

Part I - Atmospheres

The Pressure (P) in a constant temperature atmosphere varies with altitude (Z) as:

$$P = P_o e^{-Z/H} \quad \text{where} \quad H = \frac{kT}{Mg}$$

P_o is the surface pressure, H is the scale height, M is the molecular weight of the atmospheric gas, k is Boltzmann constant (1.38×10^{-23} J/K), T is the temperature, and g is the local gravity (GM/R^2).

Molecular weights: O = 16u, N = 14u, C = 12u (u = 1.66×10^{-27} kg).

- 1) Assume a pure N₂ atmosphere and a temperature of 300K for Earth. Calculate the pressure at the top on Mt. Rainier (5 km) **relative** to the pressure at sea level (You are calculating P/P_o).
- 2) Calculate the same ratio for the ancient Earth when it had a pure CO₂ atmosphere.
- 3) Calculate the same ratio for Mars. Assume a pure CO₂ atmosphere and T = 250K.

Part II - Internal Heat

- 4) The asteroid Vesta has a radius of 250 km and a density of 2900 kg/m³. What is the mass of Vesta?
- 5) Assume for the moment that Vesta is composed entirely out of silicon atoms. If the mass of one silicon atom is 28u, How many silicon atoms make up Vesta?
- 6) The masses of ²⁶₁₃Al and ²⁶₁₂Mg are 25.986892 u and 25.982594 u respectively. Calculate the energy released in the decay ²⁶₁₃Al → ²⁶₁₂Mg. This is the value of ΔE.
- 7) The ratio of ²⁶₁₃Al to all Al atoms is about 5×10^{-5} . Assume that aluminum constitutes about 8680 ppm (parts per million) of the atoms in Vesta. How many ²⁶₁₃Al atoms are in Vesta? This is the value of N₀

The amount of energy released per second (J/sec) at a time (t) due to decays with in Vesta is:

$$\frac{dE}{dt} = \lambda (\Delta E) N_0 e^{-\lambda t} \quad \lambda = \frac{\ln 2}{\tau_{1/2}}$$

- 8) If the half-life of ²⁶₁₃Al is $\tau_{1/2} = 716,000$ years, how long would it take for the energy production in Vesta to drop to it present rate of about 1×10^{13} J/sec? (Set $dE/dt = 1 \times 10^{13}$ and solve for t).
- 9) How does this time compare to the age of the solar system (4.5 billion years)?

Part III - Destruction

The self gravitational potential energy (in Joules) of a uniform sphere is

$$-\frac{3}{5} \frac{GM^2}{R}$$

This is the amount of energy you need to give the sphere to move all of its components pieces infinitely far away (i.e. to destroy it!).

10) Assume that Vesta is bound together only by gravity. Calculate how big a rock (radius) it would take impacting Vesta at 15 km/s to destroy Vesta. Assume the rock has a density = 2900 kg/m³.

11) Calculate how big a rock impacting at 15 km/s you need to destroy the Earth.

Please show all your work (including units) in as complete, concise, neat, and organized a manner as possible.

Due: Thur May 21 in class (−2% for every hour late)