \text{ W from this effect.}
\]