INTRODUCTION TO NUCLEAR AND PARTICLE PHYSICS
Homework Set 8
April 6, 2016

1. The present ^{14}C content of organic matter gives it an activity of 15 decays per minute per gram of carbon. Determine the ratio of the number of ^{12}C atoms to the number of ^{14}C atoms that gives rise to this specific activity.

2. The mean lifetime of an unstable particle with speed $v = \beta c$ is $\tau = \gamma\tau_0$, where $\gamma = 1/\sqrt{1 - \beta^2}$ and τ_0 is the mean lifetime that is measured when the particle is at rest. If the particle has mass m and momentum p, then relativistically, $p = mv\gamma$ and the kinetic energy of the particle (in units where $c = 1$) is given by $K = \sqrt{p^2 + m^2} - m$. Given that $K = 100$ MeV, find the mean distance d traveled by each of the following three unstable particles before decay occurs:

   (a) neutron ($m = 939.6$ MeV, $\tau_0 = 8.9 \times 10^2$ s),

   (b) charged pion ($m = 139.6$ MeV, $\tau_0 = 2.6 \times 10^{-8}$ s),

   (c) muon ($m = 105.7$ MeV, $\tau_0 = 2.2 \times 10^{-6}$ s).

3. A sample of a certain element with two naturally occurring isotopes becomes activated by neutron capture. After 1 h in the reactor, it is placed in a counting room, in which the total number of decays in 1 h is recorded at daily intervals. Here is a summary of the recorded data:

Time (d)	No. Decays	Time (d)	No. Decays
0	102,515	20	2372
1	79,205	40	1421
2	61,903	60	1135
3	48,213	80	862
4	37,431	100	725
5	29,367	120	551
6	23,511	140	462
7	18,495	160	359
8	14,829	180	265
9	11,853	200	225
10	9,595		

From these data, determine the half-lives and initial activities of the two components. What is the element? (*Hint:* Use the handout, Appendix C, for Homework Set 2.)