CONF-8708101--6
BNL 40157

Spin-Spin and Isospin Interactions from Capture Measurements

BNL--40157

DE87 014396

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ABSTRACT: A reanalysis of the $^9Be(n,\gamma)^{10}Be$ data yields a revised value of 1.25±0.15 MeV for the spin-spin potential, $V_{I\sigma}$. Other evidence for such a term is derived from $^{10}B(n,\gamma)^{11}B$ where $V_{I\sigma}$ = 1.6±0.6 MeV. The Lane isovector symmetry potential is determined from $^{48}Ca(n,\gamma)^{49}Ca$ where

$$W_D = 11.3 - 67.8 \left(\frac{N-Z}{A}\right) \text{ MeV.}$$

1. INTRODUCTION

Because of the A^{-1} damping effect[1] of the spin-spin interaction, its influence can be most favorably observed in light weight nuclides. In previous studies[2],[3], spin-spin interaction, $V_{I\sigma}$, strengths were derived for the target nuclides ^9Be and ^{27}Al within the framework of the direct capture model[4]. Additional information on $V_{I\sigma}$ can now be obtained for ^{10}B because of an improved determination of the neutron radiative capture cross section for this nuclide[5]. Due to recent considerable interest in the Lane isovector potential, a determination of its strength is made on the basis of thermal capture data of ^{48}Ca.

2. SPIN-SPIN POTENTIALS FOR ^9Be and ^{10}B

Due to a recent measurement[6], a reanalysis of the $^9Be(n,\gamma)^{10}Be$ reaction[2] resulted in a revised value of 1.25±0.15 MeV for $V_{I\sigma}$. This quantity agrees well with calculated[7],[8] values of 0.85 MeV and ≃1 MeV for the central spin-spin interaction. It is of particular interest to note that an additional spin-spin term of tensor origin and strength of 0.8 MeV was invoked[7] to describe the depolarization parameter, D, for the $^9Be\ (p,p_0)\ ^9Be$ reaction at 220 MeV.

The present available data on the n,p, and d reactions on ^{10}B provide accurate information[4],[9]-[12] to allow another determination for $V_{I\sigma}$. The required quantities are summarized in Table 1 where most of the entries are self explanatory. The fourth column presents the % (I+1/2) channel spin for the final states[12],[13]. Since the coherent scattering length of ^{10}B has an imaginary component, its contribution is appropriately taken into consideration. The interaction radii for channel spins, I+1/2 and I-1/2, are designated by + and - respectively.

From the ground state transition, one obtains $R_- = 3.7\pm0.2$ fm. In contrast, one finds from the other γ-ray transitions a weighted-average value of $R_+ = 1.79\pm0.16$ fm. A strength of $V_{I\sigma} = 1.6\pm0.4$ MeV is then derived from R_+ and R_- on the basis of a spherical optical model calculations[13]. This result is consistent with previous determinations[2],[3] and with the findings[10],[14] of a spin-dependent R'. Because the potential capture cross sections for channel spin 7/2 are small, the observed thermal cross sections are dominated by valence capture (7th column of Table 1) in the tail of the strong 7/2 s-wave resonance (370 keV). From nuclear structure information and the valence model[15], a partial radiative width of 3.9 eV is deduced for the γ-ray transition feeding the state at 4.445 MeV. This valence radiative width accounts for the measurement of this transition, demonstrates the negligible contribution of compound nucleus contributions, and settles a question which was raised in ref. [16].

TABLE 1. Nuclear Spectroscopic data and partial radiative capture cross sections of n + ^{10}B.

E_x (MeV)	J_f	S_{dp}^a	% (+) channel spin[b]	$\sigma_{\gamma if}$ [c] (mb)	$\sigma_{\gamma if}^{(+)}$(pot) (mb)	$\sigma_{\gamma if}$(valence)[d] (mb)
0	3/2	1.2	0	13.6±2.1		
4.445	5/2	0.35	76.3	160±23	5.2±1.3	108±14
6.743	7/2	1.1	24.6	75.4±10.8	2.3±0.9	51±10
8.920	5/2	0.49	99.4	41.8±8.4	1.6±0.4	27±10

a) ref [1] b) ref [12] c) refs [5], [9] d) from columns 5 and 6

3. THE LANE ISOVECTOR POTENTIAL

Recent years witnessed interest in the optical model (OM) potential and in the determination of its parameters. One such important parameter. which plays an important role in the excitation of isobaric analogue resonances, is the Lane isovector potential W_1. A reasonable estimate for W_1 can be readily derived by comparing the potential scattering lengths R' of ^{48}Ca and ^{48}Ti. An accurate value for the former is deduced from the ^{48}Ca thermal capture cross section when accounted for by direct capture. With an intraction radius of 4.98±0.07 fm, obtained from a variety of other data, R' = 1.0±0.2 fm is computed for ^{48}Ca. A comparison of the ^{48}Ca and ^{48}Ti potential scattering lengths yields

$$W_o = 11.3\,^{+1.7}_{-1.4}\ \text{MeV and}\ W_1 = 67.8\,^{+10.4}_{-8.4}\ \text{MeV},$$

both of which are in excellent agreement with the results obtained from the s-wave strength functions of the Te isotopes[17]. The large W_1 value may be attributed to an anomaly at very low neutron energies. It is of interest to note that, when applied to ^{136}Xe, these parameters predict a small s-wave strength function for this nuclide.

Without the support and encouragement of Drs. R.E. Chrien, H. Kouts, and S. Pearlstein, this work would have not been possible. Fruitful discussions with Drs. D.J. Millener, R.E. Chrien and J.A. Harvey are gratefully acknowledged.

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Research carried out under the auspices of the U.S.Department of Energy under Contract No. DE-AC02-76CH00016.