PHYS 171: Planetary & Stellar Astronomy
Due: Friday, October 11, 2019

Problem Set #6

1. Frost line

Explain what the frost line represents and the role it played in the formation of the Solar System. Your explanation should reference specific molecular compounds and elements. Furthermore, your answer should include a diagram and also give an approximate value for the location of the frost line (or a bracket of values).

Note: The frost line is often called the snow line or ice line.

2. Density of the Sun

The radius and mass of our Sun are $M_{Sun} = 1.99 \times 10^{30}$ kg and $R_{Sun} = 6.96 \times 10^{5}$ km, respectively.

a) Calculate the density of the Sun in kg/km^3.

b) Convert your answer in a) into g/cm^3.

c) At room temperature and pressure, hydrogen gas has a density of 0.09 g/L (L=Liter). A liter has the same volume as a cube that is 10 cm on the side. What is the density of hydrogen in g/cm^3 at room temperature condition?

c) The Sun is mostly made of hydrogen gas in plasma form, i.e. electrons are stripped from nucleus. Is this density comparable to hydrogen gas we find on Earth?

3. Guessing the composition of Iapetus

Iapetus is the third largest moon of Saturn and has a mass and diameter of $M_{Iapetus} = 1.81 \times 10^{21}$ kg and $D_{Iapetus} = 1.47 \times 10^{3}$ km, respectively.

a) Calculate the density of Iapetus in g/cm^3.

b) Assuming that Iapetus is not a differentiated body and has a roughly uniform density, make an informed guess about its composition.

4. Radioactivity of a potassium salt substitute

Potassium-40 (^{40}K) is radioactive and has a half-life of $t_{1/2}=1.25 \times 10^{9}$ years. A ^{40}K atom decays into two possible elements: 10.72% of decays yield argon-40 (^{40}Ar), and 89.28% of decays yield calcium-40 (^{40}Ca). Both of these daughter isotopes are stable and have essentially the same atomic mass as their parent.

a) Suppose you have a 10 g sample of pure ^{40}K. How long will it take for the sample to decay to just 2.5 g of ^{40}K.

b) How much ^{40}Ca and ^{40}Ar will be in the resulting sample?

c) How long will it take for the sample to contain only 1 g of ^{40}K?