

Comment on “Structure effects in the $^{15}\text{N}(n,\gamma)^{16}\text{N}$ radiative capture reaction from the Coulomb dissociation of ^{16}N ”

Peter Mohr*

Diakonie-Klinikum, D-74523 Schwäbisch Hall, Germany
and Institute for Nuclear Research (ATOMKI), H-4001 Debrecen, Hungary

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In their recent study Neelam, Shubhchintak, and Chatterjee have claimed that “it would certainly be useful to perform a Coulomb dissociation experiment to find the low-energy capture cross section for the reaction” $^{15}\text{N}(n,\gamma)^{16}\text{N}$. However, it is obvious that a Coulomb dissociation experiment cannot constrain this capture cross section because the dominating branchings of the capture reaction lead to excited states in ^{16}N , which do not contribute in a Coulomb dissociation experiment. An estimate of the total $^{15}\text{N}(n,\gamma)^{16}\text{N}$ cross section from Coulomb dissociation of ^{16}N requires a precise knowledge of the γ -ray branchings in the capture reaction. Surprisingly, the calculation of Neelam, Shubhchintak, and Chatterjee predicts a strongly energy-dependent ground-state branching of the order of 0.05% to 0.6% at energies between 100 and 500 keV, which is almost 2 orders of magnitude below calculations in the direct capture model. Additionally, this calculation of Neelam, Shubhchintak, and Chatterjee deviates significantly from the expected energy dependence for p -wave capture.

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Neelam, Shubhchintak, and Chatterjee (hereafter NSC) [1] study the Coulomb dissociation (CD) cross section of ^{16}N and apply detailed balance to derive the inverse $^{15}\text{N}(n,\gamma)^{16}\text{N}$ radiative capture cross section. In detail, NSC calculate the CD for the four low-lying states in ^{16}N with $J^\pi = 2^-, 0^-, 3^-,$ and 1^- which are located below excitation energies of $E^* \approx 400$ keV. NSC use spectroscopic factors from the shell model taken from Ref. [2], which are close to unity for the states under consideration. This is confirmed experimentally by transfer data in Ref. [3] and by the analysis of neutron scattering lengths [4] but also lower values have been derived from transfer [5,6]. Spectroscopic amplitudes close to unity have also been calculated recently in Ref. [7].

Indeed, such a study can be made in theory; however, under normal experimental conditions ^{16}N is in its 2^- ground state, and thus a CD experiment is only able to constrain the $^{15}\text{N}(n,\gamma_0)^{16}\text{N}_{\text{g.s.}}$ cross section but not the partial capture cross sections to the low-lying excited states. Consequently, the conclusion of NSC “to find the low-energy capture cross section” from CD is misleading. Additionally, it will be difficult to obtain a sufficient energy resolution in the CD experiment to derive the low-energy capture cross section using Eq. (3) of NSC [1].

It is stated by NSC that CD theory has been used successfully to determine the $^8\text{Li}(n,\gamma)^9\text{Li}$ [8] and $^{14}\text{C}(n,\gamma)^{15}\text{C}$ [9] cross sections from CD of ^9Li and ^{15}C . Indeed, for these capture reactions the ground-state contributions are dominating, and thus experimental CD data can be used to determine the total capture cross section. However, later NSC claim that “the Coulomb dissociation method has been used to find the neutron capture cross section to different states of ^8Li [10] and also to find the contributions of the projectile excited states in the charged particle capture reactions [11,12].” Reference [10] explicitly states that the experimental CD data for ^8Li have to

be corrected for excited state contributions in the $^7\text{Li}(n,\gamma)^8\text{Li}$ reaction, and this correction of about 10–20% is estimated from experimental branching ratios in the $^7\text{Li}(n,\gamma)^8\text{Li}$ capture reaction; see Eq. (6) in Ref. [10]. Reference [11] studies the $^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$ reaction where the ground-state contribution is dominating. Reference [12] analyzes the $^{30}\text{S}(p,\gamma)^{31}\text{Cl}$ reaction with its tiny Q value of about +280 keV, where the ground state of ^{31}Cl is the only bound state. Thus, none of Refs. [10–12] matches the statement of NSC.

Experimental ^{16}N CD data can indeed be used to determine the $^{15}\text{N}(n,\gamma_0)^{16}\text{N}_{\text{g.s.}}$ cross section. The determination of the total $^{15}\text{N}(n,\gamma)^{16}\text{N}$ capture cross section is practically not constrained by the small ground-state contribution which is experimentally accessible by CD. According to calculations (details see below), the contribution of each low-lying excited state exceeds the ground-state contribution. Thus, the determination of the total capture cross section from CD data requires additional information on the γ -ray branching ratios in the $^{15}\text{N}(n,\gamma)^{16}\text{N}$ capture reaction.

Surprisingly, in the calculations of NSC this branching shows a significant energy dependence (see Fig. 2 of Ref. [1]; note that the energies of the experimental data points in the upper part differ from the lower part, which is probably the consequence of a missing conversion to the center-of-mass system). This energy-dependent branching is a very unexpected result because the energy dependence of the capture cross section at low energies is typically governed by the angular momentum l of the incoming neutron, leading to an approximate $\sigma_{(n,\gamma)} \sim E^{l-1/2}$ proportionality. For the transitions under consideration from incoming p waves to bound s and d states a similar energy dependence ($\sim \sqrt{E}$) is expected, and the best description of the energy dependence in direct capture (DC) calculations below about 500 keV has been found [2] with

$$\sigma_{(n,\gamma)} = A E^{0.5} - B E^{1.2} \quad (1)$$

*WidmaierMohr@t-online.de

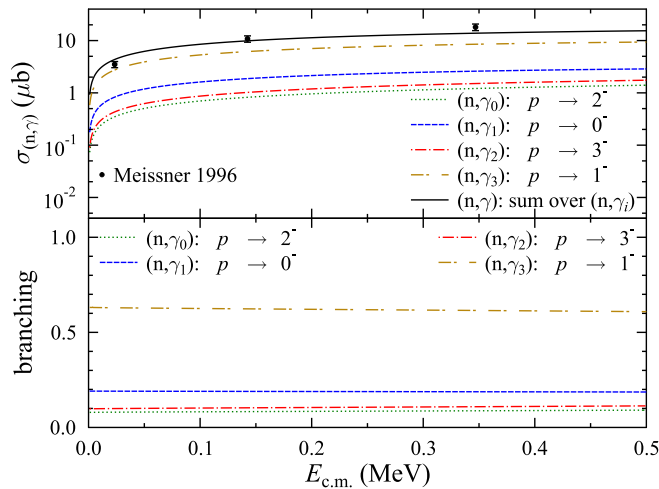


FIG. 1. Partial cross sections of $^{15}\text{N}(n, \gamma_i)^{16}\text{N}$ (upper part) and branching ratios $\sigma_{(n, \gamma_i)}/\sigma_{(n, \gamma)}$ (lower part). The data are taken from Ref. [2]. For further discussion, see the text.

and the parameters A and B as given in Table III of Ref. [2]. Note that $B < A$ which makes the second term in Eq. (1) to a small correction to the dominating \sqrt{E} energy dependence for $E < 1$ MeV. These results are shown in Fig. 1 together with the experimental data of Ref. [2]. For easy comparison the same scale as in Fig. 2 of NSC [1] has been chosen for the presentation of the cross sections.

The lower part of Fig. 1 shows that the calculations of Ref. [2] in the DC model lead to an almost energy-independent branching ratio for the transitions from the incoming p wave

to the four bound s and d states in ^{16}N . The ground-state contribution amounts to about 10% in the whole energy range up to 500 keV. Contrary to the DC calculations of Ref. [2], the new results of NSC show a significantly steeper energy dependence for the transitions to the bound d states ($2^-, 3^-$) with a ground-state branching of about 0.05% at 100 keV and about 0.6% at 500 keV. This essential discrepancy of about 2 orders of magnitude for the ground-state branching ratio has to be well understood before any conclusions on the total $^{15}\text{N}(n, \gamma)^{16}\text{N}$ capture cross section can be drawn from experimental CD data of ^{16}N and the model calculations of NSC.

For completeness I point out that the expected weak energy dependence of the branching ratios has also been found in DC calculations for the corresponding transitions from incoming p waves to bound s and d states in the neighboring $^{14}\text{C}(n, \gamma)^{15}\text{C}$ [13] and $^{16}\text{O}(n, \gamma)^{17}\text{O}$ [14,15] reactions. As Fig. 1 in Ref. [15] shows, this weak energy dependence of the branching ratio is also confirmed experimentally for the $^{16}\text{O}(n, \gamma)^{17}\text{O}$ reaction.

In conclusion, contrary to the suggestion of NSC, the determination of the total $^{15}\text{N}(n, \gamma)^{16}\text{N}$ capture cross section from a CD experiment on ^{16}N is not possible because the CD data are related only to the small ground-state branch in the capture reaction. The huge and surprising discrepancy between the energy dependence of the branching ratios in the CD calculations by NSC and in the DC calculations [2] (and similar results in Refs. [13,15] for the neighboring ^{14}C and ^{16}O nuclei) makes it impossible to correct experimental CD data of ^{16}N for the determination of the total $^{15}\text{N}(n, \gamma)^{16}\text{N}$ cross section using theoretical branching ratios.

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