Name: ______________________________

Homework 4 – Ast 281 – Spring 2009 – [70 pts]
Due Thursday 02/12/09 – 12:00pm, Watanabe 420

1. For each of the situations in the table below, list which dating technique would be appropriate: crater counts, radiogenic dating, cosmic ray exposure age. [15]

____________	[**a**] Looking at spacecraft photos of Mars, you notice that the Tharsis region has very few craters, but that the Argyre region is heavily cratered. You want to determine how much older the Argyre region is than the Tharsis region.
____________	[**b**] You are interested in studying the orbits of an asteroid family which has a group of very small asteroids on very similar orbits. The "family members" are probably remnants of a much larger asteroid that was broken apart in a catastrophic collision. For your orbital study, you wish to know when this collision occurred.
____________	[**c**] You wish to know when the earth solidified.
____________	[**d**] You want to know the age of the surface of Mercury – recent volcanism.
____________	[**e**] You want to know the age of a meteorite you just found.

2. The scale height (H), or the height at which the atmosphere decreases by about 1/3, for the atmospheres of Venus, Earth, Mars and Saturn's satellite Titan are shown in the table below.

Planet	H [km]	Dist to $\odot$ [AU]	Diam [km]	Atmospheric Composition molecular [%]
Venus	15	0.723	12,104	CO_2 [96%], N_2 [3.5%]
Earth	6	1.000	12,756	N_2 [78%], O_2 [20%], Ar [0.9%]
Mars	18	1.524	6,787	CO_2 [95%], N_2 [2.7%], Ar [1.6%]
Titan	140	9.539	1,222	CH_4

Recall that the atomic number of an element is the number of electrons which are in orbit around the nucleus. It is this number which largely gives rise to the chemical properties of the atom. Typically the nucleus consists of protons (positively charged) and neutrons (neutral). Electrons have very little mass compared to the protons and neutrons. Different isotopes of a species are elements with different numbers of neutrons in the nucleus, but the same number of protons. Therefore isotopes will have different atomic masses. The isotope of a species is written as a superscript. Often this is omitted if the number of neutrons = the number of protons. The atomic masses are all written in terms of the mass of the proton or hydrogen nucleus ($m_H = 1.6725 \times 10^{-27}$ kg; $m_e = 9.1091 \times 10^{-31}$ kg). For example, the primary isotope of carbon (^{12}C) is 12 times heavier than H, so its atomic mass, $\mu = 12$. In the equation for the scale height, this atomic mass is written as μm_H, where μ is the atomic mass.

(a) Write the equation for the scale height, identifying all the terms. [8]

Atom	Atomic #	Atomic mass	Protons	Neutrons	Electrons	Comment
H	1	1	1	–	1	
3He	2	3	2	1	2	Nuclear fuel
4He	2	4	2	2	2	
C	6	12	6	6	6	
14C	6	14	6	8	6	Radioactive
N	7	14	7	7	7	
O	8	16	8	8	8	
Ne	10	20	10	10	10	
Ar	18	40	18	22	18	
Xe	54	131	54	77	54	

(b) Calculate the average molecular weight for each atmosphere by adding up all the molecular components according to the fraction of the atmosphere they account for. You may assume that Titan's atmosphere (Titan is a moon of Saturn) is all methane (CH_4) for this calculation. You do not need to calculate the average value of the molecular weight in terms of kg, just compute the average value of μ. For example, if an atmosphere was 50% hydrogen and 50% ^{3}He, then the value μ_{avg} = 0.5 × (1) + 0.5 × (3) = 0.5 + 1.5 = 2. [12]

(c) The true mean molecular weight of Titan's atmosphere is about 28. What does this tell you about other molecules in the atmosphere? Where might these other molecules be located? Do you think that the scale height of an atmosphere is constant as a function of altitude based on this? [5]

(d) Why is the scale height of the atmosphere of Titan so large? [5]

(e) Recall that temperature is a measure of how fast a molecule or atom is moving. If anything exceeds the escape velocity for a planet or a satellite, then it will leave the body. Nobel gases are atoms which are chemically inert, and don't combine with other species. Examples include He, Ar, Ne, Xe etc.

i. Where in the atmosphere of the terrestrial planets and outer planet satellites is the atmosphere the hottest? Why is this? [5]

ii. How should the mean molecular weight of an atmosphere vary with time (*i.e.* how should it evolve over the age of the solar system)? [5]

iii. Why do you think noble gases are good tracers of what the primordial atmospheres of planets were like? [5]

3. Below is a chemical description of silicate weathering.

- CO_2 in the atmosphere dissolves in rain water to form carbonic acid:

$$CO_2 + H_2O \longrightarrow H_2CO_3 \tag{1}$$

- This dissolves silicate minerals which are exposed in rocks:

$$CaSiO_3 + 2H_2CO_3 \longrightarrow Ca^{++} + 2HCO_3^- + SiO_2 + H_2O \tag{2}$$

- The dissolved silica (SiO_2), calcium and bicarbonate ($HCO_3{}^-$) are transported by rivers to the ocean, where the bicarbonate eventually precipitates out as calcium carbonate (nowadays this is partly an inorganic process, and partly accomplished through biology):

$$Ca^{++} + 2HCO_3^- \longrightarrow CaCO_3 + CO_2 + H_2O \tag{3}$$

Discuss the net effect of this process on the Earth's atmosphere in terms of the CO_2 budget, and what this might imply for climate in the long-term. Does CO_2 increase or decrease? What other geological processes that we have discussed in class could alter the balance of CO_2? [10]