

Solution 4:

- 1). There are mainly two reactions by which the Sun produces energy: Hydrogen fusion (direct proton-proton fusion) and the CNO cycle. The former is the dominant reaction.
- 2). Fraunhofer lines indicate absorption by elements such as Fe, Mg, and Ca. Since these elements are produced by supernovae, any star with Fraunhofer lines must be a second generation star
- 3). The Sun is supposed to have about 10 billion years lifetime.
 - a) At present, the Sun is around 5 billion years old, and both the H fusion and CNO cycle process take place in the Sun.
 - b) After another 5 billion years, the H in the core will be converted to He. The core will cool as H-burning slows and be heated again by contraction. The Sun will move from the main sequence to become a red giant. When temperatures reach 10^8 K, He-burning will happen, typically through triple alpha process:
$${}^4\text{He} + {}^4\text{He} \rightarrow {}^8\text{Be}$$
$${}^8\text{Be} + {}^4\text{He} \rightarrow {}^{12}\text{C}$$
As ${}^{12}\text{C}$ builds up in the core of the Sun, the following reaction will take place:
$${}^{12}\text{C} + {}^4\text{He} \rightarrow {}^{16}\text{O}$$
 - c) The Sun will burn He for about 0.1 billion years (1% of the time that it will spend on the main sequence). When He is largely used up, our sun will contract, heat rapidly, throw off its outer layers, and become a white dwarf.

(Please note: C-burning, Ne-, O-, Si-, and further burning will only happen for more massive stars.)

4).

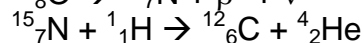
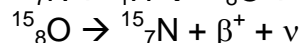
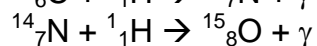
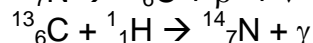
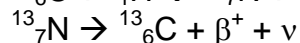
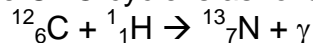
$$c = f\lambda$$

$$3.0 \times 10^8 \text{ m/s} = f(440 \times 10^{-9} \text{ m})$$

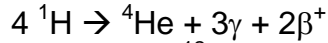
$$f = 6.8 \times 10^{14} \text{ s}^{-1} = 680 \times 10^{12} \text{ Hz} = 680 \text{ THz}$$

5). A catalyst is a substance that facilitates a reaction without eventually being consumed.

The CNO cycle is as followed:



So, the end result is four protons (${}^1_1\text{H}$) are fused to form one nucleus of ${}^4_2\text{He}$:



The nucleus of $^{12}_6\text{C}$ acts as a catalyst and is released at the end. It can then be reused for another revolution of the CNO cycle.

- 6). Lithium, boron, and beryllium have a low abundance because their isotopes either do not form in the normal chain of thermonuclear reactions (because of their short half lives and nuclear instability) or those that do form are used up as part of the hydrogen-burning process. It is now thought that stable forms of these three elements formed later than those of most other elements by spallation (fragmentation) of still heavier elements as a result of cosmic ray effects.
- 7). No, the CNO cycle could not operate in a sufficiently massive first generation star. ^{12}C and other heavier elements could form at the very end of its life. However, at that time, the star left the Main sequence and no further hydrogen-burning stage existed.
- 8). $m/q = B^2 r^2 / (2V)$
So, both increasing the accelerating potential and decreasing the magnetic field will decrease the measured mass.
- 9). You are given the accelerating voltage, the magnetic field strength, and the masses of interest. The charge will be +1, or +q. From these values, you can calculate the radius of curvature for the different masses. The isotope with the smaller radius will curve more, and therefore takes the inside path.

$$\frac{m}{q} = \frac{B^2 r^2}{2V}$$

$$r = \sqrt{\frac{2Vm}{qB^2}}$$

$$1T = 1 \frac{Vs}{m^2}$$

$$1C = 1 \frac{m^2 kg}{Vs^2}$$

For ^{85}Sr , $V = 10000V$, $B = 8000G = 0.8T$, $q = 1.6 * 10^{-19}C$

$$r = \sqrt{\frac{2(10000V)85 \frac{g}{mol}}{1.6 \times 10^{-19} C (0.8T)^2}} = \sqrt{\frac{(20000V)85 \frac{g}{mol} \frac{1mol}{6.022 \times 10^{23} atoms} \frac{1kg}{1000g}}{1.6 \times 10^{-19} \frac{m^2 kg}{Vs^2} \left(0.8 \frac{Vs}{m^2}\right)^2}}$$

$$r = \sqrt{\frac{2.82298 \times 10^{-21} Vkg}{1.024 \times 10^{-19} \frac{Vkg}{m^2}}} = \sqrt{0.027568m^2} = 0.166m = 16.6cm$$

And for ^{87}Sr :

$$r = \sqrt{\frac{2(10000V)87 \frac{\text{g}}{\text{mol}}}{1.6 \times 10^{-19} C(0.8T)^2}} = \sqrt{\frac{(20000V)87 \frac{\text{g}}{\text{mol}} \frac{1\text{mol}}{6.022 \times 10^{23} \text{atoms}} \frac{1\text{kg}}{1000\text{g}}}{1.6 \times 10^{-19} \frac{\text{m}^2 \text{kg}}{\text{Vs}^2} \left(0.8 \frac{\text{Vs}}{\text{m}^2}\right)^2}}$$

$$r = \sqrt{\frac{2.8894 \times 10^{-21} \text{Vkg}}{1.024 \times 10^{-19} \frac{\text{Vkg}}{\text{m}^2}}} = \sqrt{0.028217 \text{m}^2} = 0.168 \text{m} = 16.8 \text{cm}$$

Therefore, the lighter isotope falls on the inside of the path.