COULOMB BREAKUP OF ^{6}Li ON ^{208}Pb

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The breakup of ^{6}Li in the Coulomb field of ^{208}Pb was studied at 20-, 21-, 24-, and 26-MeV incident energy. The discrepancies between the experimental and theoretical values indicate that some of the simplifying assumptions of the theoretical description have to be improved.

The present theory of the dissociation of the ^{6}Li nucleus in the electric field of a heavy target nucleus assumes a two-step process.[1,2] The first step is the excitation of ^{6}Li to an unbound level. This process is reasonably well described by the theory of Coulomb excitation.[3] The dominant contribution is expected from quadrupole excitation of the 3^+ level at 2.18 MeV (0.71 MeV above the dissociation threshold). In the second step, the excited ^{6}Li dissociates into its fragments $\alpha+d$. The two particles are emitted into a narrow cone around the theoretical direction of the excited ^{6}Li projectile. Because of its high binding energy the α particle will remain stable after the breakup, hence its angular distribution should be similar to that of an inelastically scattered ^{6}Li particle (Fig. 1). The kinematical shift due to the cone sets an upper limit for possible deviations of the α-particle angular distribution from that of the ^{6}Li. Furthermore, the corresponding total cross sections are expected to be identical. The theoretical expression for electric quadrupole excitation is given by

$$\sigma_{E2} = (\eta/Z_p ae)^2 f_{E2} B(E2)$$

[η, Coulomb parameter; Z_p, atomic number of the projectile; $2a$, distance of closest approach; f_{E2}, cross section function; $B(E2)$, reduced transition probability].[3]

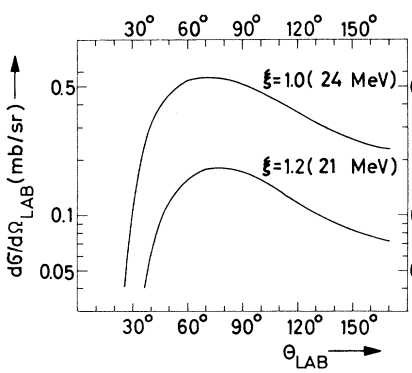

FIG. 1. Theoretical angular distributions for Li* calculated by using the cross section function f_{E2} (Ref. 3), $B(E2) = 26\times10^{-52} e^2\,\text{cm}^4$.

The behavior of $B(E2)$ evaluated from experimental cross sections is a sensitive test of the theoretical assumptions, because the $B(E2)$ values should be independent of the incident energy and consistent with results of other experiments. A comparison of the theoretical predictions with experimental values is justified if the following requirements are met by the experiments: (i) incident energy $E < E_C$ (Coulomb barrier) to eliminate nuclear contributions, (ii) Coulomb parameter $\eta \gg 1$ to allow a classical description of the relative motion by trajectories, and (iii) $\Delta E/E \ll 1$ to minimize deviations from the Rutherford trajectories due to energy transfer ΔE by excitation.

In the present experiment α-particle angular distributions of the dissociation reaction ^{208}Pb $\times(^6\text{Li}, \alpha+d)^{208}$Pb were measured at incident energies of 20, 21, 24, and 26 MeV ($E_C > 25$ MeV; $R < 15$ fm) (Fig. 2). These experimental conditions fulfill the above mentioned requirements

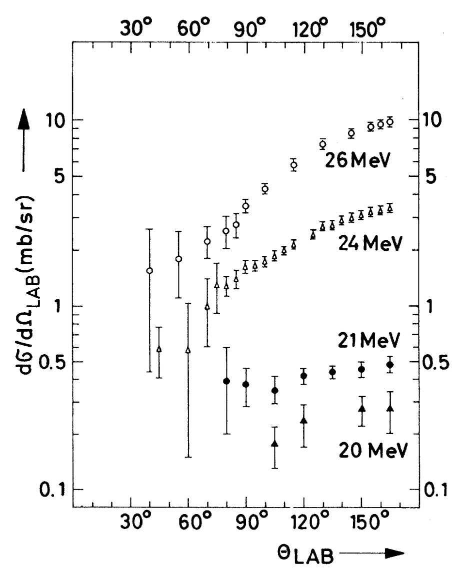

FIG. 2. Alpha-particle angular distributions.

(see table):

E (MeV)	η	$\Delta E/E$	σ (mb)	$B(E2)$ ($10^{-52}e^2$ cm^4)
26	18.5	0.08	52 ± 10%	129
24	19.4	0.09	20 ± 12%	94
21	20.6	0.10	4 ± 30%	70
20	21.2	0.11	2 ± 30%	61

The theoretical ^{6}Li angular distributions show a maximum at about 60°. The experimental α-particle distributions differ from these by more than can be accounted for by the kinematical shift due to the break-up cone (<10°).

The experimental data of the reduced transition probabilities $B(E2)$ are not in agreement with the value of $B(E2) = 26\times 10^{-52}e^2$ cm^4 obtained from electron-scattering experiments.[4] Furthermore, our values of the $B(E2)$ depend on the bombarding energy. Corrections due to possible contributions from other resonant states in ^{6}Li and continuum excitations being small[1] and higher-order effects playing a minor role,[2] we conclude that some assumptions underlying the present theory of the Coulomb breakup may not be justified.

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THREE-BODY PHOTODISINTEGRATION OF He^3 †

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The photoneutron cross section for He^3 has been measured with monenergetic photons from threshold to 30 MeV. The cross section rises to a maximum value of 0.95 mb at 15 MeV; the integrated cross section is 13.0 MeV-mb. Some structure is evident.

The complete photodisintegration of the three-body nuclei into their constituent nucleons is a process of fundamental importance in nuclear physics: The three-nucleon system is the simplest testing ground for strong many-body forces, and our knowledge of the electromagnetic interaction reduces the theoretical problem to the determination of the ground-state wave function of the nucleus and the final-state interactions of the outgoing nucleons. All previous measurements of this process have been made using continuous gamma-radiation sources,[1-3] and the cross sections obtained have been of insufficient quality to permit detailed analysis. The present measurement of the He$^3(\gamma,n)2p$ cross section was made in an effort to remedy this situation, and for this experiment monoenergetic photons were used.

The source of radiation for the present experiment was the positron-annihilation photon beam facility at the Livermore electron linear accelerator. The techniques for the use of annihilation photons for photonuclear cross-section measurements have been described elsewhere.[4] The liquid-helium sample, approximately 10 moles in size, 15 cm thick, and enriched to 98.6 at.% He^3, intercepted the entire collimated photon beam and was located at the center of a 4π neutron detector consisting of 48 BF_3 neutron detectors in a polyethylene moderator. This detector has been described by Kelly et al.[5] Its efficiency was measured by a variety of techniques, using calibrated neutron sources, spontaneous-fission coincidence measurements, and photoneutrons of known energy from C^{12} and Y^{89} (whose cross sections were measured previously at this laboratory[4,6]), and was found to vary smoothly from 24% for neutrons having an energy of 1 MeV to 17% for energies of 5 MeV and above. The photon energy resolution varied from about 300 keV at 10 MeV to 400 keV at 30 MeV.[7] The energy scale and resolution were checked by a measurement of the 17.28-MeV peak in the O$^{16}(\gamma,n)$ cross section, using a water sample in the (warm) cryostat. The absolute photon beam intensity was calibrated with the use of a 20×20 cm NaI(Tl) crystal. Backgrounds were determined from sample-blank measurements. To compensate for the effect of the reaction He$^3(n,p)$ on the neutron-detector efficiency, an amount of B^{10} was