Photodisintegration cross-section of ^{9}Be

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Introduction

One of the many nucleosynthesis reaction paths to bridge the stability gap at A = 5 and A = 8 is ^{4}He(αn, γ)^{9}Be(α, n)^{12}C. The $\alpha(\alpha n$, $\gamma)^9$Be reaction represents a two step process consisting $\alpha + \alpha = {}^8$Be followed by ^{8}Be(n, $\gamma)^9$Be. Thus, ^{8}Be(n, $\gamma)^9$Be is a key reaction which can bridge the mass gap at A = 8 to carry forward the nucleosynthesis to intermediate and to heavy mass elements in α and neutron rich environment.

A direct measurement of the cross-section of the ^{8}Be(n, $\gamma)^9$Be reaction is very difficult because of the short lifetime ($\approx 10^{-16}$s) of the ^{8}Be ground state, but they can be deduced from photodisintegration cross section ^{9}Be(γ, n)^{8}Be using the principle of detailed balance. This approach is used in many experiments [1, 2] as well as in theoretical calculations.

We are using the same approach to calculate theoretically the cross-section of ^{8}Be(n, $\gamma)^9$Be by using two different theories, first order perturbation theory [3] and finite range distorted wave Born approximation theory (FRDWBA). Our main focus is on FRDWBA, where one can calculate photodisintegration cross-sections from the Coulomb breakup of projectile on some heavy target. The Coulomb dissociation cross-sections usually have a large value, so one can easily calculate photodisintegration cross-secctions from those, and then by using the principle of detailed balance as mentioned above, one can calculate the radiative capture cross-sections.

Here, we present our preliminary results for first order perturbation theory, which are compared with data from Ref. [5]. The calculations with the FRDWBA are in progress.

Formalism

We consider the elastic breakup of a two body composite projectile a in the Coulomb field of target t. Projectile a breaks up into fragments b (charged) and c (uncharged). $a + t \rightarrow b + c + t$

The relative energy spectra for the reaction is given by

$$\frac{d\sigma}{dE_{rel}} = \int_{\Omega_{bc}\Omega_{at}} d\Omega_{bc} d\Omega_{at} \times \sum_{lm} \frac{1}{(2l+1)} |\beta_{lm}|^2 \times \frac{2\pi}{\hbar v_{at}} \frac{\mu_{bc}\mu_{at} p_{bc} p_{at}}{h^6} \quad (1)$$

where v_{at} is the $a - t$ relative velocity in the initial channel, Ω_{bc} and Ω_{at} are solid angles, μ_{bc} and μ_{at} are the reduced masses, p_{bc} and p_{at} are linear momenta repsectively. β_{lm} is the reduced amplitude in post form of FRDWBA, given by

$$\hat{l}\beta_{lm}(\mathbf{q}_b, \mathbf{q}_c; \mathbf{q}_a) = \iint d\mathbf{r}_1 d\mathbf{r}_i \chi_b^{(-)*}(\mathbf{q}_b, \mathbf{r}) \chi_c^{(-)*}(\mathbf{q}_c, \mathbf{r}_c) V_{bc}(\mathbf{r}_1) \phi_a^{lm}(\mathbf{r}_1) \chi_a^{(+)*}(\mathbf{q}_a, \mathbf{r}_i) \quad (2)$$

where, $\mathbf{q}_b$, $\mathbf{q}_c$ and $\mathbf{q}_a$ are the wave vectors of b, c, and a corresponding to Jacobi vectors $\mathbf{r}$, $\mathbf{r}_c$ and $\mathbf{r}_1$, respectively. V_{bc} is the interaction between b and c. $\phi_a^{lm}(\mathbf{r}_1)$ is the ground state wave function of the projectile with relative orbital angular momentum state l and projection m. $\chi^{(-)}$'s are the distorted waves for relative motions of b and c with respect to t and the center of mass(c.m.) of the b-t system, respectively, with ingoing wave boundary conditions. $\chi^{(+)}(q_a, r_i)$ is the distorted wave for the scattering of the c.m. of projectile a with respect to the target with outgoing wave boundary conditions.

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The evaluation of β_{lm} is quite complicated as it involves a six-dimensional integral, in our theory we are using Local Momentum Approximation (LMA) [4] to solve this. This reduces the six-dimensional β_{lm} into two three-dimensional integrals, one giving the structural information and the other involving the dynamics of the reaction which in turn can be analytically solved in terms of the Bremsstrahlung integral.

The relative energy spectra (Eq.1) is related to the photodisintigration cross-section ($\sigma_{\pi\lambda}$) as:

$$\frac{d\sigma}{dE_{rel}} = \frac{1}{E_\gamma} \sum_{\pi\lambda} \sigma_{\pi\lambda}(a + \gamma \rightarrow b + c) n_{\pi\lambda} \quad (3)$$

where π is E/M (i.e. electric or magnetic transition), λ is multipolarity, $n_{\pi\lambda}$ is equivalent photon number, $E_\gamma = E_{rel} + Q$ is energy of photon and Q is the Q-value of the reaction.

Of course, for the correct application of this theory, one has to ensure that only one multipolarity (of either E or M) contributes to the cross-section. That is why one does a first order perturbation calculation before doing a final FRDWBA calculation.

For our calculations we are using Woods-Saxon potential to obtain the ground state wavefunction $\phi_a^{lm}(\mathbf{r}_1)$. The depth of the potential is adjusted to reproduce the binding energy (1.665 MeV for ^{8}Be + n). The depth turns out to be 45.58 MeV for a radius and diffuseness parameters of 1.15 fm and 0.5 fm, respectively.

Results and discussions

Fig. 1 shows photodisintegration cross-section ^{9}Be(γ, n)^{8}Be as a function of photon energy (E_γ), calculated using first order perturbation theory. In this particular case Electric dipole (E_1) transitions are found to dominate. The variation in the cross-section with diffuseness parameter of Woods-Saxon potential is also studied. With increasing diffuseness, the cross-section also increases and peak becomes more narrow. We compared the calculated cross-section with the experimental data from Ref. [5]. Our calculations are in some agreement near the threshold. As

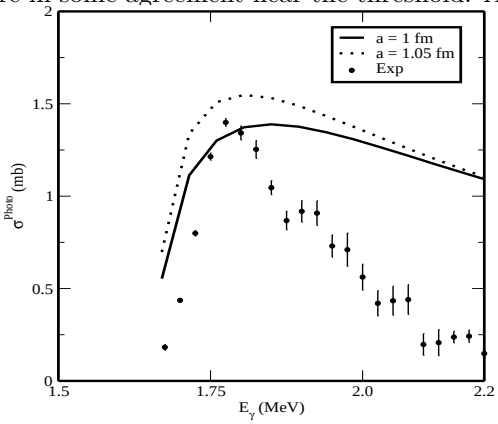

FIG. 1: The calculated ^{9}Be(γ, n)^{8}Be cross-section using first order perturbation theory, for diffuseness parameter (i) a = 1.0 fm (solid line) and (ii) a = 1.05 fm (dotted line). The experimental data is from Ref. [5]

these are our preliminary calculations, we will also try to compare our ongoing FRDWBA calculation with the recent experimental data of Ref. [6].

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