Homework #1

Solar System Abundances

Assigned: Feburary 03, 2021   Due: February 10, 2021

Percentages for each problem of the total grade (100%) as given. Sub-problems, if present, split the problem's percentage equally. Please show your work!

Problem 1 Element abundances in water (20%)

Water on Earth consists of two hydrogen and one oxygen atom. Its chemical formula is H_2O. Hydrogen and oxygen on Earth consist of the following isotopes:

Isotope	Relative Abundance (%)	Mass (u)
^1H	99.9885	1.008
^2H	0.0115	2.014
^{16}O	99.757	15.995
^{17}O	0.038	16.999
^{18}O	0.205	17.999

a. Using the values in the table above, calculate the concentration of hydrogen in water by mass and stoichiometrically.

b. Heavy water, i.e., water in which both hydrogen atoms are ^2H or deuterium, is commonly used as a coolant and neutron moderator in pressured heavy-water reactors.[1] These nuclear reactors have the advantage that they can use naturally occurring uranium as fuel. The chemical formula of heavy water is ^2H_2O, often written as D_2O. Calculate (1) the concentration of deuterium in heavy water and (2) the mass difference between heavy water and water.

· · · · · · · · ·

---

[1] https://en.wikipedia.org/wiki/Heavy_water_reactor

Problem 2 Abundance scale conversion (20%)

a. The Solar System initial abundance of hydrogen (linear, atom numbers) is given as 2.59×10^{10}. Calculate the abundance of silicon in logarithmic / spectroscopic abundance units.

b. Now let's assume you have been giving the spectroscopic abundance for oxygen as 8.8. Calculate how many oxygen atoms there are when assuming 10^6 silicon atoms. Use the same hydrogen abundance as in part a.

. . . .

Problem 3 Metallicity of a star (20%)

To express the metallicity of a star, astronomers often use the [Fe/H] value as a proxy for the total metallicity. The metallicity (Z) of an object is frequently compared to the solar metallicity. The solar metallicity is commonly abbreviated as $Z_{\odot}$, where $\odot$ stands for the Sun (and is in fact used for many other variables too, e.g., a solar mass: $M_{\odot}$). The solar abundance of iron (normalized to Si $= 10^6$) is 8.48×10^5. For the following exercises use the hydrogen abundance given in problem 2.

You have observed a star with a 0.3 dex enhancement in its [Fe/H] ratio. Express this enhancement in terms of solar metallicity $Z_{\odot}$.

. . . .

Problem 4 Uncertainty propagation (20%)

Using the same scenario as in problem 3, let us assume that the determination of [Fe/H] is associated with a $1\,\sigma$ uncertainty of 0.05 dex. Calculate the number abundance of iron in this star assuming that is has a solar H/Si elemental ratio and express the number abundance and its uncertainty with respect to silicon normalized to 10^6. *Hint: A symmetric error in a logarithmic unit will not be symmetric in a linear unit and vice verse.*

. . . .

Problem 5 Deuterium burning (20%)

The present-day Sun contains essentially no deuterium. All of it was burned at the beginning of the Solar System, i.e., when the Sun was a protostar. Research deuterium burning, explain the nuclear reaction that takes place, and its circumstances. Can you speculate why deuterium burning is the first burning stage of the Sun that sets in while it is still a protostar? *(Speculations will not subtract points. A physically sound speculation (not necessarily correct) will earn you a 5% bonus. The maximum achievable grade remains 100%.)*

. . . .