NUCLEAR LIFETIME IN A LIMITED SPACE

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One of the important of problems in low energy nuclear physics today is how to control the nuclear lifetime and to know what happens on the nucleus put in the limited space. Although this subject has not much been investigated so far, it might be very interesting in context of medical application, nuclear waste and realization of $\gamma-$ray laser.

In this paper, we report that the nuclear lifetime can be prolonged by putting metallic plates on both sides of the $\gamma-$ray source. Our prediction is that it may be realized if duration of the nucleus being in the excited state is increased by reabsorbing the $\gamma-$ray reflected by these plates. In order to make reabsorption of $\gamma-$ray emitted from the source, all processes, such as emission, reflection and reabsorption, should be carried out without any energy loss. Therefore, the radioactive nucleus should be planted in a compound to remove recoil effects.

We have investigated the 81 keV level of ^{133}Cs planted in $^{133}BaTiO_3$ where ^{133}Ba is the parent of ^{133}Cs. Let $2b$ be the distance between two plates. Then, the lifetime is found as

$$\tilde{\tau}_{1/2} = \frac{2b}{c} \frac{ln[1 - \frac{c\tau_{1/2}}{2b} \frac{1-a}{a}]}{ln\ a}, \tag{1}$$

where c is the speed of light, $\tau_{1/2} = (6.27 \pm 0.02)\ ns$ and

$$a = 1 - \frac{1}{4\pi} \zeta f_{DW} (Z\sigma_\pi n) \Theta d \tag{2}$$

with ζ (γ absorption probability), and f_{DW}(Debye-Waller factor of plates), Z(atomic number), σ_π(Thomson cross section of backward scattering), n(atom density per cm^2 of plates), Θ(solid angle viewing plates) and d(thickness of the plate).

Our results are $\tilde{\tau}_{1/2} = 6.45\ ns$ at $5K$ with silicon wafer plates of $0.58\ mm$ thickness and $9\ cm^2$ area. The preliminary result of the experiment performed at Tohoku with BaF detectors in $(6.63 \pm 0.08)\ ns$, while the Mössbauer experiment gave $(6.95 \pm 0.11)\ ns$ [1]. If silver or stainless plates are used, it will become larger.

[1] Il-T. Cheon, J. Phys. Soc. Japan 70, 3193(2001).