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Nuclear Physics
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Self-evaluation sheet: radioactive decay

In order to successfully take the exam, a student should know

- Radioactive decay law, decay constant, average life time, half-life, activity
- Relevant units of measure
- Secular equilibrium and the four main radioactive chains
- Bateman Equations
- Radiodating of the ^{14}C, Libby hypothesis and related error sources
- Archaeological and geological dating: lead-lead method and isocrone rocks method
- Estimate of the terrestrial age through uranium isotopes
- Fermi Golden Rule

Exercises

In the following, some calculations that the student should be able to deal with

1. The ^{14}C has an average lifetime of $5,715$ years. It decades β by emitting an electron.
   (a) Determine the decay rate λ of the ^{14}C in units of years^{-1}
   (b) The ^{14}C is produced in the upper layers of the atmosphere. Cosmic rays generate neutrons that are absorbed by nitrogen nuclei with the following reaction

   $$n + {}^{14}N \rightarrow {}^{14}C + {}^{1}H$$

   ^{14}C then mixes with the atmospheric carbon, such that at some point we can talk about balance between the two isotopes. At the equilibrium, one gram of carbon produces 14 disintegrations (β) per minute. Find the number of atoms of ^{14}C needed to get 14 counts per minute. Then determine the total number of atoms of ^{12}C in one gram of carbon. Finally find the ratio between ^{12}C and ^{14}C.

2. Please consider a radioactive nucleus A that decays into another radioactive nucleus B which then decays into a stable C nucleus. Suppose there are no B nuclei at the time $t = 0$ but there are still some A nuclei. Let us also assume that, in the experiment, you measure the activity at $B \rightarrow C$ and not $A \rightarrow B$.
   (a) Derive the time dependency of the activity observed in terms of the average life τ_A, τ_B
   (b) Analyze the limit cases: $\tau_A >> \tau_B$, $\tau_A << \tau_B$ and $\tau_A \simeq \tau_B$

(c) Does the analysis change if the A nucleus has other decay channels besides the $A \to B$?

Note: Personally I suggest to solve the exercises by forming small working groups