Study of (^{3}He, t) charge exchange reaction on Zr and Mg targets through distorted wave impulse approximation

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The advancement in experimental facilities across the globe has created a renewed interest in the study of charge exchange reactions of type (p, n)/(^{3}He, t) and (n, p)/(t, ^{3}He) on targets having wide range of Z number[1, 2]. These reactions serve as an effective tool to excite the isobaric analog state (IAS) of target through Fermi transitions (ΔL = ΔS = 0 and ΔT=1). IAS is the state with same structure as that of target except for the replacement of a neutron with a proton in residual nucleus.

Especially, in the limit of vanishing momentum transfer the Fermi transition strength may be linked with the weak nuclear transition strength. The strengths deduced through charge exchange reactions serve as inputs to the modeling of the explosion dynamics of a massive star [3].

In the past variety of codes based on different approaches have been developed to analyze the data obtained by charge exchange reactions [4, 5]. However, in these codes the knock-on exchange contribution is either completely ignored or is approximately considered. Thus here we present the results of (^{3}He, t) charge exchange reaction on ^{90}Zr and ^{26}Mg targets at 140AMeV energy obtained using the newly developed DCP-2 code (based on earlier version DCP-1[5]) developed by employing distorted wave impulse (DWI) approximation.

In this approach the differential cross section for A(a, b)B charge exchange reaction may be expressed as [6]

$$\frac{d\sigma}{d\Omega} = \frac{\mu_a \mu_b}{(2\pi\hbar^2)^2}\frac{k_b}{k_a}\left|\sum_{i=D,E}\sum_{k,l_1 t_1}\alpha^{t_1 s_1 l_1 k l_t}_{j_t s_t v_1}\, T^i_{t_1 s_1 l_1 k\, l_t m_{l_t}}\right|^2$$

Now The transition amplitude, T^i ,may be written in terms of direct and exchange overlap integrals as

$$T^i_{t_1 s_1 l_1 k\, l_t m_{l_t}} = \frac{(4\pi)^{3/2}}{k_a k_b}\sum_{l_a l_b} i^{l_a - l_b + \pi}\, \hat{l}_a\, (l_a 0 l_t\, m_{l_t} | l_b m_{l_t})\, O^i_{t_1 s_1 l_1 k\, l_t, l_a l_b}\, Y_{l_b m_{l_t}}(\hat{k}_b)$$

Here O^i represent the direct (i = D) and exchange (i = E) overlap integrals and are given as

$$O^D_{t_1 s_1 l_1 k\, l_t, l_a l_b} = \frac{1}{4\pi}\hat{l}_a \hat{l}_t \hat{l}_b^{-1}(l_a 0 l_t 0)\int dr_a\, \chi_{l_b}(r_a)\, f^D_{t_1 s_1 l_1 k\, l_t}\, \chi_{l_a}(r_a)$$

and

$$O^E_{t_1 s_1 l_1 k\, l_t, l_a l_b} = J\int dr_b \int dr_a\, r_b r_a\, \chi_{l_b}(r_a)\, f^E_{t_1 s_1 l_1 k\, l_t, l_a l_b}(r_b, r_a)\, \chi_{l_a}(r_a)$$

respectively. Further the direct (f^D) and exchange (f^E) form factors may be expressed as

$$f^D_{t_1 s_1 l_1 k\, l_t}(r_a) = \iota^{-\pi}(-)^{l_1}\hat{l}_t^{-1}\int r^2 dr V^D_{t_1 s_1 k}(r)\int r_2^2 dr_1\, \rho^D_{P,kl_t l_1}(r_a, r_1, r)\, \rho^D_{T,l_1}(r_1)$$

and

$$f^{E,PW}_{t_1 s_1 l_1 k\, l_t}(r_b) = \sqrt{4\pi}\sum_{l\lambda l_r}\iota^{-\pi - l_r - l}\hat{k}\hat{\lambda}(k0\lambda 0|l_r 0)\hat{l}_1 \hat{l}_r W(l\lambda l_t k : l_1 l_r)$$
$$\times (-)^{k + l_1 - l_t}(l m_{l_t} l_r 0 | l_t m_{l_t})\int dr\, r^{k+2} G^k_{t_1 s_1 l_1 l\lambda}(r_b, r)\, j_{l_r}(\alpha k_a r / a)$$

respectively.

The variables appeared in above Eqs. are having same meaning as in ref. [6].

Results and Discussion

This conference contribution focused on the study of Fermi transitions ((ΔL = ΔS = 0 and ΔT=1 in the limit of vanishing momentum transfer) for which proportionality relation between the differential cross section and the corresponding transition strength exists and reproduced below as [7]:

$$\frac{d\sigma}{d\Omega}(q=0) = \hat{\sigma}_F\, B(F)$$

The specific objective is, to investigate the significance of inclusion of exactly calculated knock-on exchange amplitude while analyzing the differential cross section for the ^{90}Zr(0$^+$, gs)(^{3}He, t)^{90}Nb(0$^+$, 5.01) and ^{26}Mg(0$^+$, gs)(^{3}He, t)^{26}Ar(0$^+$, 0.228) charge exchange reactions. The results of present work are presented in figures 1 and 2 and it is clearly seen from the figures that the calculations overestimates the data when performed separately for direct and exchange terms. While after inclusion of exchange term contribution in the calculations along with direct cross section reduces the differential cross section in magnitude and enhance the matching between predictions and data for $^{90}Zr(0^+, gs)(^3He, t)^{90}Nb(0^+, 5.01)$ reaction.

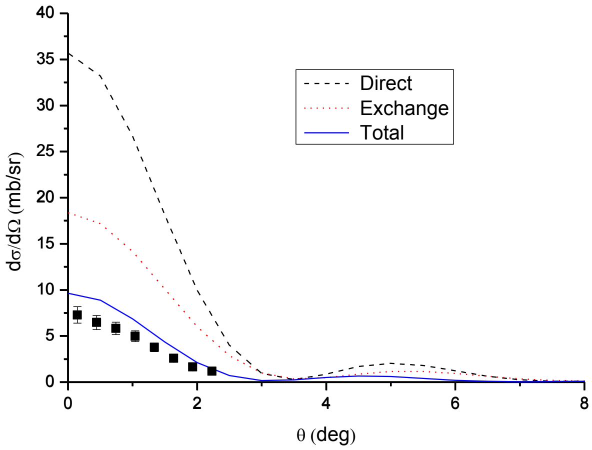

Fig.1 (color online) Differential cross section for $^{90}Zr(0^+, gs)(^3He, t)^{90}Nb(0^+, 5.01)$ reaction at 140A MeV energy. The dashed (black) and doted (red) lines corresponds to direct and exchange contribution alone. The solid (blue) line shows the results of direct summed with exchange contribution.

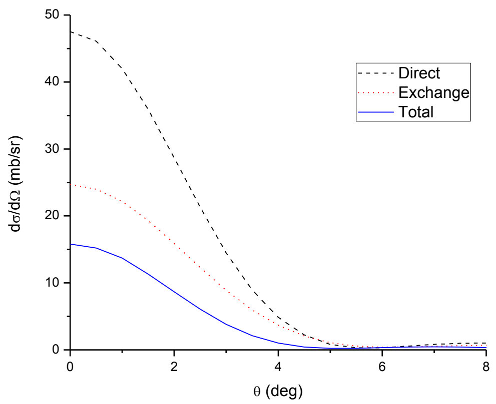

Fig.2 (color online) Same as of figure 1 but for reaction $^{26}Mg(0^+, gs)(^3He, t)^{26}Ar(0^+, 0.228)$ at 140A MeV.

In conclusion, present conference paper illustrate the importance of exactly calculated exchange terms while analyzing $^{90}Zr(0^+, gs)(^3He, t)^{90}Nb(0^+, 5.01)$ and $^{26}Mg(0^+, gs)(^3He, t)^{26}Ar(0^+, 0.228)$ reactions at 140AMeV and found that the inclusion of exchange contribution lower down the magnitude which eventually enhance the matching with data.

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