April 11, 2008 **Quiz 7 - PHY244 (Modern Physics)**

Print (Hugely) Last Name: Solution

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Giving or receiving aid is cause for dismissal from the university.

$m_e c^2 = 511000$ eV , $c = 3 \times 10^8$ m/s , $hc = 1240$ nm·eV , 1 u = 931.5 MeV/c^2.

$$dN/dt = -rN \ , \ N(t) = N_0 e^{-rt} \ , \ \tau = 1/r \ , \ t_{\frac{1}{2}} = \tau \ln 2 \ ; \quad {}^{A}_{Z}X_N : A = N + Z$$

The tiny fraction f of ${}^{14}_{6}$C to all C in the atmosphere has remained roughly constant over many thousands of years, in spite of the fact that ${}^{14}_{6}$C decays with a half-life $t_{\frac{1}{2}} = 5730$ yr. This is because ${}^{14}_{6}$C is produced continually in collisions between cosmic rays and nitrogen nuclei in the atmosphere.

Determine the maximum kinetic energy of the β^- ray from the ${}^{14}_{6}$C decay. We know the *atomic* masses:

$m({}^{14}_{6}\text{C}) = 14.003242$ u,
$m({}^{13}_{6}\text{C}) = 13.003355$ u,
$m({}^{14}_{8}\text{O}) = 14.008595$ u,
$m({}^{14}_{7}\text{N}) = 14.003074$ u.

${}^{14}_{6}C \longrightarrow {}^{14}_{7}N + e^- + \bar{\nu}_e$

$m({}^{14}_{6}C) - m({}^{14}_{7}N) = 14.003242u - 14.003074u$

$= 0.000168u = 0.1565$ MeV/c^2

$(K.E.)_{Max} = 0.1565$ MeV

Given that each gram of carbon from a living tree has a ^{14}C activity of 15 disintegration/min, determine the tiny fraction f.

$$15/\text{min} = f \frac{1\text{ gm}}{12\text{ gm/mole}} \times (6.023\times10^{23}/\text{mole}) \times \frac{\ln 2}{5730\times365\times24\times60\text{ min}}$$

$= 11.5 \times 10^{12} f$ /min.

$f = 1.3 \times 10^{-12}$

A 5 gram charcoal sample from an ancient fire pit has a ^{14}C activity of 30 disintegration/min. How old is the charcoal sample?

1 gm of charcoal sample gives 6 disint/min

$$\frac{6}{15} = \left(\frac{1}{2}\right)^{t/t_{\frac{1}{2}}} \qquad \frac{t}{t_{\frac{1}{2}}} = \frac{\ln 6/15}{\ln(0.5)} = 1.32$$

$t = 7575$ years