Excited states of ^{28}Si and the spectroscopic factor

*Aparajita Dey[1], S. Kundu[1], T.K. Rana[1], K. Banerjee[1], C. Bhattacharya[1], T.K. Ghosh[1], S. Bhattacharya[1], G. Mukherjee[1], J.K. Meena[1], M. Biswas[2], D. Gupta[3], P. Mali[4], S. Mukhopadhyay[1], S.R. Banerjee[1], D. Pandit[1], A. Shrivastava[5], Suresh Kumar[5], A. Chatterjee[5], K. Ramachandran[5]

[1]Variable Energy Cyclotron Centre, 1/AF, Bidhan Nagar, Kolkata – 700 064, INDIA
[2]Department of Physics, Heritage Institute of Technology, Kolkata, INDIA
[3]Bose Institute, Department of Physics and CAPSS, Salt Lake City, Kolkata – 700091, INDIA
[4]Department of Physics, University of North Bengal, Siliguri – 734013, INDIA
[5]Nuclear Physics Division, Bhabha Atomic Research Centre, Trombay, Mumbai – 400085, INDIA
**email: aparajita@vecc.gov.in*

The study of inelastic scattering and/or single nucleon transfer reaction gives valuable information about the nuclear structure. In recent years, there has been a lot of interest in studying different inelastic and transfer reactions and heavy-ion ($7 \leq A_{proj} \leq 20$) induced reactions provide a wide opportunity for studying various inelastic and transfer channels [1].

In the present work, we have studied the ground and excited states of ^{28}Si nucleus using ^{27}Al(^{12}C, ^{11}B)^{28}Si (one proton transfer) reaction at 81 and 85 MeV energies and ^{28}Si(^{12}C, ^{12}C*)^{28}Si* (inelastic scattering) reaction at 77 and 85 MeV energies. The spectroscopic strength values for different states of ^{28}Si were extracted several times using both light-ion and heavy-ion reactions but discrepancy still persists in the results [2-5].

The experiment was performed using ^{12}C ion beam of energies 77, 81 and 85 MeV from the BARC-TIFR 14UD pelletron facility at Mumbai. The targets were ^{27}Al (~ 550 μg/cm^2) and ^{28}Si (~ 420 μg/cm^2). Both elastic and transfer channels were detected using Si-Si (~ 10μm ΔE and 350 μm E) and Gas-Si (~ 80 Torr P_{10} ΔE and 450 μm E) telescopes. Well separated ridges corresponding to different fragments as well as excited states are clearly seen in ΔE-E scatter plot (Fig. 1).

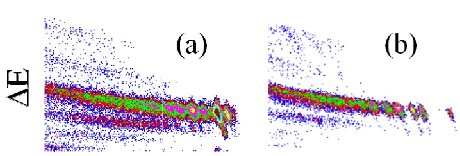

Fig. 1: Two dimensional ΔE-E plot for (a) ^{27}Al(^{12}C, ^{11}B)^{28}Si reaction at 81 MeV, $\theta_{lab} = 20^o$ and (b) ^{28}Si(^{12}C, ^{12}C)^{28}Si reaction at 77 MeV, $\theta_{lab} = 20^o$.

Here we report the spectroscopic factors for the ground and two excited states of ^{28}Si nucleus. The energy (E_X), spin and parity (J^π) of the ground, first and second excited states are 0.0 MeV 0^+, 1.78 MeV 2^+ and 4.62 MeV 4^+, respectively. These states have been populated through one proton transfer channel using ^{27}Al(^{12}C, ^{11}B)^{28}Si reaction at 81 and 85 MeV and inelastic scattering using ^{28}Si(^{12}C, ^{12}C)^{28}Si reaction at 77 and 85 MeV.

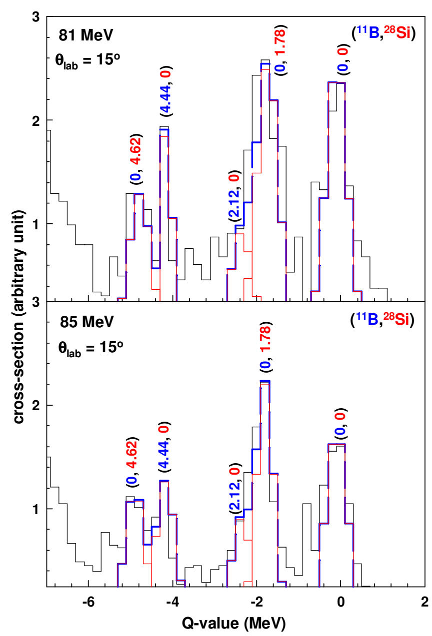

Fig. 2: Partial energy spectrum of ^{11}B measured at $\theta_{lab} = 15^o$ in ^{27}Al(^{12}C, ^{11}B)^{28}Si reaction at 81 and 85 MeV.

The partial energy spectra for one proton transfer channel (^{11}B) measured at $\theta_{lab} = 15^o$ in the ^{27}Al(^{12}C, ^{11}B)^{28}Si reaction at 81 and 85 MeV have been displayed in Fig. 2. The different states are labeled according to their excitation energy (in

MeV) in ^{11}B and ^{28}Si nucleus. The red curve shows the contribution from each states extracted using Gaussian function. The dashed curve shows the sum contribution from all indicated states. The angular distribution of ground (0^+), first (2^+) and second (4^+) excited states of ^{28}Si nucleus have been analysed using the distorted wave Born approximation (DWBA) calculation.

The theoretical zero-range and finite-range DWBA calculations have been done using the code DWUCK4 and DWUCK5 [6], respectively. The required optical model potential parameters have been extracted by fitting the elastic angular distribution data using the code ECIS94 [7].

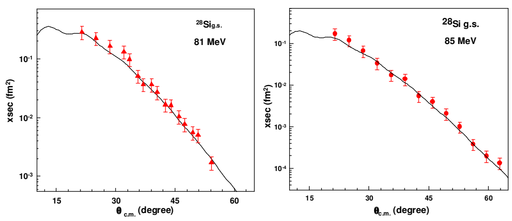

Fig. 3: The angular distribution for ground state at 81 and 85 MeV measured at ^{12}C + ^{27}Al reaction.

For finite range calculation the spectroscopic strength G is given by the relation

$$\left[\frac{d\sigma}{d\Omega}\right]_{\exp t} = Gg\left[\frac{d\sigma}{d\Omega}\right]_{DW5}$$

$$G = \frac{2j_f + 1}{2j_i + 1} C^2 S$$

where $[d\sigma/d\Omega]_{expt}$ is the experimentally measured cross-section, $[d\sigma/d\Omega]_{DW5}$ is the differential cross-section predicted by DWUCK5 and g is the light particle spectroscopic strength. For $^{12}C_{g.s.}$ = $^{11}B_{g.s.}$ + p reaction, g = 2.85 [8]. C^2 is the isospin Clebsch-Gordon coefficient, *S* is the spectroscopic factor and initial and final spin of the particle are j_i and j_f, respectively.

For zero range calculation, the experimental cross-section is given by

$$\left[\frac{d\sigma}{d\Omega}\right]_{\exp t} = N\frac{2j_f+1}{2j_i+1}\frac{2l+1}{2j+1}\left[\frac{d\sigma}{d\Omega}\right]_{DW4}$$

where N is the normalization constant, $[d\sigma/d\Omega]_{DW4}$ is the differential cross-section predicted by the code DWUCK4 and j (= l + s) is the total angular momentum of the particle.

The angular distribution for the ground state at 81 (triangle) and 85 (circle) MeV have been shown in Fig. 3 for ^{12}C + ^{27}Al reaction. The extracted G (strength) value for 81 and 85 MeV are 0.58 and 0.39, respectively and the *S* (factor) values corresponding to ground state are 0.387 and 0.327. The spectroscopic strength and factors for all three states are given in Table 1 for comparison along with the shell model value for strength.

Table 1: Extracted values for G and *S* for ^{28}Si.

State	G (present work)	G (shell model)	*S* (present work)
81 MeV			
0.0 MeV, 0^+	0.58	0.53	0.387
1.78 MeV, 2^+	0.40	0.38	1.60
4.62 MeV; 4^+	0.45	0.33	0.90
85 MeV			
0.0 MeV, 0^+	0.49	0.53	0.327
1.78 MeV, 2^+	0.47	0.38	1.88
4.62 MeV; 4^+	0.40	0.33	0.80

It has been found from Table 1 that the values of spectroscopic factors are independent of bombarding energy. The energy spectrum of ^{12}C at 21^o is shown in Fig. 4 for ^{12}C + ^{28}Si at 77 MeV. The analysis of the ^{12}C + ^{28}Si reaction is going on.

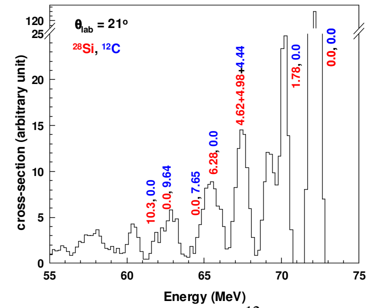

Fig. 4: Partial energy spectrum of ^{12}C at 21^o. States are indicated by their energies.

References

[1] R.A. Broglia, et al., Phys. Rep. **29** (1977) 291.
[2] J.S. Winfield, *et al.*, Phys. Rev. C **39** (1989) 1395.
[3] J. Kalifa, *et al.*, J. Phys. (paris) **34** (1973) 139.
[4] R.W. Barnard and G.D. Jones, Nucl. Phys. **A108** (1968) 641.
[5] S.K. Das, *et al.*, Phys. Rev. C **60** (1999) 044617.
[6] P.D. Kunz, http://spot.colorado.edu/~kunz/DWBA.html
[7] J. Raynal, ECIS94, NEA 0850/16.
[8] L. Jarczyk, *et al.*, Phys. Rev. C **44** (1991) 2053.