BASICS AND PARTICLE DECAY

The aims of this problem sheet are to give you practice of:

- Using conservation laws to analyse the results from typical experiments
- Applying the decay laws to problems in particle physics and nuclear physics.
- Using some of the units and dimensions encountered in nuclear and particle physics.

make list ie / Lp per particle

1.. The following weak reactions or decays involve one or more neutrinos. Supply the missing neutrinos.

how am I supposed to know this?

(a) $\pi^- \rightarrow \mu^- + ?$

(b) $\mu^- \rightarrow e^- + ? + ?$

2.. Classify the following experimentally observed processes as strong or weak interactions, giving your reasons.

(a) $\Lambda^0 + p \rightarrow K^- + p + p$ strong: colour charge

(b) $\pi^+ \rightarrow \mu^+ + \upsilon_\mu$ weak W boson

meson

3. Estimate the kinetic energy gained by a grain of sand dropping from rest through 1 millimetre in the Earth's gravitational field. Calculate the answer in Joules and MeV.

4. A radioactive sample contains 2×10^9 nuclei of ${}^{11}_{6}C$, which has a half life of 20.4 minutes. Calculate:

(i) The decay constant (λ) for ${}^{11}_{6}C$;

(ii) The initial activity (decay rate) of the sample;

(iii) The number of radioactive nuclei remaining after 8 hours;

(iv) The activity after 8 hours;

(v) The mean lifetime (1/λ) of a ${}^{11}_{6}C$ nucleus.

missing info?

5. Suppose you started out with a million muons (μ) at rest. How many would still exist 2.2×10^{-5} s later? $t_{1/2}$??

6. The strengths of radioactive sources were often measured in Curies (Ci). One Curie is 3.7×10^{10} decays per second.

(i) The Curie was originally defined as the number of disintegrations per second in 1 gram of natural radium (${}^{226}Ra$). What is the half-life of radium?

~same ish op

(ii) What mass of ${}^{60}Co$ is contained in a 10 μCi source if the half-life of ${}^{60}Co$ is 5.27 years? [1.58 x 10^3 years; 8.8×10^{-12} Kg]

NB: The SI unit for activity is the Becquerel (Bq), equal to one decay per second.

this seems straightforward and I am confused

7. Radioactive ${}^{14}C$ is constantly generated in the upper atmosphere by interactions of cosmic rays with nitrogen, so that the ratio of ${}^{14}C$ to ${}^{12}C$ in living organisms is equal to 1.3×10^{-12}. After death the ${}^{14}C$ is not replaced. Hence the number of ${}^{14}C$ decays

Set in check

in an organic sample may be used to estimate how long the material has been dead. The half-life of ^{14}C is 5730 years.

A sample of wood from an ancient shelter is analysed for its ^{14}C content and gives 2.1 decays per minute. A similar sample from a recently cut tree of the same type gives 5.3 decays per minute. What is the age of the sample?

[7,650 years]

8. The nuclear radius has been found to follow the semi-empirical relation $R = R_0\, A^{1/3}$, where $R_0 = 1.33$ fermi, and A is the mass number. Start by expressing the volume of the nucleus as a function of A (assuming it is a sphere). How does it vary for elements ${}^{12}_{6}C$, ${}^{6}_{3}Li$, ${}^{14}_{6}C$ and ${}^{241}_{95}Am$ (in fm^3) ? What can you deduce concerning the density of the nucleus (in SI units)?

9. In some Grand Unified Theories (GUTS), the proton is unstable and the half-life of the proton is predicted to be of the order of 10^{31} years. In a detector consisting of a 10m × 10m × 10m tank of water, how many protons would be expected to decay per day if this theory is correct?

10. Muons have a mean lifetime of 2.2×10^{-6} s. If a muon in free space has a kinetic energy of 1 MeV, show that it will travel a mean distance of 90 m before it decays. The rest mass of a muon is 105.7 MeV/c^2. [Hint: is the muon relativistic?]

<u>**NB:**</u> all questions in these Problems Sheets have appeared in one form or another in previous exams. This is why Problems Classes are useful ☺