Contribution of tensor forces in the analysis of (^{3}He,t) charge exchange reactions using distorted wave impulse approximation

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The charge exchange reactions wherein a neutron (proton) transfer into a proton (neutron), with ΔT=1, ΔS=1 or ΔS=0, ΔJ=1 and angular momentum transfer ΔL=0 or 2, have long been used to analyze the spin-isospin response in nuclei [1-11]. Specifically, the Gamow-Teller (GT) transition (ΔT=1, ΔS=1, ΔJ=1 with ΔL=0) have attract more attention due to owing an approximate proportionality between the cross section at 0^o and the B(GT) values through the relation [1, 5]

$$\frac{d\sigma}{d\Omega}(q=0) = \hat{\sigma}_{GT}\, B(GT) \qquad (1)$$

Here $\hat{\sigma}_{GT}$ and $B(GT)$ is the GT unit cross section at angle 0^o and transition strengths for Gamow-Teller respectively.

Although, the β-decay provide the most reliable information regarding the B(GT) but unfortunately, the states of interest are located in a high excitation-energy region which remains inaccessible by the β-decay due to the weakness of the interaction. However the charge-exchange reactions with hadronic probe serve the purpose. Therefore, in the present conference contribution we present the results obtained through the study of (^{3}He,t) charge-exchange reaction at ^{140} A MeV on ^{13}C, ^{18}O, ^{40}Ar, ^{62,64}Ni and ^{118,120}Sn targets, within the theoretical framework of distorted wave impulse approximation (DWIA).

The transition amplitude in this approach for charge exchange reaction A(a, b)B is expressed as

$$T = \left\langle \chi_b^{(-)*} Bb \left| V(\vec{r}) \right| Aa\, \chi_a^{(+)} \right\rangle$$

Here, The interaction potential, V , contains effective nucleon-nucleon potential and may be written as

$$V = \int dx_1\, dx_2\, dx_1'\, dx_2'\, \hat{\rho}_T(x_1, x_1')\, \hat{\rho}_P(x_2, x_2') \times v_{12}(x_1' x_2', x_1\, x_2)$$

The symbols appeared in above eq. are well explained in ref [8]. Now the transition amplitude, *T*, may be re-expressed as the sum of direct, T_D , and exchange, T_E , terms by choosing the interaction potential is the sum of direct and exchange part of Love and Franey and may be rewritten as

$$T = T_D + T_E$$

$$T_D = \iiint dr_a\, dx_1\, dx_2\, \chi_b^{(-)*}(\vec{k}_b, \vec{r}_b) \times \left\langle Bb \left| V^D(\vec{r})\hat{\rho}_T(x_1, x_1)\, \hat{\rho}_P(x_2, x_2) \right| Aa \right\rangle \chi_a^+(\vec{k}_a, \vec{r}_a)$$

$$T_E = \iiint dr_a\, dx_1\, dx_2\, \chi_b^{(-)*}(\vec{k}_b, \vec{r}_b) \times \left\langle Bb \left| V^E(\vec{r})\, \hat{\rho}_T(x_1, x_1')\, \hat{\rho}_P(x_2, x_2') \right| Aa \right\rangle \chi_a^+(\vec{k}_a, \vec{r}_a)$$

Initial and final nuclear states of the projectile-target and residue-ejectile systems are represented by $|Aa\rangle$ and $|Bb\rangle$ respectively. While the relative states in the incident and exit channels are obtained through distorted wave functions $\chi_a^+(\vec{k}_a, \vec{r}_a)$ and $\chi_b^{(-)*}(\vec{k}_b, \vec{r}_b)$ respectively. Further the expressions for direct and exchange amplitudes may rewritten in term of direct (f_D) and exchange (f_E) form factor

$$T_D^{t_1 s_1 l_1 k l_t m_{l_t}} = \int d\vec{r}_a\, \chi_b^{(-)*}(\vec{k}_b, \vec{r}_a)\, f_D^{t_1 s_1 l_1 k l_t m_{l_t}}(\vec{r}_a)\, \chi_a^+(\vec{k}_a, \vec{r}_a)$$

$$T_E^{t_1 s_1 l_1 k l_t m_{l_t}} = \iint d\vec{r}_a\, d\vec{r}_b\, \chi_b^{(-)*}(\vec{k}_b, \vec{r}_b)\, f_E^{t_1 s_1 l_1 k l_t m_{l_t}}(\vec{r}_b, \vec{r}_a)\, \chi_a^+(\vec{k}_a, \vec{r}_a)\,.$$

Now the differential cross section may be calculated using following expression [10]

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

A usual here μ_a , μ_b , k_a , k_b represents the reduced masses and wave numbers for incident and exit channels, respectively. While the recoupling of various angular momenta is accounted by Racah coefficient, $\alpha_{j_t s_t v_1}^{t_1 s_1 l_1 k l_t}$.

Results and Discussion

The existed proportionality for differential cross section at zero momentum transfer and the corresponding transition strengths for Gamow-Teller, motivate us to take up the current work.

In present work we focused on inclusion of exactly calculated exchange contribution and estimate the role of tensor forces which is the one of the possible cause of uncertainty in the calculation of unit cross section and hence in the validity of proportionality relation of eq.(1)[11]. For the purpose we have used a computer code DCP2 (an upgraded version of DCP) which allow to calculate the so-called knock-on exchange transition amplitudes which were approximated in most previous calculations. The calculated results so obtained for unit cross section vs mass number for the charge –exchange reaction (^{3}He, t) on ^{13}C, ^{18}O, ^{40}Ar, ^{62,64}Ni and ^{118,120}Sn targets at 140 A MeV energy, along with the empirical function line fitted to the experimental results are presented in figure.

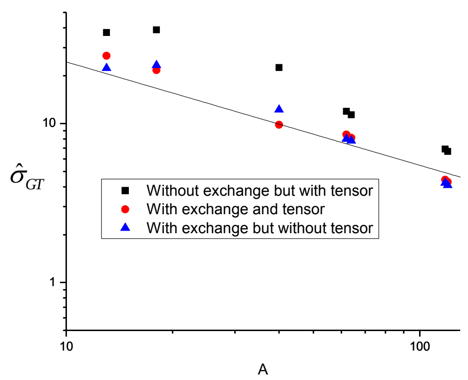

Fig. (color online) unit cross section vs. mass number for the reaction (^{3}He, t) on ^{13}C, ^{18}O, ^{40}Ar, ^{62,64}Ni and ^{118,120}Sn targets at 140 A MeV energy. The solid line depicts the power fit to the experimental results. The calculated unit cross sections with tensor forces but without and with exchange contribution are represented by Squares and Circles respectively. Triangles are representing the results without tensor forces.

It is clearly seen in the figure that the inclusion of exchange contributions in the calculations reduces the unit cross section in magnitude and increase the matching between predictions and data. Further here we have also estimated the contribution of tensor forces and found that the exclusion of these forces changes the results 5% to 16% which in results further reduces the magnitude bringing it down towards the experimental results which eventually enhance the matching between the data and predictions except ^{40}Ar [7]. It may be attributed to the fact that the tensor component of the effective nucleon-nucleon interaction that mediates the charge-exchange reaction cause the interference between the ΔL=0 or 2 amplitudes since both contributes to the ΔJ=1 GT transition. The interference can be constructive as well as destructive.

In conclusion, during the present calculation the contribution of tensor forces and the effects on including the exchange term have been studied for the

for (^{3}He, t) charge exchange reaction on ^{13}C, ^{18}O, ^{40}Ar, ^{62,64}Ni and ^{118,120}Sn targets and the results obtained clearly illustrate the importance of proper estimation of tensor forces and of correctly calculated exchange terms.

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