Comment on "Evidence for a Nucleon-Nucleus Spin-Spin Interaction in ^{9}Be"

In the last two decades, there has evolved a body of evidence for the existence of a direct mechanism in slow-neutron capture. Direct $E1$ transitions are usually most apparent in off-resonance, thermal neutron capture, and it has been demonstrated[1] for these that a closed analytical formula, originally developed by Lane and Lynn[2] on the basis of some very simple physical approximations, is successful in giving a reasonable quantitative estimate for their cross sections. But this success has led to an increasing use of the Lane-Lynn approximate channel-capture formula as a near-precision tool to deduce other physical quantities, culminating in a recent Letter by Mughabghab,[3] who has analyzed the ^{9}Be(n,γ) reaction with this formula to demonstrate apparently that the potential radii of the neutron-scattering interaction are channel-spin dependent. We assert that this is an inappropriate use of the channel-capture formula, and that the resulting deductions cannot be placed on a plane higher than that of speculation.

The Lane-Lynn formula was applied by Mughabghab, with the potential radius as an adjustable parameter, to a situation where the radial dipole matrix element is composed of large components of opposite sign, which nearly cancel, thereby giving rise to a much smaller cross section than the estimate from hard-sphere capture.[2] It follows that these components must be estimated with high accuracy if the resulting estimate of direct capture is to be accurate. However, the physical approximations inherent in the Lane-Lynn formula do not allow this. The principal approximations are that the initial (neutron-scattering state) radial wave function is precisely linear with a node at the s-wave scattering length and that the final (p-state neutron) wave function is exactly a spherical Hankel function of order 1. These approximations are based on the assumption that the nucleus is extremely sharp edged (square-well approximation). Deviations from these simple analytical forms arising from the diffuseness of the nuclear potential beyond the potential radius are totally ignored. Other approximations in the formula are the use of a very crude estimate of the amplitude of the p-state wave function at the potential radius and the complete neglect of any contribution to the radial dipole integral from the internal region of the nuclear potential well.

The likely limitations of the simple channel-capture formula can be illustrated by comparing its results with those of a more realistic computation of the same direct-capture mechanism within the framework of the optical model, as discussed briefly in Ref. 2 and more extensively by Cugnon and Mahaux[4] and Raman *et al.*[5] For fairly realistic values of optical-model parameters, we have recently shown,[5] with special reference to the sulfur isotopes, that this improved potential-capture cross-section estimate can differ by up to 40% from the estimate given by the channel-capture formula. Certain situations exist when even this level of agreement is unattainable. These situations can occur when the direct-capture cross section is much lower than the simple hard-sphere estimate (as a result of destructive interference of the terms appearing in the channel-capture formula); this is usually the case when the scattering length is considerably greater than the nuclear potential radius. In such cases [^{9}Be(n,γ) is one of them], the individual terms in the channel-capture formula cannot be estimated accurately enough (for the reasons stated previously). Some specific calculations that we have made for the ^{9}Be case show that the computed optical-potential–capture cross section (a) is less than half the value estimated from the channel-capture formula in the case of the 6.81-MeV ground-state transition, (b) is very much smaller for the case of the 3.44-MeV transition, and (c) is roughly the same for the 0.85-MeV transition. Neglect of the internal-region contribution to the potential-capture cross section does not qualitatively alter these conclusions. Our calculations show also that the potential-capture cross sections for the 6.81- and 0.85-MeV transitions, unlike those given by the channel-capture expression, are not extremely sensitive to the choice, within reasonable physical limits, of the potential radius. Such insensitivity was also found by Ho and Lone[6] in their study of a direct transition with low cross section in thermal neutron capture by ^{12}C. By contrast, it is an apparent extreme sensitivity of the channel-capture expression to the potential radius that has been exploited unjustifiably in Ref. 3 to obtain the result of spin-dependent potential radii.

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