Analysis of (^{3}He,t) charge exchange reactions using distorted wave impulse approximation

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The spin-isospin excitations in nuclei remained the subject of intense experimental and theoretical investigations in the last few decades [1]. The charge exchange, (ΔT=1), reactions (^{3}He, t) and (t, ^{3}He) at intermediate energies have been particularly frequently employed as probes of the spin-isospin excitation in nuclei [2-6]. Especially the Gamow-Teller (GT) transitions (ΔT=1, ΔS=1, ΔJ=1 with ΔL=0) have been the matter of intensive investigation due to their key role in extracting the weak transition strength in excitation-region remains inaccessible to β-decay. The deduced strengths have been employed in calculations of late stellar evolution and neutrino-driven nucleosynthesis in which weak transition strengths play a major role [7, 8]. In this context, in the current conference contribution we list the results obtained through the study of (^{3}He,t) charge-exchange reaction at 140 A MeV on ^{120}Sn and ^{208}Pb targets, analyzed within the theoretical framework of distorted wave impulse approximation.

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

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

Here, the interaction potential V is taken as the sum of effective nucleon-nucleon potential and expressed 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 used in above equation are well explained in ref. [9]. The considered NN interaction potential $v_{12}(x_1'\, x_2', x_1\, x_2)$ is the Love and Franey type effective-interaction [10], which includes knock-on exchange contributions. The transition amplitude T may be next rewritten as the sum of direct T_D and exchange T_E terms [11]:

$$T = T_D + T_E$$

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

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

The initial and final nuclear states of the projectile-target and residue-ejectile systems are given by $|Aa\rangle$ and $|Bb\rangle$ respectively. While the distorted wave functions $\chi_a^{+}(\vec{k}_a, \vec{r}_a)$ and $\chi_b^{(-)*}(\vec{k}_b, \vec{r}_b)$ represent the relative states in the incident and exit channels, respectively. Mathematical manipulations lead to the following expressions for the direct and exchange amplitudes:

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

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

with, $f_D^{t_1 s_1 l_1 k l_t m_{l_t}}(\vec{r}_a)$ and $f_E^{t_1 s_1 l_1 k l_t m_{l_t}}(\vec{r}_b, \vec{r}_a)$ are the direct and exchange form factors. The differential cross section may be next calculated with [11]

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

Here μ_a, μ_b, k_a, k_b represents the reduced masses and wave numbers in the incident and exit channels, respectively. The Racah coefficient, $\alpha_{j_t s_t v_1}^{t_1 s_1 l_1 k l_t}$, accounts the recoupling of various angular momenta.

Results and Discussion

The existence of well established proportionality relationship for differential cross section at zero momentum transfer and the corresponding transition strengths for Gamow-Teller'

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

and Fermi transitions,

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

Provide the basis for the current work. Further here we attempted to interpret the charge exchange reactions data involving composite particles. For that purpose we have used the DCP2 (an upgraded version of DCP) code which permits us to calculate the so-called knock-on exchange transition amplitudes which were approximated in most previous calculations. The results of calculationsare presented in Figs. 1 and 2, with the latter including data.

Fig. 1depicts specifically the calculated differential cross section for the ^{120}Sn(^{3}He, t)^{120}Sb(1^{+},g.s) charge exchange reaction. The dotted and dashed lines are the contribution corresponding to direct and exchange terms while the solid line gives the combination of both.

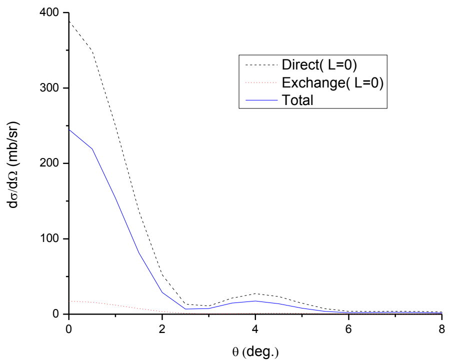

Fig. 1(color online). The calculated differential cross section for the reaction (^{3}He, t) on ^{120}Sn target at 140 A MeV energy. The solid (blue) line represents total cross section while (black) and dotted (red) lines represent, respectively, isolated direct and exchange contributions.

It is clearly seen in the fig. 1 that the inclusion of exchange contributions in the calculations reduces the differential cross section in magnitude and the similar observation can be made for fig. 2 wherein we shows the calculated differential cross section for the (^{3}He, t) reaction exciting the isobaric analogue state, together with the experimental results. The differential cross section corresponding to direct and exchange terms are shown by dashed and dotted lines, respectively, while the combination of both is represented with solid line. Again it becomes clear from the figure that the inclusion of exchange contribution in the calculations reduces the magnitude bringing it down towards the experimental results which eventually improves the agreement between the data and predictions.

To conclude, in the present calculations the exchange effects have been incorporated exactly for (^{3}He, t) charge exchange reaction on ^{120}Sn, ^{208}Pb targets. The obtained results clearly demonstrate the importance of including the correctly calculated exchange terms.

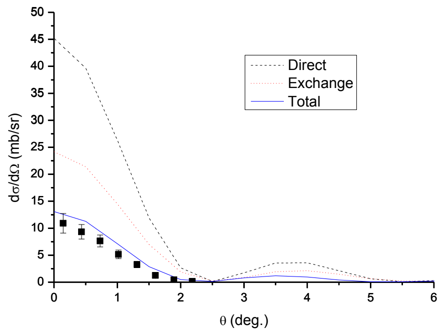

Fig. 2 (color online). Same as figure 1, but for the ^{208}Pb(0^{+}, gs)(^{3}He, t)^{208}Bi(0^{+}, 15.1) reaction at 140A MeV.

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