Inelastic scattering of alpha particles from ^{27}Al target

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At a few tens of bombarding energy, α-particle elastic scattering angular distribution exhibits pronounced structure which usually varies smoothly with target mass and incident energy. This is particularly true for the targets in the s-d shell. On the other hand, inelastic scattering angular distribution gives a flavor of the deformed configuration of the composite system formed in the nuclear reaction.

Here we report the α-particle elastic and inelastic scattering angular distributions from ^{27}Al target at 50 MeV incident energy.

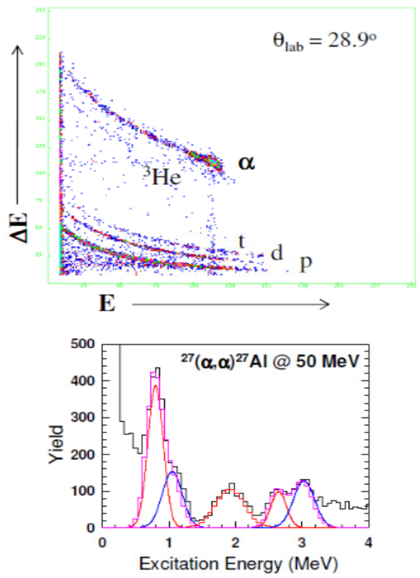

Fig. 1: Two dimensional ΔE-E plot using Si (500 μm) – CsI(Tl) combination for the α (50 MeV) + ^{27}Al reaction at the angle θ_{lab} = 28.9^o and the corresponding α-particle spectrum.

The experiment was performed using the α-ion beam of energy 50 MeV from the Variable Energy Cyclotron at VECC, Kolkata. The target was self-supporting ^{27}Al foil (~ 225 μg/cm^2). The experimental details were given in Ref. [1]. A typical ΔE-E plot along with the corresponding α-particle spectrum at θ_{lab} = 28.9^o is shown in Fig.1.

The elastic scattering angular distribution had been analyzed using the optical model potential with the following form:

$$U(r) = V(r) + i[W_F(r) + W_D(r)] + V_C(r)$$

$$V(r) = -V_o\,[1+ \exp(r-R_o)/a_o]^{-1}$$

$$W_F(r) = -W_v\,[1+ \exp(r - R_v)/a_v]^{-1}$$

$$W_D(r) = -W_s\,[1+ \exp(r - R_s)/a_s]^{-1}$$

where V(r) denotes the volume type Woods-Saxon real potential, $W_F(r)$ is a volume type Woods-Saxon imaginary potential to simulate the fusion after penetration of the barrier and $W_D(r)$ is a derivative type Woods-Saxon imaginary potential to account for the absorption due to reactions occurring at the surface and $V_C(r)$ is the Coulomb potential. The search code ECIS94 [2] was used to perform the optical model calculations to obtain the parameters of the best fit potential. The experimental elastic scattering angular distribution is shown in Fig. 2 by solid points. The best fit with optical model potential parameters is shown in Fig. 2 by solid line. The best fit parameters are given in Table 1 with r_C = 1.31 fm, the Coulomb radius.

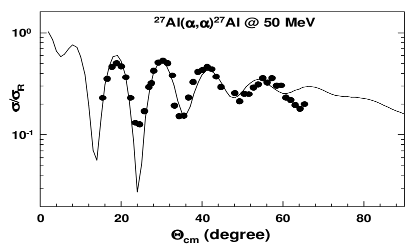

Fig. 2: Elastic scattering angular distribution for the α + ^{27}Al reaction at 50 MeV.

Inelastic scattering cross sections for the first five excited states of ^{27}Al were extracted from the corresponding inelastic yields to get the inelastic scattering angular distributions. The inelastic excitation energy spectrum at an angle $\theta_{lab} = 28.9^o$ is shown in Fig.1. The contributions from the first five excited states of ^{27}Al had been extracted using Gaussian fitting procedure. These angular distributions were analyzed in terms of the collective model using the distorted-wave Born approximation (DWBA). The distorted waves were generated by the corresponding optical potential deduced from the elastic scattering data at 50 MeV. The DWBA calculations were carried out using the computer code DWUCK4 [3].

Table 1: Best fit optical model parameters.

Vo = 210.54 MeV	Ro = 1.195 fm	ao = 0.73 fm
Wv = 50.62 MeV	Rv = 1.195 fm	av = 0.73 fm
Ws = 1.55 MeV	Rs = 1.195 fm	as = 0.67 fm

The experimental cross section is related to the differential cross section calculated from DWUCK4 by the following relation:

$$\sigma^{\exp}(\theta) = \frac{2J_e+1}{2J_g+1}\frac{1}{2l+1}\beta_l^2\sigma^{DWUCK\ 4}(\theta)$$

where J_g and J_e represent the spins of the target nucleus in the ground state and excited state, respectively, l is the orbital angular momentum transferred to the target nucleus and β_l is the nuclear deformation parameter.

We calculated the DWBA differential cross-sections for the first five excited states of ^{27}Al. The states are E_{ex1} = 0.844 MeV, J = $½^+$; E_{ex2} = 1.015 MeV, J = $3/2^+$; E_{ex3} = 2.212 MeV, J = $(7/2^+)$; E_{ex4} = 2.735 MeV, J = $5/2^+$ and E_{ex5} = 2.982 MeV, J = $3/2^+$ with a contribution from 3.0 MeV, J = $(9/2^+)$ state. The deformation parameters were also calculated for each state.

The experimental inelastic scattering angular distributions corresponding to the excited states of ^{27}Al have been shown in Fig. 3 using solid points. The DWBA angular distributions were calculated with the rotational form-factor including the Coulomb excitation. The distorted waves were generated by the optical model potential with the parameters given in Table 1. The calculated DWBA angular distributions have been shown in Fig. 3 by solid lines. All the calculations were performed with the same potential parameters in the entrance and exit channels.

The normalization of the calculated angular distributions allowed us to determine the β_l deformation parameters for all the excited states. The value varies within the range of 0.29 to 0.33.

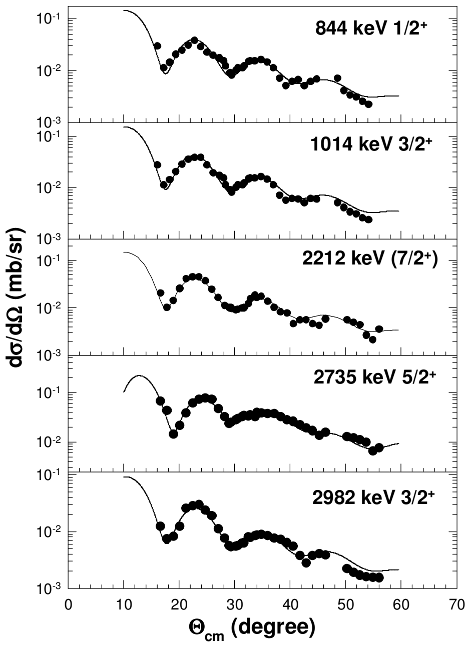

Fig. 3: Inelastic scattering angular distributions for the excited states of ^{27}Al formed in the ^{27}Al(α,α)^{27}Al* reaction at 50 MeV.

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References

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