Thermal neutron capture cross section of deuterium

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We have measured the thermal neutron capture cross section of deuterium by direct observation of the prompt gamma ray.

[NUCLEAR REACTIONS $^{2}H(n,\gamma)^{3}H$ and $^{12}C(n,\gamma)^{13}C$, E_n=th, measured $\sigma(n,\gamma)$.]

An early measurement of the thermal neutron capture cross section in deuterium by Kaplan, Ringo, and Wilzbach[1] yielded a value of 0.57 ± 0.01 mb. These authors measured the relative tritium production from $^{2}H(n,\gamma)^{3}H$ and $^{6}Li(n,\alpha)^{3}H$, then compared the cross section for the second of these reactions to a boron standard using the pile-oscillator technique. A subsequent measurement by Jurney and Motz[2] was made by comparing the intensity of the 6.2 MeV γ ray from $^{2}H(n,\gamma)^{3}H$ with that of the ground-state transition from neutron capture in ^{207}Pb, which gave a value of 0.60 ± 0.05 mb. The most recent measurement of this cross section was reported in Ref. 3 where the number of tritium atoms accumulated in a neutron-irradiated sample of D_2O was directly measured. This yielded a cross section of 0.521 ± 0.009 mb. Most calculations[4,5] of this cross section have produced significant disagreement with these experimental results (up to a factor of 2). However, Hadjimichael[6] published a calculation that considerably improved the agreement between theory and experiment. In this calculation, he included the effects of meson-exchange currents on the magnetization density of the three-body system, which resulted in a calculated cross section of 0.52 ± 0.05 mb.

In the present work, we have performed a direct measurement of the $^{2}H(n,\gamma)^{3}H$ cross section for thermal neutrons by observation of the 6.2 MeV capture γ rays to check the results of Merritt, Taylor, and Boyd[3] and hence confirm or question the agreement with the Hadjimichael calculation.

Capture gamma ray spectra from the various samples used in the experiment were recorded from a Ge(Li) detector used in conjunction with the internal-target facility[7] at the Los Alamos Omega West reactor. The detector was placed inside a large, optically-divided NaI annulus and could be operated as a double-escape spectrometer at high (>2 MeV) energies or as a Compton-suppression anticoincidence spectrometer at low (<3 MeV) energies. The deuterium target was a 1-cm diameter, 1-g disc of deuterated polyethylene. Since in the double-escape mode the detector efficiency varies only by $\sim40\%$ between 3.5 and 6.5 MeV, and since it was possible to make an accurate mass-analysis determination of the ^{12}C to ^{2}H ratio in the target, we chose to use the partial capture cross section for the 4946 keV ground state transition from $^{12}C(n,\gamma)^{13}C$ as an intermediate standard.

Thermal neutron capture by ^{12}C produces, in addition to the ground-state transition, a two-step cascade with energies 3684 and 1261 keV. (A gamma from the $J^{\pi}=\frac{1}{2}^{+}$ state at 3088 keV is also produced, but its intensity is only ~0.006 of that of the ground state gamma.) By carefully mapping the energy dependence of the detector efficiency in the double-escape mode, using mainly two-step cascades in the spectrum from $^{14}N(n,\gamma)^{15}N$, it was possible to determine the intensities of the two main branches from $^{12}C(n,\gamma)^{13}C$ as 0.686 ± 0.009 (4946 keV) and 0.310 ± 0.004 (3684 keV). The partial capture cross section for the 1261-keV transition was then determined by measuring the spectrum from a target of CH_2 with the detector in the anticoincidence mode and comparing its intensity to that from $^{1}H(n,\gamma)^{2}H$ with an accurately known cross section of 332 ± 2 mb.[8] By combining these results we deduce a value of 3.53 ± 0.07 mb for the ^{12}C capture cross section, in good agreement with the measurement of 3.50 ± 0.16 mb recently reported by Prestwich *et al.*,[9] for carbon in natural isotopic abundance. We have assumed a $1/v$ dependence for the capture cross sections of ^{1}H, ^{2}H, and ^{13}C. The value of the ^{1}H cross section that we have used as a standard is the 2200 m/sec value; the peak of the

velocity distribution in the reactor thermal column is approximately 2400 m/sec.

After introducing corrections for the ^{12}C to ^{2}H ratio in the deuterated polyethylene target and for the 6.9% difference in detector efficiency, a comparison of the intensities of the 4946 keV ground-state transition in ^{13}C and the 6255 keV ground-state transition in ^{3}H (assumed to be 100%) gives a value of 0.508 ± 0.015 mb for $^{2}H(n,\gamma)^{3}H$, thus confirming the value reported by Merritt *et al.*[3]

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