Charge exchange reactions induced by ^{3}He on medium and heavy mass targets at 140AMeV and 115AMeV beam energies

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Charge exchange reactions of type (^{3}He, t)/(p, n) and (t, ^{3}He)/(n, p) wherein a proton (neutron) transforms into a neutron (proton), eventually changes the isospin, ΔT=1, of the reactants has been proved a dependable means to analyze the spin-isospin excitation in nuclei[1-6]. Thus these reactions have been studied intensively around the globe experimentally as well as theoretically [7-12]. Most of these studies were primarily focused to extract Gamow-Teller (GT) and Fermi transition strengths. Specifically the GT (ΔT=1, ΔS=1, ΔJ=1 with ΔL=0) and Fermi ((ΔT=1, ΔS=0 and ΔL=0) transition have attracted more attention, because an approximate proportionality relation between the cross section at zero degree and the corresponding strength for these transition exist i.e

$$\frac{d\sigma}{d\Omega}(q=0) = \hat{\sigma}_{GT}\, B(GT) \quad \text{and} \quad \frac{d\sigma}{d\Omega}(q=0) = \hat{\sigma}_{F}\, B(F) \quad . \tag{1}$$

With $\hat{\sigma}_{GT}$ and $\hat{\sigma}_F$ represents the unit cross sections at zero degree angle for Gamow-Teller and Fermi transitions while $B(GT)$ and $B(F)$ are the corresponding transition strengths respectively. In the limit of vanishing momentum transfer the transition strengths, deduced from charge exchange reactions (with $\Delta T_z = -1(\beta^-)$ and $\Delta T_z = 1(\beta^+)$) may be connected directly to the weak nuclear transition strength in excitation energy region which otherwise remains inaccessible through ordinary β-decay (see fig. 1). Further, the deduced values for B(GT) and B(F) serve as major ingredients in the calculation of late stellar evolution and neutrino-driven nucleosynthesis wherein weak interactions play critical role [5,6]. Therefore here we present the results of (^{3}He,t) charge-exchange reaction at 140AMeV and 115AMeV beam energies on ^{18}O, ^{26}Mg, ^{58}Ni and ^{118,120}Sn targets, within the theoretical framework of plane wave and distorted wave impulse approximations using computer code DCP2.

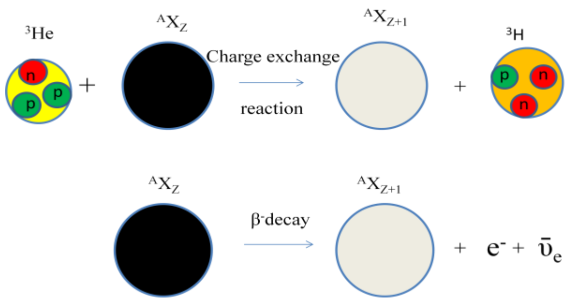

Fig. 1 (color online) Charge exchange reaction (^{3}He, t) and β$^-$ decay.

In the impulse approximation the differential cross section for inelastic charge exchange reaction of type A(a, b)B may be conveniently expressed as [9,13]

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

The symbols appeared in above eq are having their usual meanings and are discussed in details in Ref. [9,13]. Now using eqs. (1) and (2) the unit cross sections corresponding to GT transition have been calculated for above said targets and results obtained are presented in fig. (2). Here for each projectile target combination five different calculations have been made at 140AMeV energy case (I) plane-wave (PW) calculation without recoil and exchange contribution to the reaction and termed as Direct (PW) case (II) plane-wave (PW) calculation with inclusion of exchange contribution and is denoted with total (PW) case (III) plane-wave (PW with recoil) here we consider recoil effects in the plane-wave and also include the exchange terms (Total

(PW with recoil)), case (IV) distorted –wave (DW) calculations wherein calculations has been performed by employing distorted wave impulse approximation with no exchange contributions in the calculation and are presented with label Direct (DW) and in case (V) Total (DW) gives the results for distorted wave calculations with exchange contribution. Additionally, in fig. 2, we present the results corresponding to total (direct + exchange) contribution at 115AMeV just to see the sensitivity of the present calculations on projectile incident energy. The calculated results are compared with the empirical function (line) fitted to experimental results obtained through relation $\hat{\sigma}_{GT,\,fit} = 109/A^{0.65}$ for Gamow-Teller transitions. In the figure it is clearly demonstrated that the plane wave calculations substantially overestimate the fit line with a factor of 10 to 40 through whole mass range of targets. However, the consideration of recoil effect in the calculation reduces the magnitude of unit cross section significantly which finally decrease the

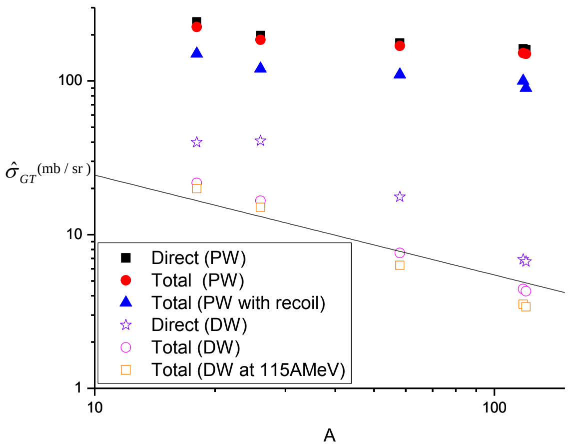

Fig. 2 (color online). Mass dependence of unit cross section obtained from charge exchange reactions induced by ^{3}He at 140AMeV for Gamow-Teller transitions. The solid line represents a power fit to the experimental results. The filled squares (Black), circles (red) and triangle (blue) represents the results without exchange(Direct (PW)), with exchange (Total (PW)) and with exchange and recoil effects in plane wave impulse approximation (total(PW with recoil)) respectively. While the results for distorted wave approximation are shown by open stars (Direct (DW)) and circles (Total (DW)) with and without exchange terms respectively. Calculations shown with open squares (Total DW) performed at 115AMeV

difference between calculations and the fitted line. Nevertheless the DW calculations also overestimate the fitted line with a factor of 2 to 4 times for ^{120}Sn to ^{18}O targets. It is worth mentioning here that unit cross section decreases up to 60% on inclusion of exchange terms in the DW calculation which in turn enhance the matching with fitted line. The detail results for Fermi transitions are given in ref [13].

In conclusion, this conference contribution presents the analysis of charge exchange reaction (^{3}He,t) on ^{18}O, ^{26}Mg, ^{58}Ni, and ^{118,120}Sn targets. The unit cross sections have been calculated through PW and DW impulse approximation with recoil effects in PW calculations. The exchange contribution to the reaction has also been incorporated. In nutshell, current analysis shows that quantitative analysis of the charge exchange reaction data really need the consideration of correctly calculated exchange terms.

Acknowledgements

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