# Contribution of tensor and exchange terms in $^{40}$Ar ($^{3}$He, t) $^{40}$K charge exchange reaction

Ankita and Pardeep Singh*
*Department of Physics, Deenbandhu Chhotu Ram Science and Technology University, Murthal-131039, Sonipat, Haryana.*

## Introduction

In recent years, significant attention has been directed to understand Fermi (F) and Gamow-Teller (GT) transitions through ($^{3}$He, t) charge-exchange reactions performed at intermediate beam energies. Also, these reactions have been a key probe to revel the nuclear structure, electron capture and nucleosynthesis processes [1-3]. These transitions are characterized by specific quantum numbers ΔT=1, ΔS=0 and ΔL=0 for Fermi and ΔT=1, ΔS=1, ΔJ=1 with ΔL=0, 2 for GT transitions. Further, the importance of charge exchange reactions also exhibits through an existing relation between the differential cross-section at zero momentum transfer and corresponding transition strengths expressed as follows:

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

Here, the symbols $\hat{\sigma}_{\mathrm{GT}}$ and $\hat{\sigma}_{\mathrm{F}}$ denote the unit cross-sections at zero-degree angle for Gamow-Teller and Fermi transitions, respectively, while, B(GT) and B(F) are the corresponding transition strengths. This relationship facilitates the extraction of B(GT) values for higher excited states in atomic nuclei, which are remains unattainable by β-decay. Therefore, in present contribution we have investigated the ($^{3}$He, t) charge exchange reactions by employing the DCP-2 computer code based on Distorted Wave Impulse Approximation (DWIA) wherein knock-on exchange effects have been treated properly.

## Results and discussion

The calculated differential cross-sections for the $^{40}$Ar ($^{3}$He, t) $^{40}$K reaction at 140 MeV/nucleon for both Fermi and Gamow-Teller transitions ground states are presented in Figures 1 and 2 respectively. We have done calculation by considering direct and exchange terms after including and excluding tensor forces. The optical model potential parameters for incoming channel were deduced by interpolating parameters from the analysis of $^{3}$He elastic scattering data on different nuclei [4,5]. One body transition densities (OBTDs) are computed by using sd-pf model space with GXPF1J interaction derived through G-matrix.[6] Additionally, the effective nucleon-nucleon t-matrix interaction strength has been determined using the Love and Franey interaction at 140 MeV/nucleon and for more detailed description readers are suggested to refer ref. [7].

It is clearly visible from figures (1) and (2) that a significant reduction in the cross-section magnitude has been observed by inclusion of exchange term with direct term.

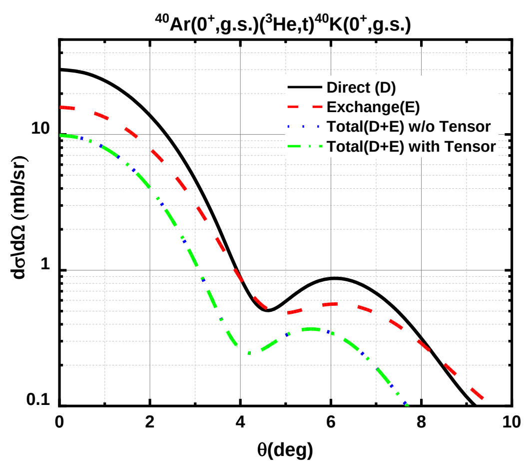


**Fig. 1** (color online) The ($^{3}$He, t) differential cross-section for $^{40}$Ar (0$^{+}$, g.s.) → $^{40}$K (0$^{+}$, g.s.) at 140 MeV/nucleon for Fermi transition. Solid (black) and dashed (red) lines represents the direct and exchange contribution separately, while dotted (blue) and dash-dotted (green) lines representing total contributions without and with tensor forces respectively.

*Electronic address: panghal005@gmail.com

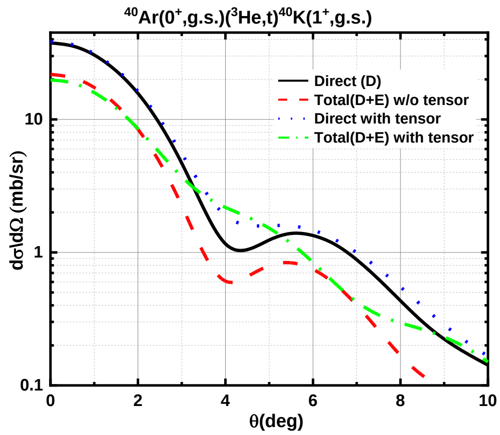


**Fig. 2** (color online) The ($^3$He, t) differential cross-section for $^{40}$Ar ($1^+$, g.s.) → $^{40}$K ($1^+$, g.s.) at 140 MeV/nucleon for GT transitions. Here, the solid (black) and dotted (blue) lines represents the direct component after excluding and including tensor forces respectively, while the dashed (red) and dash-dotted (green) lines show the total contributions without and with the tensor force respectively.

We have observed 67% decrement in the magnitude of cross-section for Fermi and 42% for Gamow-Teller transitions due to the inclusion of exchange terms contribution. Furthermore, the magnitude has been decreased by 10% at forward angles by including tensor force contribution in the total (D+E) calculation for GT transitions, while there is no effect observed for Fermi transitions on including tensor forces. Here, we have also calculated the unit cross-section at zero-degree angle using equation (1) and predicted results are tabulated in Table 1. The corresponding results has been compared with the results of empirical relations $\hat{\sigma}_{GT,fit} = 109/A^{0.65}$ and $\hat{\sigma}_{F,fit} = 72/A^{1.06}$ [9] which gives a fit to experimental results. Furthermore, in these calculations, we have noticed that due to inclusion of tensor forces contribution the results corresponding to Total (D+E) cross-section for Gamow-Teller transitions are moves closer to the empirical fitted data. This improvement may be due to the influence of tensor force on effective NN interactions, particularly in ΔJ=1 transitions. Since, the interference effects between ΔL=0 and ΔL=2 amplitudes can be either constructive or destructive in nature.

**Table 1:** The estimated unit cross-section for $^{40}$Ar ($^3$He, t) $^{40}$K reaction at 140 MeV/nucleon with and without inclusion of tensor term for Fermi and Gamow-teller transitions.

| Reaction / Unit cross-section | $^{40}$Ar ($0^+$, g.s.) → $^{40}$K ($0^+$, g.s.) (IAS) | $^{40}$Ar ($1^+$, g.s.) → $^{40}$K ($1^+$, g.s.) (GT) |
|---|---|---|
| $\hat{\sigma}_{exp.fit}$(mb/sr) | 1.44 | 9.91 |
| $\hat{\sigma}_{D}$(mb/sr) | 7.52 | 19.38 |
| $\hat{\sigma}_{D+E}$(mb/sr) w/o tensor | 2.46 | 11.23 |
| $\hat{\sigma}_{D+E}$(mb/sr) with tensor | 2.46 | 10.20 |

## Conclusion

The exchange terms and tensor force contributions have been accounted in the $^{40}$Ar ($^3$He, t) $^{40}$K charge-exchange reaction at 140 MeV/nucleon using DWIA approximation. The results demonstrate that the inclusion of both exchange terms and tensor forces significantly impact the cross-section calculations and narrowing the gap between theoretical predictions and fit to experimental results.

## References

[1] M. N. Harakeh and A. Vander Woude, Giant Resonances (Oxford University, New York, 2001).
[2] K. Pham et al., Phys. Rev. C **151**, 2 (1995).
[3] T. N. Taddeucci et al., Nucl. Phys. A **469**, 125 (1987).
[4] A.J. Koninga, J.P. Delarocheb Nucl. Phys. A **713**, 231 (2003).
[5] R. G. T. Zegers et al., Phys. Rev. Lett. **99**, 202501 (2007).
[6] Khalid. S. Jassim Chinese Journal of Physics **51**, 441 (2013).
[7] M. A. Franey and W. G. Love et al., Phys. Rev. C **31**, 488 (1985).
[8] Pardeep Singh et al., Mod. Phys. Lett. A **35**, 2050045 (2020).
[9] Ankita and Pardeep Singh Mod. Phys. Lett. A **38**, 2350066 (2023).