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Breakup of 42 MeV ^{7}Li projectiles in the fields of ^{12}C and ^{197}Au nuclei

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Abstract. Inclusive cross sections of α particles and tritons from the breakup of 42 MeV ^{7}Li by ^{12}C and ^{197}Au targets are presented and analysed in the framework of the Serber model. Spectral distortions due to the targets and relevant reaction mechanisms are discussed.

Keywords. Projectile breakup; Serber model; target effects.

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Projectile breakup of loosely bound nuclei plays a prominent role in nucleus–nucleus collisions [1,2] and the projectile structure information can be obtained from such reactions. The target supposedly raises the projectile into its continuum. However, as the target may not remain as a mere catalyst, it is pertinent to understand its role in projectile breakup. The nucleus studied here is ^{7}Li which is stable but weakly bound ($^{7}\text{Li} \rightarrow \alpha + t, Q = 2.47$ MeV). As its structure is well known, a thorough understanding of its breakup in the field of targets of different mass and charge number, can provide important guidelines for studying the nearby exotic neutron/proton-rich nuclei. Earlier, Serber gave a model [3] for projectile breakup, which explained very well fast neutron production from deuterons. In its simplest form the target is assumed to be transparent to the breakup fragments, the ‘transparent Serber model’ (TSM). But, at low energies, the target may absorb (opaque target nucleus) the unobserved breakup fragment for which ‘opaque Serber model’ (OSM) is applicable [4,5]. The extent of applicability of TSM/OSM with different targets can provide an estimation of the target effects in breakup.

This work presents inclusive α-particle and t cross section data from 42 MeV ^{7}Li projectile breakup with ^{12}C and ^{197}Au targets, measured at the BARC-TIFR Pelletron, Mumbai. The targets were chosen to study widely different Coulomb and nuclear effects. The thickness were respectively 0.75 and 2.2 mg/cm^{2}. To detect the emitted particles, telescopes employing surface barrier ΔE and Si(Li) E detectors were used. Details of experiments are given in [1,2]. The measured spectra integrated over 1 MeV energy bins at $\theta_{\rm lab} \sim$

20°–60° were obtained. The α-spectra using ^{12}C target show predominant compound nuclear/pre-equilibrium contributions, attenuating with the increase of $\theta_{\rm lab}$. Distinct states to residual nucleus are also apparent (figure 1a). In the t-spectra broad bumps are observed, also decreasing in cross-section with angle (figure 1b). For ^{197}Au target, both the α and t-spectra show broad bumps, which are prominent at larger angles and are centered near the beam velocity (figure 2a, b). Compound nuclear contributions are not significant.

Both the TSM/OSM calculations were performed. The basic formalism is the same as in [3,4], with the projectile a wave function an Yukawa type $\psi_a(r) = (\alpha/2\pi)^{1/2}{\rm e}^{-\alpha r}/r$, where $\alpha = \sqrt{2\mu\epsilon}/\hbar$, with reduced mass μ and fragment separation energy ϵ. The laboratory momentum of the observed fragment b is $\vec{p_b} = \vec{p} + \vec{p_0}$ where, $\vec{p}$ is the relative momentum of the fragments in a, $\vec{p_0}$ is the momentum due to incident motion, θ is the angle between $\vec{p_b}$ and $\vec{p_0}$. The OSM cross section is given as [4]

$$\frac{{\rm d}^2\sigma}{{\rm d}\Omega_b{\rm d}E_b} \propto m_b p_b \frac{(2\mu\epsilon)^{\frac{1}{2}}}{(2\mu\epsilon + p^2)^2}\left[\frac{(2\mu\epsilon + p^2)^{\frac{1}{4}} P_{\frac{1}{2}}(s)}{(2\mu\epsilon + p^2 - p_b{}^2 \sin^2\theta)^{\frac{3}{4}}}\right], \quad (1)$$

where $P_{\frac{1}{2}}(s)$ is Legendre function of the argument,

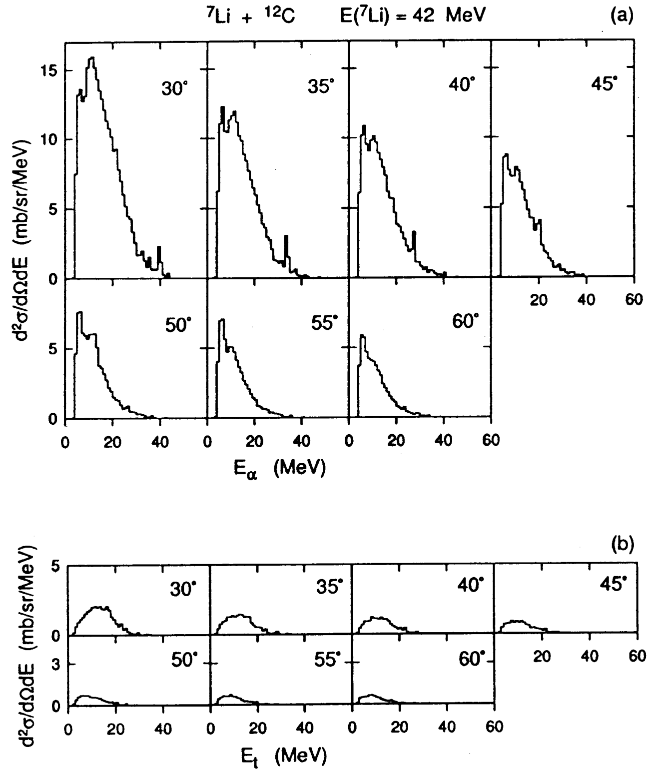

Figure 1. (**a**) α and (**b**) t inclusive energy spectra at several laboratory angles for 42 MeV ^{7}Li on ^{12}C.

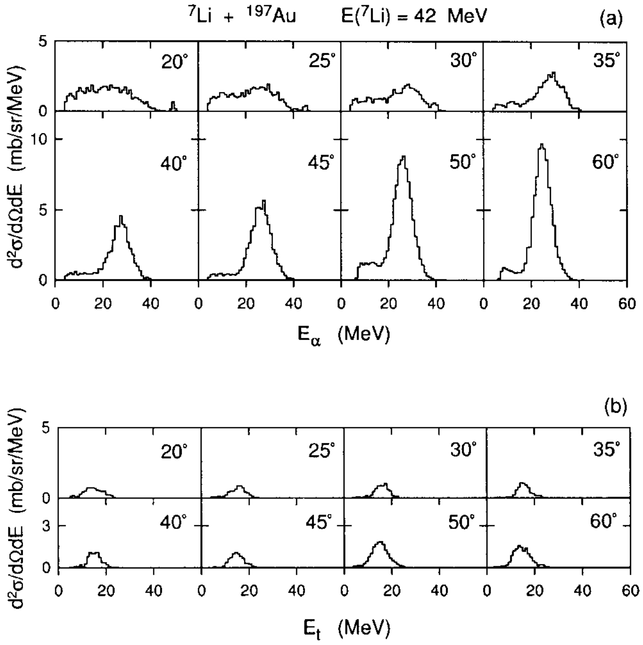

Figure 2. The (**a**) α and (**b**) t inclusive energy spectra at several laboratory angles for 42 MeV ^{7}Li on ^{197}Au.

$$s = \frac{2\mu\epsilon + p^2 - \frac{1}{2}{p_b}^2\sin^2\theta}{(2\mu\epsilon + p^2)^{\frac{1}{2}}(2\mu\epsilon + p^2 - {p_b}^2\sin^2\theta)^{\frac{1}{2}}}. \tag{2}$$

The TSM cross section is the expression without the factor in the large parentheses of eq. (1). Similar approaches were also followed in [6,7] and breakup cross sections were observed to be as large as fusion cross sections. To account for the deflection (θ_c) of the observed particle in the target Coulomb and nuclear field, θ is replaced by $\theta - \theta_c$ in TSM/OSM calculations. For ^{197}Au, θ_c is taken to be 20°, as the peak energy at the smallest detection angle here (20°) would be maximum [8], including distortions due to the Coulomb barrier height difference in the entrance and exit channels. Figure 3a shows the TSM/OSM fits to the t-spectra at 45° for the ^{12}C target, where appreciable θ_c ($\sim$ 20°) was also required to fit the data. The bumps are centered at energies appreciably shifted from beam velocity. Moreover the predicted TSM/OSM calculations had to be shifted further towards lower energies to fit the spectra. The inset shows the approximate shifts (OSM calculations) and the $E_t^0 \sin^2\theta_{\text{lab}}$ curves. Figure 3b, c shows the Serber model fits for the t and α spectra using ^{197}Au target at 45°. The OSM give narrower and better fits compared to the TSM calculations, both normalized to the experimental peak yields. The OSM calculations had to be shifted by $\sim$ 1.5 MeV towards lower energies to fit the spectra, increasing with angle, though small compared to the ^{12}C target. Also at higher θ_{lab}, increasing θ_c gives better fits, implying a variable deflection in the target fields for the range of angles studied here at this energy.

If the OSM calculations are normalized to the experimental data at θ_{lab} = 45° for ^{197}Au target, then the ratio of the predicted and observed yields of α and t vary differently (figure 4), reflecting different probabilities of absorption of α and t. Similar data over larger angular range with several other targets would thus be useful.

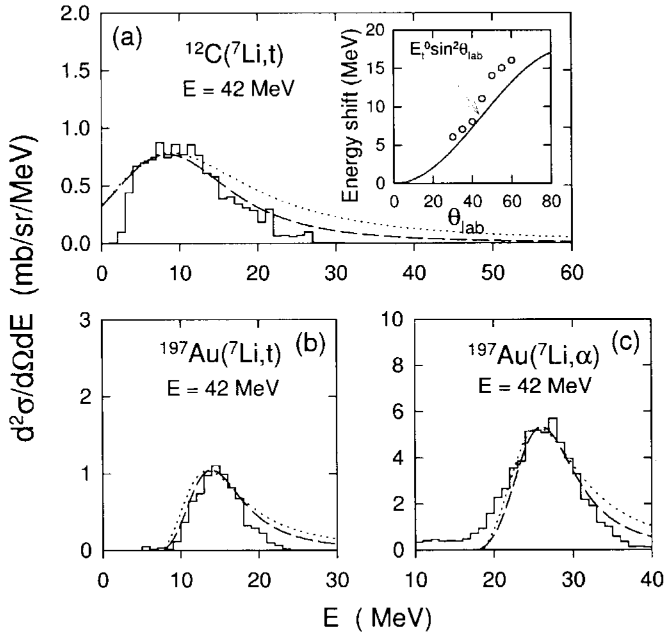

Figure 3. The inclusive energy spectra at $\theta_{\rm lab} = 45°$ for (**a**) t from 42 MeV ^{7}Li on ^{12}C; (**b**) α and (**c**) t from 42 MeV ^{7}Li on ^{197}Au; the OSM/TSM calculations (see text) are shown by dashed/dotted curves. The approximate peak energy shifts of the ^{12}C(^{7}Li, t) reactions and the $E_t^0 \sin^2\theta_{\rm lab}$ curve is shown in the inset of (a), E_t^0 being the t-beam velocity energy.

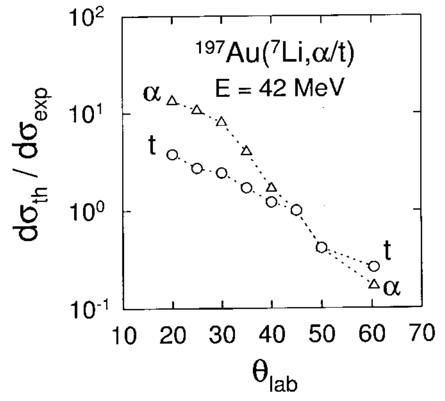

Figure 4. Ratio of the theoretical and experimental inclusive yields, with the theoretical calculations (OSM) normalized to the experimental data at $\theta_{\rm lab} = 45°$. The dotted lines are guides to the eyes.

In summary, inclusive double differential cross sections of the α and t fragments from 42 MeV ^{7}Li breakup with ^{12}C and ^{197}Au targets are measured. The experimental data are explained satisfactorily by the Serber model and show the importance of target induced distortion effects in projectile breakup.

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References

[1] D Gupta, C Samanta, R Kanungo, M K Sharan, S Kailas, A Chatterjee, K Mahata and A Shrivastava, *Nucl. Phys.* **A646**, 161 (1999); see references therein

[2] D Gupta, C Samanta, A Chatterjee, S Kailas, B J Roy, K Mahata and A Shrivastava, *Nucl. Phys.* **A683**, 3 (2001); see references therein

[3] R Serber, *Phys. Rev.* **72**, 1008 (1947)

[4] H Utsunomiya, *Phys. Rev.* **C30**, 1748 (1984); see references therein

[5] H Jelitto, J Buschmann, V Corcalciuc, H J Gils, N Heide, J Kiener, H Rebel, C Samanta and S Zagromski, *Z. Phys.* **A332**, 317 (1989)

[6] S L Tabor, L C Dennis and K Abdo, *Nucl. Phys.* **A391**, 458 (1982)

[7] S Kailas, R Vandenbosch, A Charlop, A Garcia, S Gil, S J Luke, B McLain and D Prindle *Pramana – J. Phys.* **35**, 439 (1990)

[8] H Utsunomiya, S Kubono, M H Tanaka, M Sugitani, K Morita, T Nomura and Y Hamajima *Phys. Rev.* **C28**, 1975 (1983)