

Structure of ^{26}Al studied by one - nucleon transfer reaction $^{27}\text{Al}(d,t)$

Vishal Srivastava^{1,a}, C. Bhattacharya¹, T. K. Rana¹, S. Manna¹, S. Kundu¹, S. Bhattacharya¹, K. Banerjee¹, P. Roy¹, R. Pandey¹, G. Mukherjee¹, T. K. Ghosh¹, J. K. Meena¹, T. Roy¹, A. Chaudhuri¹, M. Sinha¹, A. Saha¹, A. Dey¹, Md. A. Asgar¹, Subinit Roy², and Md. M. Shaikh²

¹Variable Energy Cyclotron Centre, 1/AF, Bidhan Nagar, Kolkata 700064, India

²Saha Institute of Nuclear Physics, 1/AF, Bidhan Nagar, Kolkata 700064, India

Abstract. The excited states of ^{26}Al have been produced and studied using $^{27}\text{Al}(d,t)$ reaction with 25 MeV deuteron as projectile. Optical model potential parameters were extracted from the measured elastic scattering angular distribution. Zero range distorted wave Born approximation analysis for the ground and 0.223 MeV states of ^{26}Al have been done. The spectroscopic factors calculated for these states are found to be in good agreement with the previously reported values.

1 Introduction

Transfer reaction provides a powerful tool to study the structure of nuclei. The nucleus ^{26}Al is the first radioisotope detected in the interstellar medium with half life 7.2×10^5 years. Its lifetime is much shorter than the $\sim 10^{10}$ years of galactic evolution. So from astrophysics point of view as well as basic nuclear physics, the nucleus ^{26}Al has evoked lot of interest - as the decay of ^{26}Al may be used as isotopic chronometer for galaxies [1]; moreover, it is also used to probe the Standard model [2], [3]. In each case, specific aspects of the structure of ^{26}Al nucleus, e.g., excitation energies, spin and parity assignments, branching ratios, spectroscopic factors and life times are required.

Though, many of these specifics are known [4], yet, there are possibilities to search for new levels for ^{26}Al . Very recently, five new levels of ^{26}Al have been identified using the reaction $^{28}\text{Si}(p,^3\text{He})$ [5]. The structure of ^{26}Al has already been studied by one as well as two nucleon transfer channels using several reactions, like $^{28}\text{Si}(d,\alpha)$ and $^{24}\text{Mg}(^3\text{He},p)$ [6], $^{27}\text{Al}(p,d)$ [7] and $^{27}\text{Al}(^3\text{He},\alpha)$ [8]. However, the (d,t) channel has not been explored to study the structure of ^{26}Al .

Recently, we have studied the structure of ^{26}Al by single nucleon transfer reaction $^{27}\text{Al}(d,t)$ producing various final states of ^{26}Al and compared them with those produced from other single nucleon transfer reactions. The other aim was to search for any new states at higher excitations in ^{26}Al . In this work, we report our initial results for ground (5^+ : 0.0 MeV) and first excited (0^+ : 0.223 MeV) states of ^{26}Al produced via $^{27}\text{Al}(d,t)$ reaction. The spectroscopic strengths for these states were measured and reported in this work.

^ae-mail: vishalphy@vecc.gov.in

2 Experimental procedure

The experiment was performed using 25 MeV deuteron beam from the Variable Energy Cyclotron at VECC, Kolkata. The target was a self-supporting ^{27}Al foil ($90 \mu\text{g}/\text{cm}^2$). The angular distributions of various transfer channels were measured using a three-element telescope, consisting of a single-sided $55 \mu\text{m}$ thick Si (ΔE) strip detector (16 vertical strips of 3 mm width), followed by a double-sided $1030 \mu\text{m}$ Si (E) strip detector (16 strips, width 3 mm, both side mutually orthogonal to each other) backed by four CsI(Tl) detectors, each of thickness 6 cm. A 6 mm horizontal slit was placed in front of the telescope. The solid angle subtended by each strip was 0.47 msr. Calibration of each detector has been done using Th- α source.

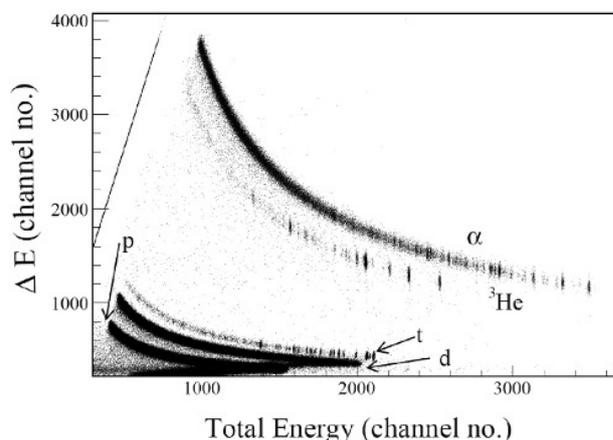


Figure 1. Two dimensional $\Delta E - (E + \Delta E)$ plot obtained using Si ($55 \mu\text{m}$)- Si ($1030 \mu\text{m}$) combination for the d (25 MeV) + ^{27}Al reaction at $\theta_{lab} = 37^\circ$.

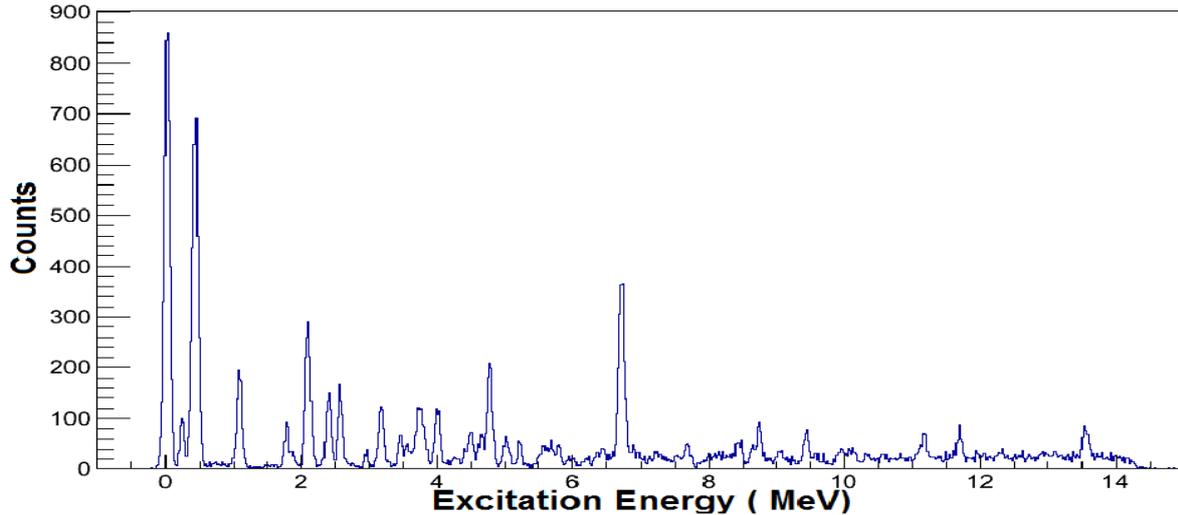


Figure 2. An excitation energy spectrum of ^{26}Al obtained from $^{27}\text{Al}(d,t)$ reaction at $\theta_{lab} = 37^\circ$.

The inclusive angular distributions of the ejectiles have been measured in the angular range of 16° to 40° in the step of 0.9° . Well separated ridges corresponding to different outgoing particles as well as excited states corresponding to the nuclei ^{26}Al , ^{26}Mg and ^{25}Mg produced via the reaction channels $^{27}\text{Al}(d,t)$, $^{27}\text{Al}(d,^3\text{He})$ and $^{27}\text{Al}(d,\alpha)$ are clearly seen in $\Delta E-(E+\Delta E)$ scatter plot (Fig.1). A typical excitation energy spectrum of ^{26}Al populated via the reaction channel $^{27}\text{Al}(d,t)$ is shown in Fig.2. Well separated peaks corresponding to different populated states in ^{26}Al are clearly visible. The angular distributions of elastically scattered deuteron and states of ^{26}Al at excitation energies 0.0 MeV and 0.223 MeV are displayed in Figures 3 and 4 respectively.

3 Results and Discussion

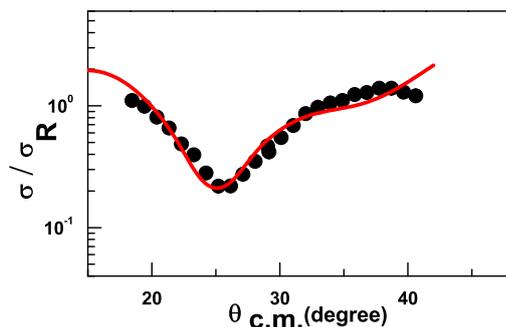


Figure 3. Angular distribution of elastically scattered deuteron from ^{27}Al at $E_{lab} = 25$ MeV. The filled circles represent experimental data points and solid line represents optical model fitting.

The measured angular distribution for the elastically scattered deuteron (filled circles in Fig.3) has been fitted (shown by solid lines in Fig.3) using the optical model search code ECIS94 [9]. The parametric Wood Saxon (WS) form is used for optical model analysis for both real

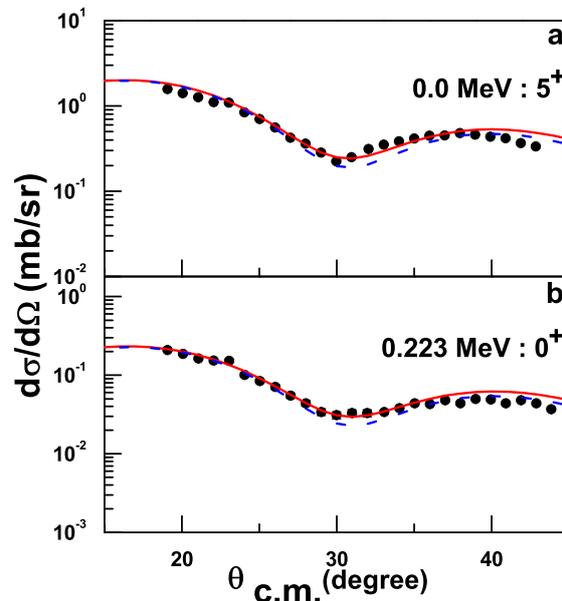


Figure 4. Angular distribution of differential cross-sections for (a) 0.0 MeV and (b) 0.223 MeV states of ^{26}Al from the reaction $^{27}\text{Al}(d,t)$. The filled circles represent experimental data points, solid line represents zero range DWBA predictions and dashed line represents predictions from DWBA calculation using finite range parameter 1.36 fm^{-1} .

and imaginary potentials. The search was started from the parameters given in [10]. The parameters of the real and imaginary potentials were varied to arrive at the minimum χ^2 per degree of freedom, χ^2/N_f . The best fit potential parameters corresponding to minimum χ^2/N_f are listed in Table 1. The distorted wave Born approximation (DWBA) calculations have been performed using DWUCK4 code [11] for the observed states of ^{26}Al produced in $^{27}\text{Al}(d,t)$ reaction. The triton optical model parameters were ob-

Table 1. The best fit potential parameters used in DWUCK4 code for $^{27}\text{Al}(d,t)$ reaction.

Reaction	V (MeV)	R_R (fm)	a_R (fm)	W (MeV)	W_D (fm)	R_I (fm)	a_I (fm)	V_{Is} (MeV)	R_{Is} (fm)	a_{Is} (fm)	R_C (fm)
$^a d+^{27}\text{Al}$	89.209	1.061	0.701		2.25	1.36	0.850	9.00	1.061	0.801	1.25
$^b t+^{26}\text{Al}$	161.91	1.200	0.720	39.99		1.40	0.840	2.50	1.20	0.720	1.30
$^c n+^{26}\text{Al}$		1.300	0.600								

^aPresent data^bPerey and Perey¹²^cPotential strength adjusted to get the correct binding energy.

tained from the global fit parameters given by Perey and Perey [12]. In this work, we are presenting DWBA calculation for ground state (5^+) and first excited state (0^+ : 0.223 MeV) states of ^{26}Al . The transferred angular momentum (L_{tr}) was estimated for neutron pick up from $0d_{5/2}$ orbital using the relation given in [13]. To determine the spectroscopic factors, we used the following relation between experimental and theoretical cross sections [14];

$$\left(\frac{d\sigma}{d\Omega}\right)_{exp.} = \frac{NC^2S}{2J+1} \left(\frac{d\sigma}{d\Omega}\right)_{DWBA} \quad (1)$$

where $\left(\frac{d\sigma}{d\Omega}\right)_{exp.}$ is the experimental differential cross-section and $\left(\frac{d\sigma}{d\Omega}\right)_{DWBA}$ is the cross-section predicted by the DWUCK4 code. C^2 is the isospin Clebsch-Gordon coefficient and S is the $n+^{26}\text{Al}$ spectroscopic factor. The extracted values of the spectroscopic factors for two states of ^{26}Al are listed in Table 2. Two different approaches were followed in the estimation. First a zero range calculation was performed (solid lines in Fig. (4a), (4b)), followed by a DWBA calculation including a finite range parameter of 1.36 fm^{-1} (dashed lines in Fig. (4a), (4b)). A normalization $N = 2.54$ used in [14], calculated with a finite range parameter of 1.36 fm^{-1} for (d,t) by Hering et al. [15], was used to estimate C^2S in this work. It is obvious from Fig. 4 that both the assumptions reproduced the angular distributions quite well, especially in the forward angles. However, the zero range calculation described the minima in the angular distribution better. We used the extracted C^2S values with the two approximations as the two limits and determined the uncertainties in the spectroscopic factors. In addition, uncertainty due to the average error in the experimental data points used to extract C^2S values was also included in the uncertainty in spectroscopic factors. The two uncertainties are added in quadrature.

Table 2. Comparison of spectroscopic factor obtained from different reactions.

Ex(MeV)	J^π	$C^2S_{exp.}$	$(p, d)^7$	$(^3\text{He}, \alpha)^8$
0.0	5^+	0.76 ± 0.15	1.37	1.05
0.223	0^+	0.09 ± 0.02	0.20	0.14

4 Summary and Conclusion

One-neutron transfer reaction channel has been studied using the reaction $^{27}\text{Al}(d,t)^{26}\text{Al}$ at $E_d = 25 \text{ MeV}$. In the tritium ejectile spectrum different peaks corresponding to different excited states of ^{26}Al have been observed. The optical model potential parameters have been extracted from $d+^{27}\text{Al}$ elastic scattering data. The experimental angular distributions for ground state and 0.223 MeV state of ^{26}Al have been studied with zero range approximation of DWBA and also with the finite range correction term. The zero range approximation yielded a better overall description of angular distribution data. The extracted values of spectroscopic factors are within 20% uncertainty and also compare well with the previous measurements.

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