SCATTERING OF 99-MeV ^{6}Li IONS

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First measurements of the differential cross sections for elastic and inelastic scattering of ^{6}Li ions at 99.1 MeV bombarding energy have been made. Partial angular distributions have been obtained for targets of ^{12}C, ^{28}Si, ^{40}Ca, ^{58}Ni, ^{90}Zr and ^{208}Pb in two experimental runs. Additional runs will be scheduled (after further development to increase the Li beam intensity on target) to extend some of the present angular distributions towards larger angles and to obtain data for additional targets.

The first run at the end of November 1976, with only 0.1 to 1 enA of ^{6}Li^{3+} on target, yielded angular distributions for the above targets over a range of lab. angles from 6° to about 30-40° (47° for ^{12}C). In the second run at the end of February 1977, with 5-15 enA on target, the angular distributions for ^{28}Si, ^{90}Zr and ^{208}Pb were extended to θ_L=50°, 41°, and 54°, respectively, where the elastic cross section in all cases had plummeted to roughly 10μb/sr. For the elastic scattering, the combined experimental data are presented in Fig. 1 which displays the elastic cross section as ratio-to-Rutherford as a function of c.m. scattering angle. Inelastic scattering data have not yet been extracted from the spectra.

The measurements were carried out in the 64" scattering chamber. Isotopically enriched targets (except for Si) of thickness from 11 to 33 mg/cm^2

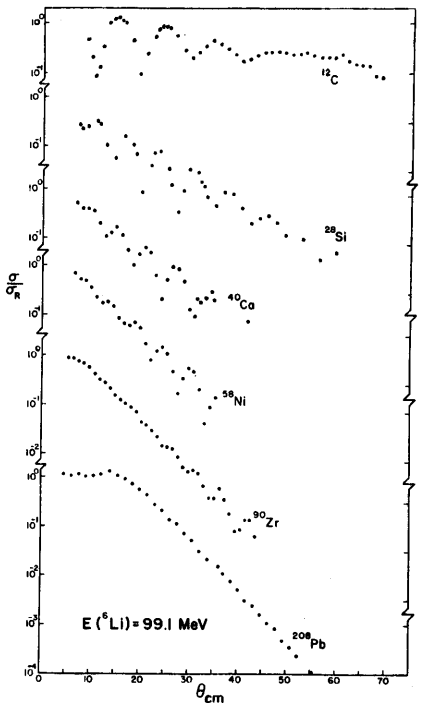

Figure 1.

were used. The scattered Li ions were detected in 3 ΔE-E silicon surface-barrier detector telescopes (200 μm + 1000 μm) with angular acceptance of ∿1°. Hardware pulse-height discrimination effectively eliminated all reaction products other than ^{6}Li and ^{7}Li. With the exception of ^{208}Pb, the (^{6}Li,^{7}Li) reaction Q-values are highly negative ($Q \leq -5$ MeV) for the targets studied, eliminating the need for more sophisticated particle-identification techniques (also, test runs made earlier at 55 MeV had shown the ^{7}Li yield for ^{90}Zr at 30° to be of order 1% of the ^{6}Li yield). Total energy resolution in these measurements was typically 300 to 500 keV. Fig. 2 shows a spectrum for ^{28}Si (before discrimination against

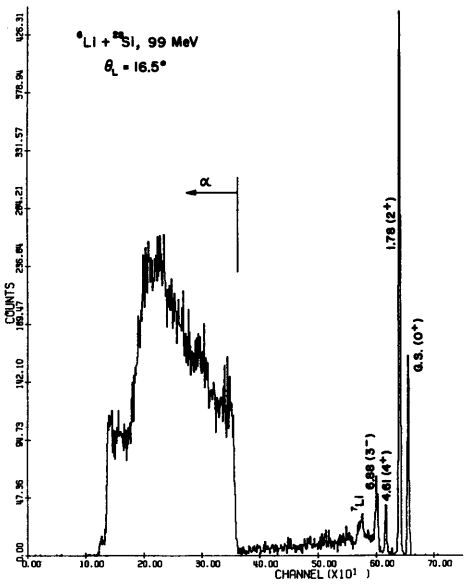

Figure 2.

the large but well-separated break-up α group), illustrating the relatively clean region up to 7 MeV excitation and below the first ^{7}Li group (Q = -9.97). For the first run at beam currents below 1 enA, a fourth detector telescope was used at a fixed forward angle to serve as a monitor for relative normalization of the data since subnanoamp currents could not be reliably integrated. In the second run the beam current was sufficient for accurate charge integration, allowing determination of the absolute cross section to $\pm$ 10%. The relative accuracy of the data ranges from $\pm$ 3% to $\pm$ 30% at some of the largest angles.

The absolute elastic cross sections for the Si, Zr and Pb targets span a range of values covering 7 to 8 decades over the angular range measured, corresponding to an average rate of fall-off by a factor of 10 over 8° to 6°. For the lighter mass targets ($A \lesssim 30$) the ^{6}Li elastic scattering exhibits forward-angle diffractive oscillations which die out somewhat with increasing angle. For the heavier targets ($A \gtrsim 60$), on the other hand, the forward-angle data beyond the Coulomb-nuclear interference "knee" start out as a relatively smooth exponential fall-off, with increasingly pronounced oscillatory structure appearing at larger angles. These features are typical of the scattering of strongly absorbed ions which is characterized by 2 parameters and corresponding features: The Sommerfeld parameter η which characterizes the Coulomb interaction, and the critical angular momentum λ for which $|S_\ell| = 0.5$ and which characterizes strong absorption. For $\lambda >> 1$, the nuclear scattering is diffractive. This condition is fulfilled for all of the present data where λ=28 and 50 for Si and Pb, respectively. However, the nature of the diffractive scattering (i.e., whether Fraunhofer or Fresnel) depends on whether the Coulomb interaction satisfies the condition $p << 1$ (Fraunhofer-diffraction scattering) or $p >> 1$ (Fresnel-diffraction scattering) where $p \equiv 2\eta[1-(2E/V_c-1)^{-2}]$. For the present ^{6}Li experiment, p = 3 for Si and p = 13 for Pb. The scattering from Pb and Zr at this energy is therefore qualitatively of the Fresnel type with a typical structureless exponential fall-off of σ/σ_R with scattering angle (i.e., contributions from only one side of the large absorptive nuclear disc are seen). For the lightest targets one observes Fraunhofer oscillations at the forward angles (where one sees interfering contributions from opposite sides of the interaction region);

with increasing Coulomb interaction these oscillations move to larger angles because of the "diverging" lens" effect of the repulsive Coulomb field. The disappearance of the Fraunhofer oscillations at larger angles for the lightest targets signals the change from peripheral diffractive scattering to smooth refractive scattering from the nuclear interior.

Previously available Li scattering data is limited to energies below 60 MeV and one recent $^{6}Li + ^{28}Si$ measurement at 135 MeV. The primary motivation for the present study is to partly fill the data gap and to provide a reliable optical-model parametrization of ^{6}Li elastic scattering at 100 MeV, suitable for use in analyses of reactions such as $(^{6}Li,d)$ and $(^{6}Li, ^{6}He)$ whose study at IUCF has been proposed and approved. Optical-model fits to the new data are in progress. Subject to availability of a 100 MeV ^{6}Li beam of higher intensity ($\geq$ 50 enA), the measurements on the lighter targets in particular (e.g. ^{28}Si) will be extended into the smooth fall-off or "nuclear rainbow" region, which is necessary for an unambiguous determination of the unique optical potential strength.

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