Contribution of E2 transition in ^{8}Li(n,γ)^{9}Li and its inverse reaction ^{208}Pb(^{9}Li, ^{8}Li+n)^{208}Pb

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Introduction

Various astrophysical problems like energy production and nuclear synthesis of heavier elements in stellar environment are associated with radiative capture reactions at low energies. In the inhomogeneous Big-Bang model the radiative capture reaction ^{8}Li(n,γ)^{9}Li competes with the α- capture reaction ^{8}Li(α,n)^{11}Be and ^{8}Li β-decay and affects the production of heavier elementst. Specifically these capture reactions provide two alternative reaction paths to bridge the mass A=8 gap in the process of nucleosynthesis[1]. In a particular astrophysical environment the reaction rates of ^{8}Li(α,n)^{11}Be and ^{8}Li(n,γ)^{9}Li reactions determine which reaction path is taken and hence the abundance of heavier isotopes. A lot of efforts have already been devoted to determine the rates of these reactions leading to quite accurate value of the cross section of the former reaction while the large uncertainty has been found as associated with the cross section of ^{8}Li(n,γ)^{9}Li reaction[2-4]. Therefore it needs further investigations.

Recently, some efforts have also been made to study the reaction ^{8}Li(n,γ)^{9}Li through Coulomb breakup method[5-6]. But, the results so obtained may not be free from bias because of the fact that different multipole transitions contribute differently in the radiative capture and Coulomb breakup reactions[7]. Thus here we present preliminary results of our calculation for cross section for ^{8}Li(n, γ)^{9}Li and its inverse Coulomb breakup ^{208}Pb(^{9}Li, ^{8}Li+n)^{208}Pb reaction with a motive to find the contribution of E2 transition in these reactions.

Theoretical Formalism

The explicit expressions for the strength functions corresponding to electric dipole and quadrupole transitions are given as

$$\frac{dB(E1)}{dE_x}=36\pi(Z_1^{eff})^2\frac{\sqrt{2\mu^3(E_x-S_n)}}{(2\pi\hbar)^3}\left|-\frac{Y_{oo}}{3}\int_0^\infty r^3\,dr\,j_1(qr)R_1(r)\right.$$
$$\left.-\left[\frac{4}{\sqrt{15}}Y_{20}+\frac{2}{\sqrt{5}}Y_{21}+\sqrt{\frac{2}{5}}Y_{22}+\sqrt{\frac{2}{5}}Y_{2-2}+\frac{2}{\sqrt{5}}Y_{2-1}\right]\int_0^\infty r^3 dr\,j_2(qr)R_1(r)\right|^2 \qquad (1)$$

and

$$\frac{dB(E2)}{dE_x}=60\pi(Z_2^{eff})^2\frac{\sqrt{2\mu^3(E_x-S_n)}}{(2\pi\hbar)^3}\left|-\left\{\frac{\sqrt{2}+\sqrt{6}+2\sqrt{3}}{5\sqrt{6}}(Y_{1-1}+Y_{11})-\frac{2}{5\sqrt{3}}Y_{10}\right\}\right.$$
$$\times\int_0^\infty r^4\,dr\,j_2(qr)R_2(r)-$$
$$\left[\frac{\sqrt{3}+\sqrt{6}}{\sqrt{105}}[Y_{3-2}+Y_{32}]+\sqrt{\frac{3}{35}}[Y_{3-3}+Y_{33}]+\frac{2\sqrt{3}+3}{5\sqrt{7}}Y_{30}+\frac{\sqrt{6}+7\sqrt{3}}{5\sqrt{42}}[Y_{31}+Y_{3-1}]\right]$$
$$\left.\times\int_0^\infty r^3 dr\,j_2(qr)R_1(r)\right|^2 \qquad (2)$$

The photoabsorption cross section may be obtained by the following relation

$$\sigma_{photo}(E_x)=\frac{(2\pi)^3(l+1)}{l[(2l+1)!!]^2}\left(\frac{E_x}{\hbar c}\right)^{2l-1}\frac{dB(El)}{dE_x}$$

Alternatively, the photoabsorption cross section may also be estimated from the knowledge of differential Coulomb breakup cross section, $\frac{d\sigma_{CD}}{dE}$, via relation $\sigma_{photo}(E_\gamma)=\frac{E_\gamma}{nE_1}\frac{d\sigma_{CD}(El)}{dE_\gamma}$

Where the differential Coulomb breakup cross section, $\frac{d\sigma_{CD}(El)}{dE_\gamma}$, for the electric dipole and quadrupole transitions may conveniently be obtained within the framework of eikonal approximation by the following expressions[8]

$$\frac{d\sigma_{E1}}{dE_{rel}}=\int_0^\pi\frac{4Z_t^2(Z_1^{eff})^2\alpha^2}{3\gamma^2\beta^2}\xi^2 I_{011}^2\left[(K_1^2-K_0^2)\left\{(1+2P_2)-(1-P_2)\gamma^2\right\}+\frac{2}{\xi}K_0K_1(1-P_2)\gamma^2\right]$$
$$\times\sqrt{2E_{rel}\left(\frac{\mu}{\hbar^2}\right)^3}\ \sin\theta d\theta \qquad (8)$$

and

$$\frac{d\sigma_{E2}}{dE_{rel}}=\int_0^\pi\frac{Z_t^2(Z_2^{eff})^2\alpha^2}{105\,\gamma^2\beta^4}\left(\frac{\omega}{c}\right)^2\xi^2\left(I_{022}\right)^2$$
$$\times\left[\frac{4}{\xi^2}K_1^2(7-10P_2+3P_4)\ +(K_1^2-K_0^2)(28+20P_2+57P_4)\right.$$
$$\left.+(7+5P_2-12P_4)\gamma^2(2-\beta^2)^2\left(\frac{2}{\xi}K_0K_1-(K_1^2-K_0^2)\right)\right]$$
$$\times\sqrt{2E_{rel}\left(\frac{\mu}{\hbar^2}\right)^3}\sin\theta d\theta$$

rspectively. All the symbols have same meaning as defined in ref.[8]. The photoabsorption cross section so obtained may be used to determine the radiative capture cross section, through the detailed balance theorem. However, in astrophysical studies the energy dependence of the cross section is usually expressed in terms of the astrophysical S-factor which is defined as $S(E_{CM})=\sigma_{CAP}\ E_{CM}\ \exp(2\pi\eta)$ with E_{CM} and $\eta\left(=\frac{Z_bZ_ce^2}{\hbar v}\right)$ as the center of mass energy and Coulomb parameter respectively.

Results and Discussions

Since the quantity of experimental interest is the radiative capture cross section so we have calculated it for ^{8}Li(n, γ)^{9}Li reaction and results so obtained are displayed in Fig. 1 along with the experimental data taken from ref[5].

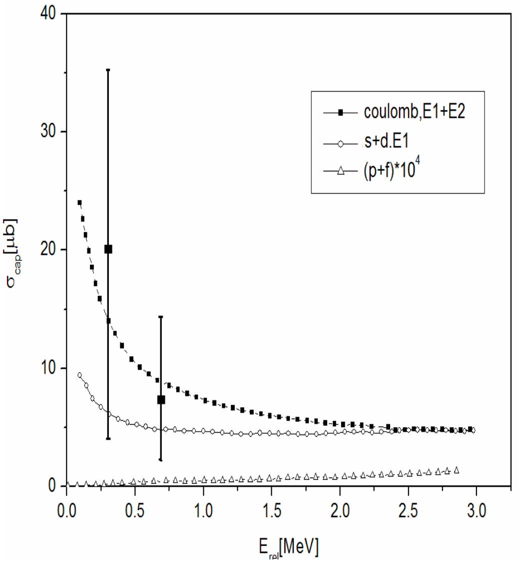

Fig.1 Radiative capture cross section for ^{8}Li(n,γ)^{9}Li reaction as a function of neutron energy relative to the ^{8}Li core.

It is found that the theoretical results of both the approaches are consistent with the measured one. The contribution of E2 multipole in radiative capture cross section is found to be negligible in the low relative energy region while it starts contributing in the higher energy region. In Fig.2, the astrophysical s-factor of ^{8}Li(n, γ)^{9}Li radiative capture reaction is plotted as a function of neutron relative energy.

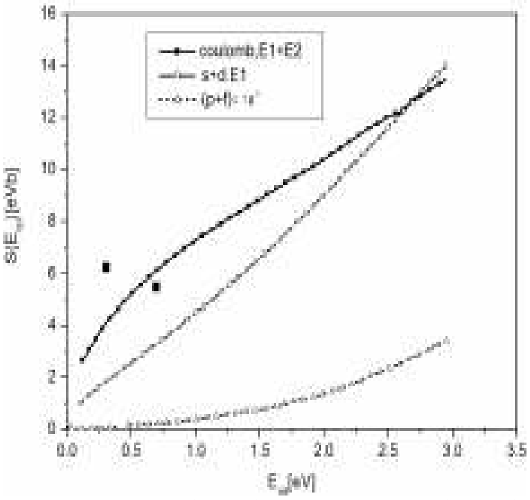

Fig.2 Energy dependence of astrophysical s-factor for reaction ^{8}Li(n,γ)^{9}Li. The dark points represent s-factors corresponding to the experimental values of radiative capture cross sections given in ref.[5].

The energy dependence of S(E_{rel}) is smooth for transition involving both E1 and E2 multipoles. Again, the predictions of Coulomb breakup method are consistent with measured one. In conclusions, we have studied ^{8}Li(n, γ)^{9}Li radiative capture reaction by two different approaches with a special emphasis on the role of E2 transition in the reaction. We find that the Coulomb breakup method provides the results which are in much better agreement with the measured data. Further, the contribution of E2 transition is found to be insignificant at lower excitation energies while it becomes significant at higher excitation energies.

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