PHOTODISINTEGRATION OF ^{7}Li

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The bremsstrahlung weighted cross section for the photodisintegration of ^{7}Li is calculated using the cluster model wave function. The range of the parameters in the fully antisymmetrized cluster model wave function which account for both the r.m.s. radius and the bremsstrahlung weighted cross section, are determined.

1. *Introduction*

The study of photodisintegration of ^{7}Li reported here is intended to obtain information about the cluster model wave function of ^{7}Li [1]. An earlier study of the r.m.s. radius of ^{7}Li, using the cluster model by Srinivasa Rao and Sridhar [2] yielded the range of values of the parameters in the wave function which have been favourably compared with the experimental results. In the case of some light nuclei such as ^{3}He, ^{3}H and ^{4}He – the bremsstrahlung weighted cross section, which is the energy-weighted electric dipole cross section for the nuclear photoeffect, is directly proportional to the r.m.s. radius of the target nucleus. However, this is not true in the case of ^{6}Li and ^{7}Li, since the cluster model ground state wave functions [1] of these nuclei are not completely symmetric in the space coordinates of all nucleons. Therefore, a study of the bremsstrahlung weighted cross section for the photodisintegration of ^{7}Li is expected to provide additional information about the cluster model wave function of ^{7}Li.

2. *The bremsstrahlung weighted cross section*

The bremsstrahlung weighted cross section for the photodisintegration of ^{7}Li is given by

$$\sigma_b = \int (\sigma/W)dW, \tag{1}$$

where σ is the electric dipole cross section for a given photon energy W. Following Dellafiore and Brink [3] equation (1) can be written as

$$\sigma_b = \frac{4\pi^2}{3}\frac{e^2}{\hbar c}\frac{z^2N^2}{A^2}\langle R^2_{pn}\rangle, \tag{2}$$

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where $\boldsymbol{R}_{pn} = \boldsymbol{R}_p - \boldsymbol{R}_n$, $\boldsymbol{R}_p$ and $\boldsymbol{R}_n$ representing the centres of mass of protons and neutrons, respectively, and the expectation value is in the groundstate of the nucleus. Explicitly, the operator R^2_{pn} is given by

$$R^2_{pn} = \left[\frac{1}{z}\sum_{i=1}^{7} \boldsymbol{r}_i\left(\frac{1+\tau_3^i}{2}\right) - \frac{1}{N}\sum_{i=1}^{7} \boldsymbol{r}_i\left(\frac{1-\tau_3^i}{2}\right)\right]^2$$

$$= \tfrac{1}{144}\left[7(\varrho_1+\varrho_4+\varrho_5)+2\boldsymbol{R}\right]^2 \tag{3}$$

in terms of the relative co-ordinates: $\varrho_i = \boldsymbol{r}_i - \boldsymbol{R}_\alpha$ $(i = 1, 2, 3, 4)$, $\varrho_j = \boldsymbol{r}_j - \boldsymbol{R}_t$ $(j = 5, 6, 7)$ and $\boldsymbol{R} = \boldsymbol{R}_\alpha - \boldsymbol{R}_t$, defined in Ref. [2] with the subscripts 1, 4, 5 being used for the protons (and the subscripts 2, 3, 6, 7 being used for neutrons). The expectation value of R^2_{pn} takes the form

$$\langle R^2_{pn}\rangle = \frac{7!}{N^2}\int(\psi_0 - 3\psi_1 + 3\psi_2 - \psi_3)^* R^2_{pn}\psi_0 d\tau$$

$$= \frac{7!}{N^2}\left[B^0_{pn} - 3B^1_{pn} + 3B^2_{pn} - B^3_{pn}\right], \tag{4}$$

where ψ_0, ψ_1, ψ_2 and ψ_3 correspond to the no-exchange, one-nucleon exchange, two--nucleon-exchange and three-nucleon exchange wavefunctions respectively. The normalization factor:

$$N^2 = 7!\int(\psi_0 - 3\psi_1 + 3\psi_2 - \psi_3)^*\psi_0 d\tau = 7!(A_0 - 3A_1 + 3A_2 - A_3) \tag{5}$$

has already been evaluated and the expressions for A_0, A_1, A_2 and A_3 are given in equations (10)–(19) of Ref. [2].

A straightforward but lengthy calculation yields the following expressions

$$B^0_{pn} = \tfrac{7}{144}\frac{A_0}{2\alpha}\left(21 + \frac{14}{z} + \frac{3}{x}\right), \tag{6}$$

$$B^1_{pn} = \tfrac{7}{144}A_1\left(1+\tfrac{2}{5}\frac{q_1^2}{4p_1^2}\right)^{-1}\left(1-\frac{q_1^2}{4p_1^2}\right)^{-1}\left\{\frac{7}{\alpha}\left(1+\frac{25}{8+9z}\right)\left(1+\tfrac{2}{5}\frac{q_1^2}{4p_1^2}\right)\right.$$

$$\times\left(1-\frac{q_1^2}{4p_1^2}\right) + 24\left(\frac{3-z}{8+9z}\right)^2\left[\frac{7}{p_1}\left(1+\tfrac{4}{5}\frac{q_1^2}{4p_1^2}\right)\right.$$

$$\left.\left. + \frac{2}{q_1}\left(1+\tfrac{46}{5}\frac{q_1^2}{4p_1^2}+\tfrac{12}{5}\left(\frac{q_1^2}{4p_1^2}\right)^2\right)\right]\right\}, \tag{7}$$

$$B^2_{pn} = \tfrac{7}{144}A_2\left(1+\tfrac{2}{5}\frac{q_2^2}{4p_2^2}\right)^{-1}\left(1-\frac{q_2^2}{4p_2^2}\right)^{-1} 3\left\{\frac{7}{4\alpha}\left(1+\frac{4}{1+z}+\frac{1}{2+3z}\right)\right.$$

$$\times\left(1+\tfrac{2}{5}\,\frac{q_2^2}{4p_2^2}\right)\left(1-\frac{q_2^2}{4p_2^2}\right)+\tfrac{1}{2}\left(\frac{3+z}{2+3z}\right)^2$$

$$\times\left[\frac{7}{p_2}\left(1+\tfrac{4}{5}\,\frac{q_2^2}{4p_2^2}\right)+\frac{2}{q_2}\left(1+\tfrac{46}{5}\,\frac{q_2^2}{4p_2^2}+\tfrac{12}{5}\left(\frac{q_2^2}{4p_2^2}\right)^2\right)\right]\Bigg\}, \tag{8}$$

$$B_{\mathrm{pn}}^3=\tfrac{7}{144}A_3\left(1+\tfrac{2}{5}\,\frac{q_3^2}{4p_3^2}\right)^{-1}\left(1-\frac{q_3^2}{4p_3^2}\right)^{-1}4\Bigg\{\frac{7}{\alpha(1+z)}\left(1+\tfrac{2}{5}\,\frac{q_3^2}{4p_3^2}\right)\left(1-\frac{q_3^2}{4p_3^2}\right)$$

$$+\tfrac{8}{3}\left[\frac{7}{p_3}\left(1+\tfrac{4}{5}\,\frac{q_3^2}{4p_3^2}\right)-\frac{2}{q_3}\left(1+\tfrac{46}{5}\,\frac{q_3^2}{4p_3^2}+\tfrac{12}{5}\left(\frac{q_3^2}{4p_3^2}\right)^2\right)\right]\Bigg\}, \tag{9}$$

where q_i and p_i $(i = 1, 2, 3)$ are as defined in Ref. [2], and the following are the parameters in the cluster model wave function $\alpha = a_{1s}^2$, $\bar{\alpha} = a_{1p}^2$, $\beta = \frac{1}{7}(3\alpha+4\bar{\alpha})$, $z = \bar{\alpha}/\alpha$ and $x = \beta/\alpha$.

3. *Numerical evaluation*

The bremsstrahlung weighted cross section, σ_b, for the photodisintegration of a nucleus is determined from a plot of experimental results for the nuclear photodisintegration reaction. A graph of σ/W versus W is drawn, where σ is the total cross section for a given incident photon energy W and the area under the curve gives the bremsstrahlung weighted

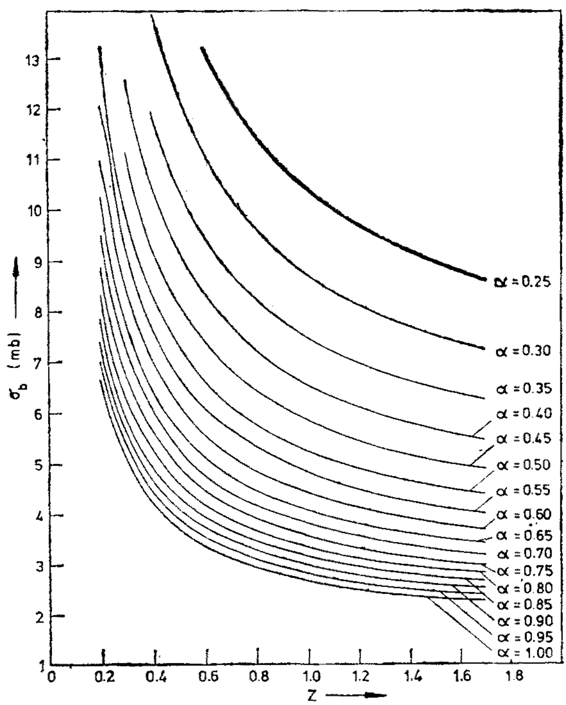

Fig. 1. Bremsstrahlung weighted cross section for ^{7}Li using the unantisymmetrized cluster model wave function

cross section. From the data of Ahrens et al. [4] for the photoneutron yield of photon absorption at energies from 10 MeV to 100 MeV, σ_b was measured as 5.224 mb.

The bremsstrahlung weighted cross section for the photodisintegration of ^{7}Li has been computed by varying the parameters α and z within the ranges: $0.25\ \text{fm}^{-2} \leqslant \alpha \leqslant 1.0\ \text{fm}^{-2}$ and $0.20 \leqslant z \leqslant 1.7$ respectively. In Fig. 1 σ_b is plotted for several values of

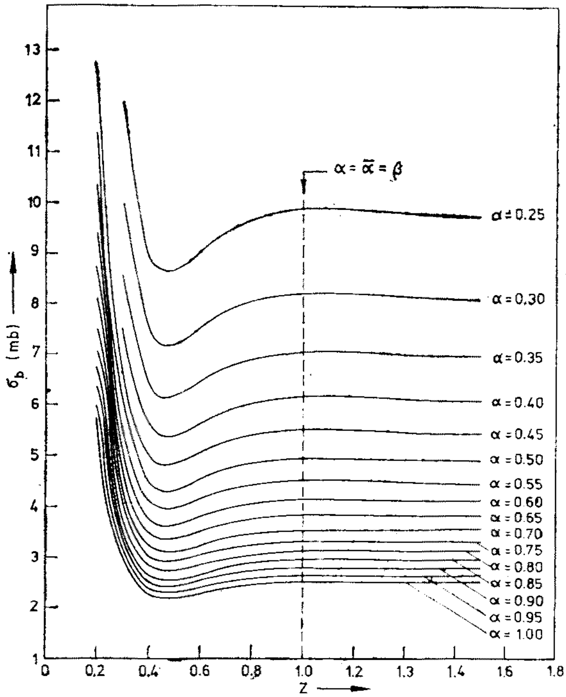

Fig. 2. Bremsstrahlung weighted cross section for ^{7}Li using the antisymmetrized cluster model wave function

α, as a function of z making use of the normalized, unantisymmetrized wavefunction for ^{7}Li. In Fig. 2, σ_b is plotted for the same values of α as a function of z, including the terms that arise due to the antisymmetrization of the cluster model wavefunction. The effect of antisymmetrization is to reduce σ_b for $z \leqslant 1$ and then make σ_b a constant for $z > 1$. This is in contrast to the effect of antisymmetrization on the r.m.s. radius [2], where the value of $\langle r^2 \rangle^{1/2}$ was enhanced throughout the range of z, for all values of α. The cluster model wave function will correspond to the single oscillator shell model wavefunction in the lowest configuration when $\alpha = \bar{\alpha} = \beta$.

4. Conclusions

In conclusion, it is noted that with the unantisymmetrized wavefunction, the experimental value of the bremsstrahlung weighted cross section can be obtained for $\alpha > 0.4\ \text{fm}^{-2}$ and $z > 0.3$. But with the antisymmetrized wavefunction the experimental value of σ_b is attained, with the same range for α while the range of z is significantly changed to $0.2 < z < 0.4$ (except for $\alpha = 0.45\ \mathrm{fm}^{-2}$, where a larger value of $z = 0.7$ is also allowed). Thus it is found that for a range of values of α around $0.5\ \mathrm{fm}^{-2}$ and $0.2 \leqslant z \leqslant 0.4$, in the fully antisymmetrized cluster model wavefunction, it is possible to account for both the r.m.s. radius and the bremsstrahlung weighted cross section for the photodisintegration of ^{7}Li.

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