PROBLEM SET 3

Due 2:40pm Wednesday 30 July

Astro/EPS C12 -- Mike Wong

Write your name at the top of your problem set solutions. Feel free to collaborate with other students to figure things out, but turn in your own unique, legible, handwritten solutions (DO NOT COPY). Show all your work, keep careful track of units, and box in your final answers.

1. **Comet baseball.** 8 points.

Imagine you are an astronaut on a comet. Answer the following questions.

A. The comet has an average radius of 60 km, and you perform studies to discover that this comet is made entirely of water ice. What is the mass of the comet? For convenience, assume the comet is spherical.

B. You pitch a baseball straight up from the comet's surface. The ball contains a tiny radio transmitter. A receiver on your spacecraft detects this signal and determines that the ball is moving away at a speed of 30 m s^{-1}. Draw a diagram to explain whether the receiver detects a radio signal that is shifted toward longer wavelengths (redshifted) or shorter wavelengths (blueshifted).

C. Will you ever see your baseball again? Or will it fly off into space, never to return?

2. **Pressure and vapor pressure.** 12 points.

Examine the variation of pressure and H_2O boiling point at high altitudes. You will need to refer to the H_2O saturation vapor pressure curve in the figure on the next page.

A. First, use the periodic table to determine the molecular weights of N_2 and H_2O. For example, molecular oxygen (O_2) has a molecular weight of $\mu_{O_2} = \mu_O + \mu_O = 16 + 16 = 32$. Molecular weight is a plain number, so there are no units this time.

   Assume that the Earth's atmosphere is composed of 78% N_2, 21% O_2, and 1% H_2O. Now determine the average molecular weight of air.

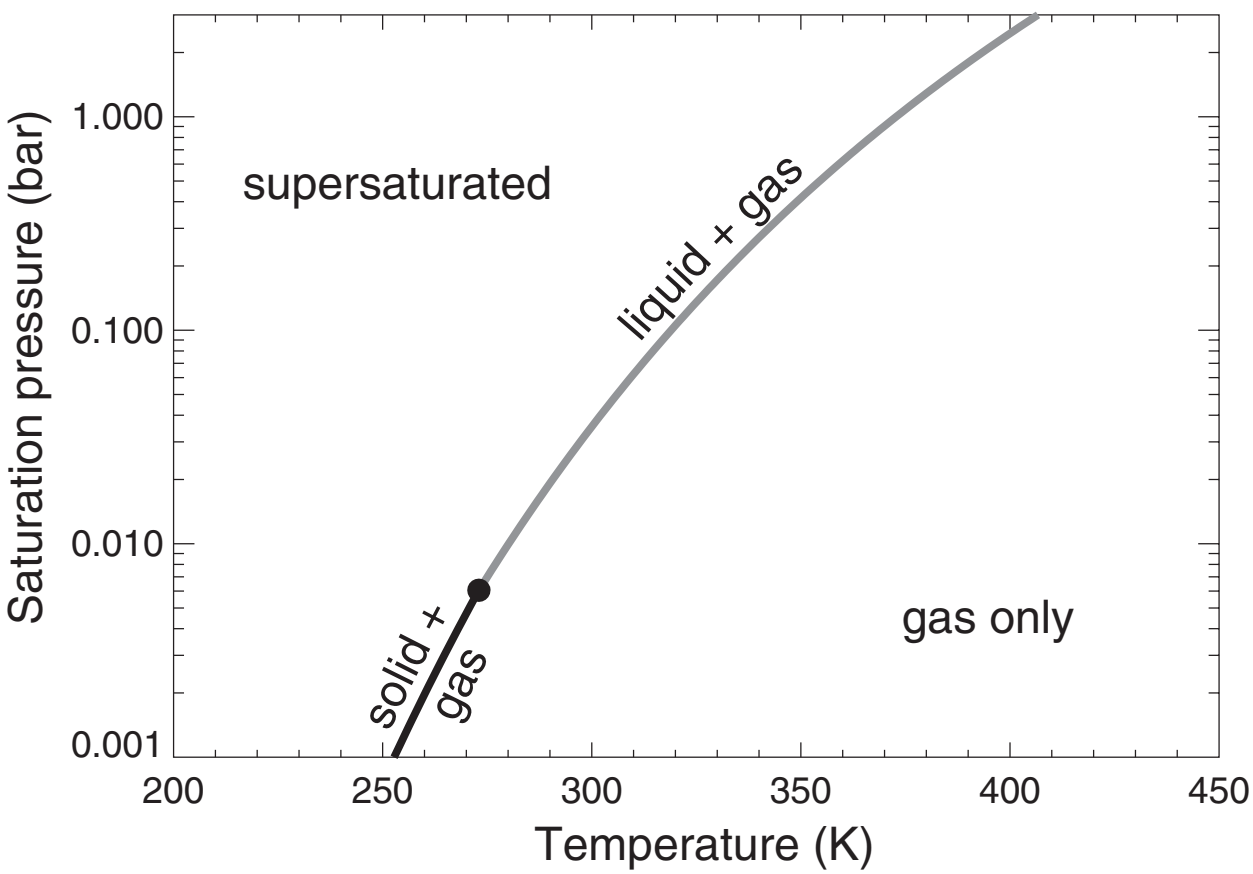
B. Altitudes of 8 km can be reached in the Himalayan mountains. Calculate the pressure at 8 km. To get the scale height, assume an average temperature of 250 K.

   Passenger aircraft typically fly at 11 km. What is the pressure at this altitude? Assume an average temperature of 250 K again.

   Michel Fournier recently tried to break world records by riding a helium balloon up to 40 km and jumping out of the balloon. What is the pressure at 40 km? Use an average temperature of 240 K to calculate the scale height.

C. At a given pressure, the boiling temperature of water is the temperature where the saturation vapor pressure is equal to the atmospheric pressure. For instance, consider standard atmospheric pressure at a pressure of 1 bar. The saturation vapor pressure of water is equal to 1 bar at 373 K (see figure below), so you would say that at standard atmospheric pressure, water boils at 373 K.

Use your answers to part B to find the boiling temperature high in the Himalayas.

What is the boiling temperature of water at the cruising altitude of passenger aircraft?

D. If Michel Fournier had reached 40 km, he would have found that only two phases of H_2O could exist at that pressure, no matter what the temperature was. Which two phases could exist? Explain how you can tell.