Solutions

ASTR/ATOC 3720: Homework Assignment #4

Due: Thur. March 20, in class

1. Calculate the escape velocities **and** the most probable speeds of hydrogen atoms at the top (exobase) of Venus and Jupiter's atmospheres. assuming that the mass of a hydrogen atom is 1.67×10^{-27} kg and Newton's Universal Gravitational Constant is $6.67 \times 10^{-11} \frac{m^3}{kg \cdot sec^2}$. Use planetary masses and radii from the tables in the back of NSS. Assume that the height of the exobases for the two planets is 500 km above the radii of the planets given in the tables in NSS, and also assume that the temperature at the exobase of Venus is 300 K and of Jupiter is 1000 K.

2. The Moon most likely formed after the Earth as the result of a huge collision; therefore, the Moon started with almost no volatiles in it's bulk composition. and has no appreciable magnetic field. What do you think the dominant source processes for atmospheric gases on the Moon currently are? Given this, what do you think the atmosphere of the Moon would consist of primarily?

3. Why does the atmosphere of Venus have such a smaller fraction of N_2 in it than the atmosphere of Earth (3.5% for Venus, 78% for Earth, by number).

4. Using the saturation vapor pressure vs. temperature diagram for H_2O as shown in class to demonstrate your answer, explain why oceans of liquid water on Mars are or were unlikely.

HW #4 Solutions

① $v_{esc} = \sqrt{\frac{2GM}{r}}$, $v_{max} = \sqrt{\frac{2kT}{m}}$

10 pts

Given: $m_H = 1.67 \times 10^{-27}$ kg = mass of H atom
$G = 6.67 \times 10^{-11} \frac{m^3}{kg\,sec^2}$ = Gravitational Constant
$T_{Venus} = 300K$, $T_{Jupiter} = 1000K$ Temps @ exobase

Look up: $k = 1.38 \times 10^{-23}$ J/K = Boltzmann's Constant
$M_{Venus} = 4.865 \times 10^{27}$ g $= 4.865 \times 10^{24}$ kg
$M_{Jupiter} = 1.898 \times 10^{30}$ g $= 1.898 \times 10^{27}$ kg } Note NSS #s are in grams
$R_{Venus} = 6052$ km $= 6.052 \times 10^{6}$ m
$R_{Jupiter} = 71,492$ km $= 7.1492 \times 10^{7}$ m } Note NSS #s are in km

Note $r = R + Z = R + 500\text{ km} = R + 5 \times 10^5$ m

For Venus (♀):

$$v_{esc_♀} = \sqrt{\frac{2GM_♀}{r_♀}} = \sqrt{\frac{2(6.67\times10^{-11}\frac{m^3}{kg\,sec^2})(4.865\times10^{24}kg)}{(6.052\times10^{6}m + 5\times10^{5}m)}} = 9.95\times10^{3}\,m/sec$$

$$\boxed{v_{esc_♀} = 9.95\text{ km/sec}}$$

$$v_{max_♀} = \sqrt{\frac{2kT_♀}{m_H}} = \sqrt{\frac{2(1.38\times10^{-23}J/K)(300K)}{1.67\times10^{-27}kg}} = 2.23\times10^{3}\,m/sec$$

$$\boxed{v_{max_♀} = 2.23\text{ km/sec}}$$

For Jupiter (♃):

$$v_{esc_♃} = \sqrt{\frac{2(6.67\times10^{-11}\frac{m^3}{kg\,sec^2})(1.898\times10^{27}kg)}{(7.1492\times10^{7}m + 5\times10^{5}m)}} = 5.93\times10^{4}\,m/sec$$

$$\boxed{v_{esc_♃} = 59.3\text{ km/sec}}$$

$$v_{max} = \sqrt{\frac{2(1.38\times10^{-23}J/K)(1000K)}{1.67\times10^{-27}kg}} = 4.06\times10^{3}\,m/sec$$

$$\boxed{v_{max} = 4.06\text{ km/sec}}$$

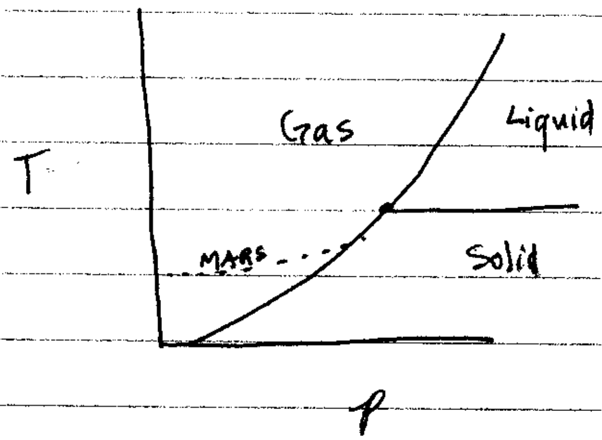
(2) Since the currently popular theory of the Moon's origin has it forming with little volatile abundance the best guess for sources of atmospheric gases are (1) sputtering or micrometeoritic impacts knocking up surface material and (2) later arival of volatiles by ice-rich planetesimals/comets. For case (1) you'd expect to see things like sodium and silicon in the Moon's tenuous atmosphere, and these are observed. For case (2) you'd expect to see things like H_2O, CH_4, NH_3 and so on, but with so little atmosphere these would be broken apart by solar UV light, so you'd expect to see H atoms or H_2 molecules, which you do see. Oddly enough, though, the main constituents of the Moon's thin atmosphere are ^4He, ^{20}Ne, H_2, ^{40}Ar with much smaller amounts of other stuff. This indicates outgassing from the interior is still a major source of atmosphere on the Moon.

10 pts

③ This was, perhaps, a too simple question. Even if Venus & Earth have close to the same amount of N_2 by total number of molecules, because the total atmosphere of Venus is ~90 times thicker than Earth's, the fraction of N_2 would be much smaller ($\frac{1}{90}$th). The fact that Venus actually has more N_2 molecules in it's atmosphere than Earth is probably an indication that on Earth some N_2 has been removed, most likely by life/water processes, or that, because we didn't have a runaway greenhouse heating the surface, Earth didn't outgas as much over time, but that wasn't actually the point of my simple question.

10 pts

(4) 10/10



There are not enough greenhouse gases on Mars to raise the temperature and pressure to allow liquid water to exist. Any water released into the atmosphere would either stay as a gas or freeze as a solid. Most of the current H_2O on Mars is in the form of ice.