Problem Set 1

1. (***This is the super-problem***.) Given that the r-process nucleosynthetic production ratio for $^{235}U/^{238}U$ is roughly 1.35 ± 0.3, use the present-day terrestrial isotope ratio to estimate the "age of the elements" assuming a one-time production event for these isotopes. If the comparable production ratio for $^{232}Th/^{238}U$ were 1.65 ± 0.2 and the present-day terrestrial Th/U ratio is 4, what "age" do you get from these isotopes? How do the two "ages" compare and what are the relative merits/challenges of each approach? Using a "constant nucleosynthetic production" scenario, can you achieve concordant ages and what does this suggest about the timing of the events. You may solve this analytically or numerically (bonus points for doing both). Compare, qualitatively, how an exponentially decreasing production ratio would affect the "age of the elements".

2. A so-called "H-bomb" or thermonuclear weapon actually uses a lithium deuteride fuel and a fission bomb trigger. The latter provides a source of heat, compression, and neutrons to initiate a fusion reaction that proceeds as follows:

$$^{6}_{3}\mathrm{Li}+\mathrm{n} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{3}_{1}\mathrm{H}$$

$$^{7}_{3}\mathrm{Li}+\mathrm{n} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{3}_{1}\mathrm{H} + \mathrm{n}$$

$$^{3}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{5}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + \mathrm{n}$$

   The last two of which produce neutrons that sustains a chain reaction (starts the first one). Calculate the energy yield from this reaction. Given that a 1 Mt warhead corresponds to 4.18×10^{15} joules, how much lithium deuteride (in Kg) would you need in the bomb (assuming 100% of the Li^2H is "burned", and that the Li is normal terrestrial isotopic abundance) and what fraction of the original mass would be converted to energy? *Warning: do not attempt this experiment at home.*

3. The integrated neutrino flux from SN1987A was 5×10^{10} cm^{-2}. Assuming that approximately 10% of the neutrinos were produced by electron capture ($\mathrm{p} + \mathrm{e}^- \rightarrow \mathrm{n}$) in the collapsing core (with the remainder produced during core cooling), use this fact combined with the geometric strategy mentioned in class to estimate the size of the collapsing core, and decide whether a neutron star or a black hole was created (*i.e.,* whether the mass of the collapsing core exceeds 1.4 or is less than 3 solar masses).

4.

	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
Nuevo Laredo	50.28	34.86	67.97
Forest City	19.27	15.95	39.05
Modoc	19.48	15.76	38.21
Henbury	9.55	10.38	29.54
Canyon Diablo	9.46	10.34	29.44

   Determine the atomic abundances of the Pb isotopes in the Nuevo Laredo and Canyon Diablo meteorites, the atomic weights of both, and the $^{207}Pb/^{206}Pb$ age of these five meteorites.

5. If the freshwater flux to the oceans ceased tomorrow, when would the present-day ($^{234}U/^{238}U$) of seawater of 1.14 be in secular equilibrium. What is the ($^{234}U/^{238}U$) of the freshwater flux that is need to keep the ocean's ($^{234}U/^{238}U$) at 1.14? (Assume that the residence time of seawater with respect to the freshwater flux [not U!] into the ocean is 30,000 years, that the ratio of seawater U concentration to freshwater U concentration is 12, that sea- and fresh-waters today are at steady state with respect to U concentrations and U activity ratios, and that freshwater input is the only source of U to seawater. Simplify this problem as much as possible, but justify your assumptions.

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