#1

$H = \frac{kT}{mg} = \frac{kT}{\mu m_A g}$ where $\mu \simeq 12 + 2 \cdot 16 = 44$ amu

m_A = mass of 1 AMU

$$= \frac{1.381 \times 10^{-23}\ J/K \cdot 700\ K}{44\ amu * 1.66 \times 10^{-27}\ kg/amu * 0.88 * 9.8\ m/s^2}$$

↑ from pg 200, Table 7.1 in Christiansen + Hamblin

$$= 15.3 \times 10^3\ m = 15.3\ km.$$

note the units cancel to give m $\frac{J/K * K}{amu * kg/amu * m/s^2}$

$$= \frac{joules}{kg\ m/s^2} = \frac{kg\ m^2/s^2}{kg\ m/s^2} = m$$

$$\Gamma_{adiabatic} = \frac{T}{H}\frac{\gamma-1}{\gamma} = \frac{mg}{k}\frac{\gamma-1}{\gamma} = \frac{700K}{15.3\ km}\frac{\frac{4}{3}-1}{\frac{4}{3}}$$

$$= 45.8\ K/km * \frac{\frac{1}{3}}{\frac{4}{3}} = 45.8\ K/km * \frac{1}{4} = 11.4\ K/km$$

#2

From the Seiff 1983 figure in the lecture $T \simeq 740$ K at the surface and $\simeq 260$ K at 60 km $\Rightarrow \Gamma = \frac{740-260}{60}\frac{K}{km} = 8$ K/km

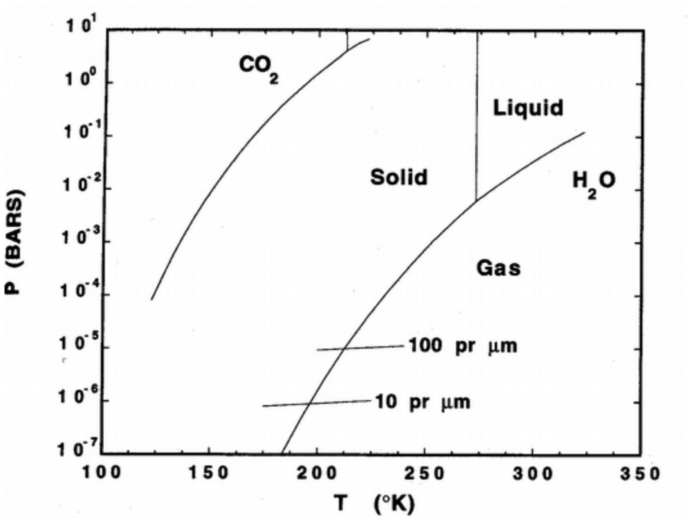
So the observed Γ is a little less than $\Gamma_{adiabatic}$

In reality we should use a slightly more complicated form for $\Gamma_{ad.}$ because at these pressures ($\simeq 90$ atmospheres) the CO_2 does not behave as an ideal gas. If we used the full form for $\Gamma_{ad.}$ we would find Γ only slightly less than $\Gamma_{ad.}$

Planetary Geology 4460 (SOLUTION)
Homework #7 Question 3
Due Friday Nov. 3, 2017

For those problems which require calculations, show your work and be careful to use correct "units". You man need to convert some units to compatible values.

#3) Interpreting the H_2O phase diagram for atmospheres (10 points)



Part A. (5 points) The vertical reference level used for elevations on Mars (i.e. the Mars replacement for Earth "sea level") is somewhat arbitrarily chosen to be the average elevation where the pressure is equal to 6.1 millibars. That pressure level was chosen because it corresponds to a special point in the above diagram. Some parts of Mars are above this elevation and some parts of Mars are below this elevation.

Suppose you have an equatorial location where the temperature reaches 280 K at noon, and suppose you expose some H_2O ice on the surface there. Explain what happens to the ice as it heats up if the location is higher than the reference level, then explain what happens to the ice if the location is lower than the reference level.

ANSWER:
In the above diagram (280K, 6.1 mb) is the H_2O triple point, where solid, liquid, and gas phases can coexist. If you are located above this elevation (so at lower pressure) when you heat up ice it sublimates directly to form vapor. At this pressure you cannot form liquid water because the water would immediately boil to vapor.

If you are located below this elevation (so at higher pressure) and you heat the ice it can melt to form water. Note that as long as the water vapor pressure is less than the saturation pressure given by the curve (6.1 mb at the triple point) then the water will evaporate. However because the confining (mostly CO_2) pressure is large enough this evaporation only happens from the water's surface. It won't immediately boil. That is, H_2O vapor bubbles won't be able to form throughout the liquid.

Part B. (5 points) The phase diagram can also be used to understand the formation of clouds. The almost horizontal lines labeled 100 pr μm and 10 pr μm (i.e. percipitable microns) represent the surface partial pressure of H_2O when the atmosphere contains an amount of water which if condensed would form a layer 100 or 10 microns deep on the surface.

If the atmosphere contained 50 pr μm of H_2O, how cold would it have to get at night before the water condensed as a fog of ice particles (or perhaps as a surface frost)? When interpolating between 10 and 100 pr μm on the plot, remember that the vertical axis is the log of pressure.

ANSWER:

Drawing a line parallel to the 100 pr μm and 10 pr μm ones, interpolated vertically between them to the 50 pr μm level (on a log scale) gives a line just slightly below the 100 pr μm one. It crosses the solid-gas phase boundary at 205K. That is the temperature to which you must cool the atmosphere for ice fog to form.

Note that in the real world if the atmosphere doesn't contain enough condensation nuclei you may need to cool it considerably below the saturation point to get ice crystals to actually form.