Limits on n - $\bar{n}$ Oscillations

A recent paper[1] reported an upper limit of 0.7 $\times 10^{-30}$ yr^{-1} for the rate of $n \to \bar{n}$ transitions[2] in oxygen nuclei and deduced a corresponding lower limit of 2×10^7 s for the free-neutron oscillation time, by use of a relation taken from Dover, Gal, and Richard.[3] This is the latest in a series of papers (Refs. 11–17 of Ref. 1) which reflect the prevalent view that there is a direct relation between the $n \to \bar{n}$ transition rates for free neutrons and for those inside a nucleus. This had led to the unjustified interpretation that improved tests of nuclear stability automatically lead to correspondingly lower bounds for free $n \to \bar{n}$ transition times. The purpose of this Comment is to rectify that mistaken impression and to emphasize the continuing need for refined experiments on $n \to \bar{n}$ transitions using unbound neutrons.[4]

The time evolution of a "neutron" wave function Ψ is governed, in its rest system, by the equation (with $\hbar = c = 1$)

$$\frac{i\partial\Psi}{\partial t} = M\Psi; \quad \Psi = \begin{pmatrix} \psi_n \\ \psi_{\bar{n}} \end{pmatrix}, \qquad M = \begin{pmatrix} m_n + V_n & \epsilon \\ \epsilon & m_n + V_{\bar{n}} \end{pmatrix}, \tag{1}$$

where m_n is the mass of a free neutron (required to be the same as that of a free antineutron by *TCP* invariance) and ϵ is a parameter describing the strength of $n \to \bar{n}$ and $\bar{n} \to n$ transitions (assumed to be equal by time-reversal invariance). V_n is the potential experienced by a neutron, while $V_{\bar{n}} = U_n - iW_n$ is the corresponding complex potential experienced by an antineutron; to simplify the discussion, we take these to be constants[5] characteristic of nuclear matter. Diagonalization of M yields two complex eigenvalues with corresponding eigenstates which must be interpreted as the states of a neutron and an antineutron, respectively, inside nuclear matter. The width (decay rate) of the longer-lived "neutron" state is given, for $|\epsilon| \ll |V_n - V_{\bar{n}}|$, by

$$\Gamma = 2\epsilon^2\{W_n/[(U_n - V_n)^2 + W_n^2]\}. \tag{2}$$

If the curly-bracketed "nuclear physics" factors are taken as known,[6] Eq. (2) provides a direct connection between the rate of disappearance of neutrons within nuclear matter and the $n \to \bar{n}$ oscillation time $\tau_{n\bar{n}} = \epsilon^{-1}$, provided that the ϵ which appears in Eq. (2) can be taken to be the same as ϵ_0, the corresponding quantity for an isolated neutron. Consequently, experimental limits on nuclear stability restrict the admissible value of ϵ but do not constrain the value of the free-neutron oscillation time ϵ_0^{-1} unless $\epsilon_m = \epsilon - \epsilon_0$ can be shown to be negligible in comparison to ϵ_0. The value of ϵ_0 is a matter of speculation; any assertion about its magnitude relative to ϵ_m—which represents all $n \to \bar{n}$ transition processes[7] which could be catalyzed in the presence of other nucleons, but which are forbidden for a single neutron —is at least as speculative. Suffice it to say that ϵ_m and ϵ_0 are of the same order in the baryon-nonconserving interactions and may be expected to be comparable in magnitude. Therefore, one should view the neuclear stability tests and searches for free-neutron transitions as furnishing complementary information on ϵ and ϵ_0, respectively.

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[1]M. L. Cherry *et al.*, Phys. Rev. Lett. 50, 1354 (1983).

[2]G. W. Foster reported similar results from the Irvine-Michigan-Brookhaven experiment [Bull. Am. Phys. Soc. 28, 683 (1983)].

[3]C. B. Dover, A. Gal, and J. M. Richard, Phys. Rev. D 27, 1090 (1983).

[4]G. Puglierin reported a preliminary lower limit of 10^6 s from an experiment at Institute Laue-Langevin, in Proceedings of the International Colloquium on Matter Nonconservation, Frascati, Italy, 1983 (to be published).

[5]The spatial variation of V_n and $V_{\bar{n}}$ in finite nuclei is readily taken into account, as for example in Ref. 3, and does not change the qualitative conclusions which follow.

[6]While known in principle from other experiments, in practice there is a considerable range in their estimated values [R. N. Mohapatra, in *Proceedings of the Workshop on Neutron-Antineutron Oscillations, Cambridge, 1982,* edited by M. S. Goodman, M. Machacek, and P. D. Miller (Harvard Univ. Press, Cambridge, Mass., 1983); G. T. Condo and C.-Y. Wong, private communications].

[7]Mohapatra (Ref. 6) noted the possibility of additional $\Delta B = 2$ reactions in nuclei, but did not consider processes coherent with $n \to \bar{n}$ transformation.