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Author

Shotter, A.C.

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OBSERVATION OF THE DIRECT AND SEQUENTIAL BREAKUP OF
 ${}^7\text{Li}$ FROM ${}^{12}\text{C}$ AND ${}^{208}\text{Pb}$ TARGETS AT 70 MeV*

A. C. Shotter^a, A. N. Bice, J. M. Wouters, W. D. Rae
and Joseph Cerny

Lawrence Berkeley Laboratory and
Department of Chemistry
University of California
Berkeley, California 94720

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Abstract:

A study has been made of the breakup of 70 MeV ${}^7\text{Li}$ into the $\alpha + t$ channel. For reactions on a ${}^{12}\text{C}$ target the ${}^7\text{Li}$ breakup proceeds sequentially through its 4.63 MeV, $7/2^-$ state. For reactions on a ${}^{208}\text{Pb}$ target there is evidence both for sequential breakup and for an additional breakup process which does not proceed through an excited state of ${}^7\text{Li}$. This latter process is attributed to direct projectile breakup in the nuclear field of the target.

The subject of projectile dissociation in the field of a target nucleus encompasses a variety of phenomena and is currently attracting substantial interest.¹⁻⁵ For projectile energies below the Coulomb barrier, the projectile may be excited by the electromagnetic field between the incident channel nuclei. If the excited states are above the threshold for particle emission, and have small energy widths, the projectile will in most instances sequentially breakup beyond the influence of the target's nuclear field.⁶ In contrast, at high energies (~ 100 MeV/A) a projectile incident on the peripheral region of the target nucleus might be expected to undergo a rapid fragmentation in the surface field of the nucleus.⁷

For a projectile with an intermediate energy it should be possible to identify a transition from sequential breakup to a rapid non-sequential process, i.e. a direct breakup mode. A recent study⁸ of the breakup of 75 MeV ${}^6\text{Li}$ projectiles into $\alpha + d$ fragments has revealed evidence for two possible mechanisms. The first was identified as sequential breakup through the 2.18 MeV ${}^6\text{Li}$ state, while the second could not be correlated with transitions through any specific state. However, this lack of correlation could also have been due to transitions through the higher ${}^6\text{Li}$ states which all have large energy widths. For the observation of a possible direct projectile breakup a projectile should be used with a large energy separation between the breakup threshold and the next excited state. A suitable projectile is ${}^7\text{Li}$, in which the first α decaying state is at 4.63 MeV, 2.16 MeV above the $\alpha + t$ breakup threshold. By an appropriate choice of detector geometry, direct ${}^7\text{Li}$ breakup events with an $\alpha - t$ relative energy smaller than ~ 2.1 MeV can be clearly distinguished from all possible sequential breakup events.

We present here results of an investigation of 70 MeV ${}^7\text{Li} \rightarrow \alpha + \text{t}$ breakup on ${}^{12}\text{C}$ and ${}^{208}\text{Pb}$ targets. For those breakup events in which the relative energy between the fragments is below 3 MeV, it is found that the breakup of ${}^7\text{Li}$ on the ${}^{12}\text{C}$ target is predominantly sequential—proceeding through the 4.63 MeV state of ${}^7\text{Li}$. In contrast, the breakup of ${}^7\text{Li}$ on the ${}^{208}\text{Pb}$ target has two components, this sequential component involving excitation to the 4.63 MeV state as well as a direct component.

The experiment was performed using a 70 MeV ${}^7\text{Li}$ beam produced by the Lawrence Berkeley Laboratory 88-inch cyclotron. The breakup fragments from the decay of ${}^7\text{Li}^*$ are confined to a cone of angular width that is determined by their relative energy ϵ , and the laboratory energy of the ${}^7\text{Li}^*$. For the detection of those events in which ϵ is small, it is essential to have the fragment detectors in close proximity. This was achieved by constructing two particle telescopes in close vertical geometry, with one telescope above and the other below the reaction plane. The telescopes consisted of pairs of ΔE (200 μ) and E (5mm) detectors manufactured on the same silicon wafer such that the vertical angular acceptance of the telescopes was 1.5° to 9.9° and the horizontal angular acceptance was 3° . Reject detectors placed behind the E detectors were employed to veto high energy events.

Figure 1a. presents coincidence data for the ${}^7\text{Li} + {}^{12}\text{C}$ reaction at 15° in the laboratory, in which the summed energy of coincident events in the two telescopes is displayed, with the requirement that an α -particle be recorded in one and a triton in the other. The three peaks correspond to those breakup events which leave the ${}^{12}\text{C}$ target in the ground state or excited to the 4.4 MeV, 2^+ or 9.6 MeV, 3^- states. The angular distribution of the production of ${}^7\text{Li}^*$ (4.63 MeV) for the ${}^{12}\text{C}$ remaining in the ground state is shown in Fig. 2a. (The angular distribution has been corrected for the $\alpha + \text{t}$ detection efficiency.)

Further interpretation of the character of these breakup events can be obtained from the α or t projected energy spectra for coincident $\alpha + t$ events that yield a total energy corresponding to one of the peak energies in Fig. 1a. Such a projected spectrum for the t particle corresponding to the ^{12}C ground state transition is shown in Fig. 3a. The two peaks of Fig. 3a correspond to the two kinematically allowed t energies from the breakup of $^7\text{Li}^*$ (4.63 MeV). The shape of these peaks is determined by the geometry of the two telescopes as well as by the center-of-mass breakup energy, ϵ , and the energy of the recoiling $^7\text{Li}^*$ projectile. Calculated energy windows in this projected spectrum for breakup from the 4.63 MeV state ($\epsilon = 2.16$ MeV) are indicated in Fig. 3a by arrows. It is seen that most of the events are located within these narrow limits.

If direct breakup had occurred in the field of the target nucleus the relative energy, ϵ , between the α and t would no longer be restricted to a definite value corresponding to the decay of an excited state of ^7Li , but rather the value of ϵ could vary over some continuous distribution related to the momentum distribution of the fragments in the projectile ground state.⁹ From Fig. 3a there is little, or no, evidence of such a distribution of ϵ , since the projected spectrum is consistent with a single value of $\epsilon = 2.16$ MeV arising from the decay of the 4.63 MeV state of ^7Li . In fact, for all detector angles between 13° and 33° the shapes of the projected spectra for the ^{12}C ground state transition are similar.

The corresponding experimental results for the ^{208}Pb target are shown in Fig. 1b, Fig. 2b, 2c, and Fig. 3b, c. The summed energy of coincident $\alpha + t$ events is shown in Fig. 1b, in which it is seen that the majority of breakup events into the $\alpha + t$ channel leave the target in its ground state.

The projected energy spectrum for the \underline{t} fragment corresponding to this transition, and for the detector system set at 32° in the laboratory is shown in Fig. 3b; arrows indicate the triton energy limits for a sequential breakup of ${}^7\text{Li}^*$ (4.63 MeV). A projected energy spectrum of the \underline{t} fragment when the detectors are located at 18° is shown in Fig. 3c (the arrows have the same significance as in Fig. 3b.)

It is apparent that Figs. 3a and 3b are similar, showing little evidence for direct breakup. In contrast, data taken on ${}^{208}\text{Pb}$ at the more forward angles, presented in Fig. 3c, include events with a continuous distribution of ϵ which cannot arise from discrete states of ${}^7\text{Li}$. This is taken as evidence of direct breakup.

The angular distribution of the sequential component involving excitation of the 4.63 MeV ($\epsilon = 2.16$ MeV) state is shown in Fig. 2b. This angular distribution is corrected for the change of $\underline{\alpha} + \underline{t}$ detection efficiency as a function of angle. The yield of the direct component corresponding to $\epsilon \lesssim 2.0$ MeV is shown in Fig. 2c, but is not corrected for detection efficiency changes since the shapes of the projected spectra vary with angle.

The events occurring with $\epsilon \lesssim 2.0$ MeV have been attributed to a direct breakup of ${}^7\text{Li}$. Such events might be thought of as arising: a) by a rapid reemission of a transferred projectile fragment and/or b) by inelastic scattering of the projectile to the continuum of the $\underline{\alpha} + \underline{t}$ system. For the process a) the fragment reemission would have to occur within the nuclear transit time otherwise the momentum correlation between the $\underline{\alpha}$ and \underline{t} fragments would be lost. The distribution of relative energies between the fragments for a direct breakup process is determined by the phase space of the final state

particles, by their mutual Coulomb interaction and by their momentum distribution in the bound ${}^7\text{Li}$ system. Since the outgoing fragments have different Z/M ratios, the target-fragment Coulomb interaction will distort the initial ϵ distribution in such a way as to enhance the yield of lower ϵ energy values. This effect is clearly seen in Fig. 3c and is evident at all angles measured.

There is a distinct difference between the angular distribution for the direct component $\epsilon \lesssim 2.0$ MeV, and the sequential component $\epsilon = 2.16$ MeV. It is possible to speculate that the direct component originates from a greater overlap between the incident nuclei than that needed for simple projectile excitation, which might result in a nuclear deflection to smaller angles than the grazing angle of $\sim 30^\circ$. One could also argue that both the direct and sequential breakup processes have enhanced yield at forward angles due to strong Coulomb effects. However, an investigation of the breakup of 32 MeV ${}^7\text{Li}$ projectiles from ${}^{197}\text{Au}$ gave a very small cross section for Coulomb breakup.¹⁰

Whatever the precise reaction mechanisms are, it will be of great interest to determine how the direct and sequential breakup components vary with incident energy, especially in the region 10-100 MeV/A, since this could lead to a much greater understanding of fragmentation processes in general.

Footnotes and References

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(a) Permanent address: Physics Department, University of Edinburgh,
Edinburgh, Scotland EH9 3JZ

1. D. K. Scott, Invited talk, Int. Conf. Nuc. Phys., Aug. 1980, Berkeley, to be published Nucl. Phys.
2. G. Baur, R. Shyam, F. Rösel and D. Trautmann, Phys. Rev. C21, 2668 (1980).
3. J. R. Wu, C. C. Chang and H. D. Holmgren, Phys. Rev. Lett. 40, 1013 (1978).
4. K. W. McVoy and M. C. Nemes, Z. Physik A 295, 177 (1980).
5. C. K. Gelbke, M. Bini, C. Olmer, D. L. Hendrie, J. L. Laville, J. Mahoney, M. C. Mermaz, D. K. Scott and H. H. Wieman, Phys. Lett. 71B, 83 (1977).
6. H. W. Wittern, Phys. Lett. 32B, 441 (1970).
7. A. S. Goldhaber and H. H. Heckman, Ann. Rev. Nucl. Sci. 28, 161 (1978).
8. C. M. Castaneda, H. A. Smith, P. P. Singh and H. Karwowski, Phys. Rev. C21, 179 (1980).
9. R. Shyam, G. Baur, F. Rösel and D. Trautmann, Phys. Rev. C19, 1246 (1979).
10. J. L. Quebert, B. Frois, L. Marquez, G. Sousbie, R. Ost, K. Bethge and G. Gruber, Phys. Rev. Lett. 32, 1136 (1974).

Figure Captions

- Fig. 1. a) Summed energy spectrum for coincident $\alpha + t$ particles from the breakup of ${}^7\text{Li}$ on ${}^{12}\text{C}$ target nuclei.
 b) As for a) but for a ${}^{208}\text{Pb}$ target.
- Fig. 2. a) The differential cross section for the $\alpha + t$ breakup of 70 MeV ${}^7\text{Li}$ from the ground state of ${}^{12}\text{C}$. The dashed lines in a), b) and c) are to guide the eye.
 b) The differential cross section for the sequential $\alpha + t$ breakup of 70 MeV ${}^7\text{Li}$ from the ground state of ${}^{208}\text{Pb}$, following excitation to the 4.63 MeV state of ${}^7\text{Li}$.
 c) The yield of direct breakup events as a function of ${}^7\text{Li}^*$ c.m. angle for ${}^7\text{Li}$ scattering from the ${}^{208}\text{Pb}$ target.
- Fig. 3. a) The triton energy spectrum for coincident $\alpha + t$ events in which the residual ${}^{12}\text{C}$ nucleus remained in its ground state. The detector system was located at $\theta_{\text{LAB}} = 15^\circ$.
 b) The triton energy spectrum for coincident $\alpha + t$ events in which the residual ${}^{208}\text{Pb}$ nucleus remained in its ground state. The detector system was located at $\theta_{\text{LAB}} = 32^\circ$.
 c) As for b) but with the detector system at $\theta_{\text{LAB}} = 18^\circ$.

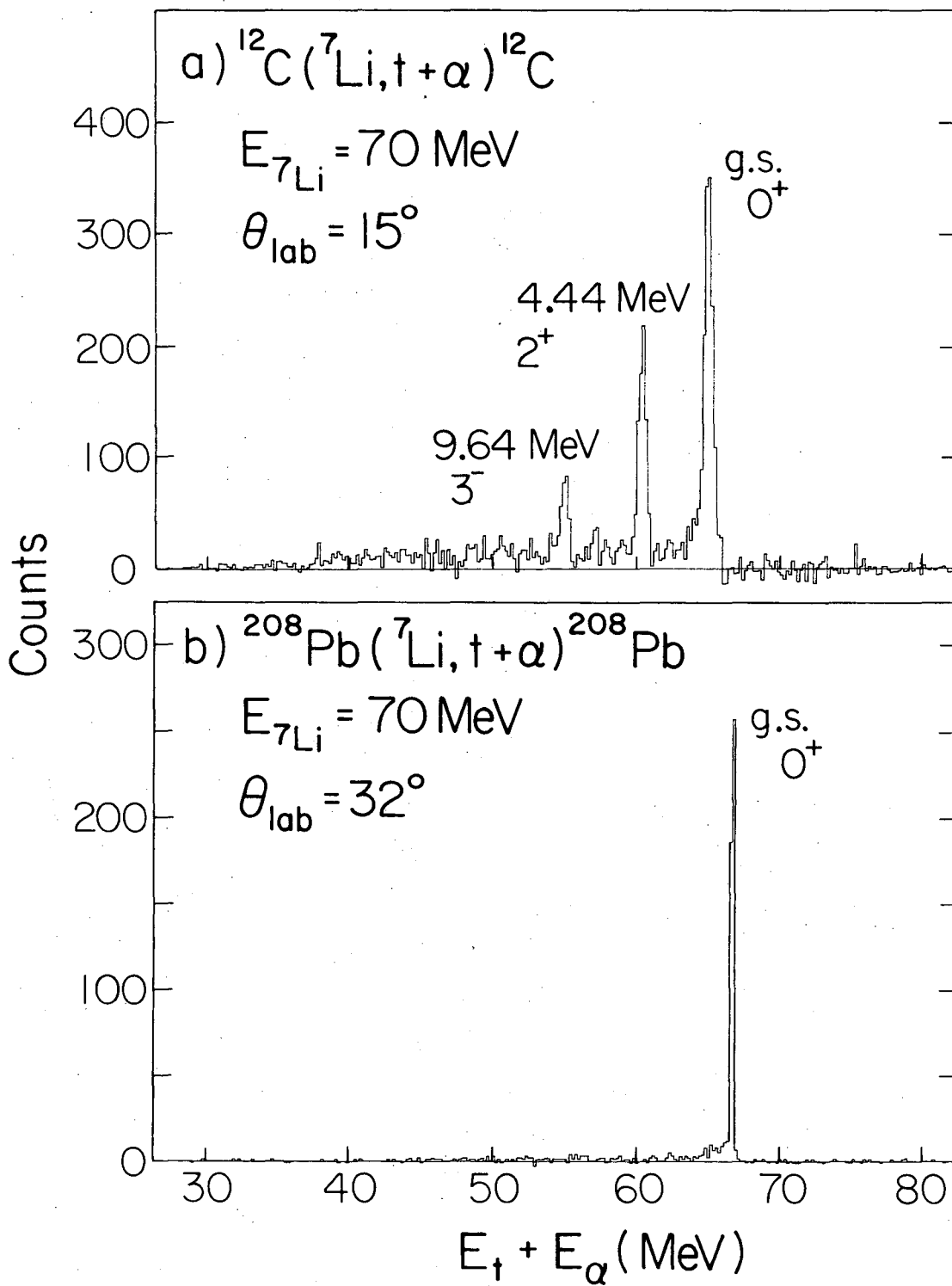


Fig. 1

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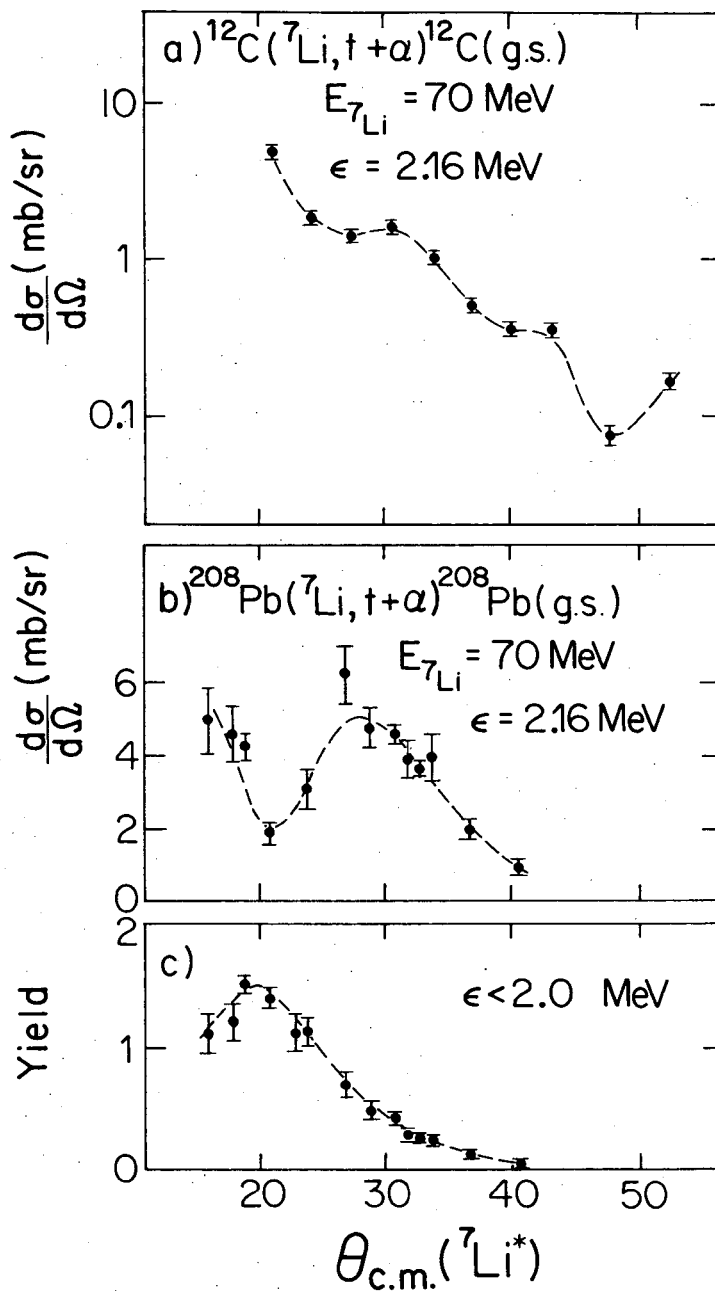
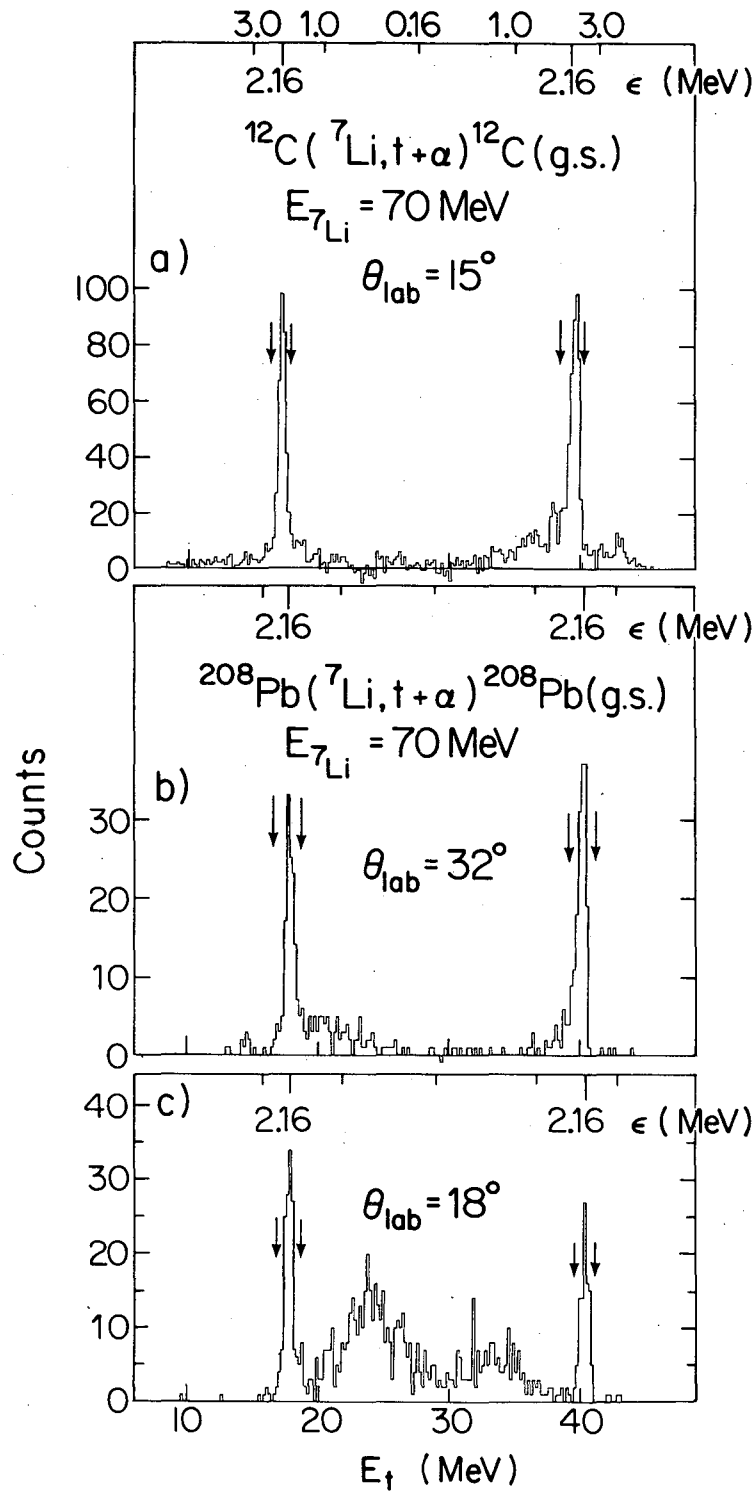


Fig. 2

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Fig. 3

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