DETECTION OF THE POLARIZATION OF RECOIL NUCLEI IN STRIPPING REACTIONS

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The polarization of Li^8 nuclei from the $Li^7(p, d)$ reaction was determined from the asymmetry of their β decay. Nuclei ejected from the target were accumulated in helium and were carried by a fast stream of the gas in a strong magnetic field to well-shielded counters. There was practically no depolarization of the nuclei. Asymmetry values for two intervals of the c.m.s. emission angle of the nuclei were obtained.

THE polarization of recoil nuclei produced in stripping reactions [1] can be determined from the measurement of their β-decay asymmetry. [2] The basic experimental difficulty in such measurements is the γ-ray background. An attempt can be made to improve the ratio of the effect to the background by the accumulation of polarized nuclei in a gas with a large nuclear-spin relaxation time, for example, in helium, and to transport them by a fast stream of this gas to well-shielded counters.

To avoid depolarization, the following conditions must be fulfilled:

1. The intensity of the external magnetic field in the direction normal to the reaction plane should be sufficient for the complete rupture of the coupling between the magnetic moments of the nucleus and the electronic shell of the atom (Paschen-Back effect). For neutral atoms or for singly-charged light ions this condition is fulfilled when $H \approx 10^4$ G.

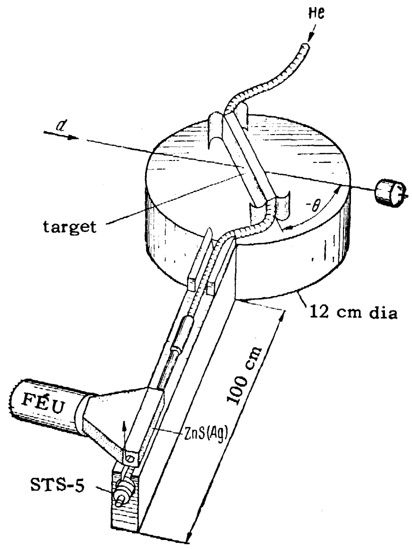
2. The velocity of the gas stream should be such that no depolarization on impurity molecules and on the walls of the gas tubing occurs during the time of transport.

3. An electric field should be applied to the target to remove ions produced by the deuteron beam in helium. (The ions can depolarize the nuclei similarly to paramagnetic impurities.)

An attempt to observe the depolarization of Li^8 nuclei from the reaction

$$Li^7(d, p)Li^8 \xrightarrow{\beta^-} Be^8 \rightarrow 2\alpha$$

at a deuteron energy $E_d = 10$ MeV was made with the extracted beam from the cyclotron of the Institute of Theoretical and Experimental Physics. We chose this reaction in view of the possibility of using $\alpha\beta$ coincidences in the measurement of the β-decay asymmetry in order to decrease the background.



Experimental arrangement (the upper pole of the magnet and FÉU phototube on the right-hand side are not shown in the figure).

The basic experimental arrangement consisted of an electromagnet of special shape, which provided a field intensity $> 10^4$ G over a segment of the helium flow which included the target, gas tubing, and α counter (a diagram of the arrangement is shown in the figure). The magnetic gap over the entire segment was 5.5 mm. A hollow target consisting of two electrically insulated aluminum foils coated by a layer of Li_2O (20 μg/cm^2) was mounted between the pole pieces in such a way that it could be rotated at different angles relative to the direction of the deuteron beam, which impinged on the target and was then stopped in a Faraday cup. The gap between the foils (about 1 mm) permitted the separation of the recoil nuclei in a small solid angle, since at the Li^8 energies of

200—400 keV used in the experiment, the range of Li^8 in helium exceeded 10 mm.[1)]

The helium (of 99.5% purity), additionally purified by passage through a column with activated carbon, was cooled by liquid nitrogen, passed through the target, and then traveled through a one-meter tube (the tube was made from teflon and stainless steel of 2.0 mm diameter) to a gas-flow scintillation α counter. The latter consisted of a chamber of 2×3 mm cross section with side walls of organic glass on which a thin layer of ZnS(Ag) was deposited, two hollow light pipes with silvered walls, and two FÉU-13B phototubes connected in coincidence with each other and the β counters. The β-decay asymmetry was measured by two halogen counters of type STS-5, which were placed in recesses in the upper and lower poles at a distance of 15 mm from the α-counter axis. The effective solid angle at which the α particles entered the counter was about 0.5 sr. The section of the magnet containing the counters was mounted in a shield (10 cm Fe + 20 cm Pb + 60 cm borax and paraffin).

To prevent an instrumental asymmetry, we made two measurements of the ratio $R_\theta = N_{up}/N_{down}$: once with the target at an angle $-\theta$ to the beam and a second time at an angle $+\theta$. Such a rotation reversed the spin directions of the polarized nuclei. The true value of the β-decay asymmetry is obviously $a = \sqrt{R(-\theta)/R(+\theta)}$. During the measurements, the target was rotated to the angles $-\theta$ and $+\theta$ every 5 min.

With a 0.3 μA deuteron current passing through the target, a transport time of 10^{-2} sec for the nuclei to travel from the target to the α counter (the helium flow rate was ~ 300 cm^3/sec), and a field intensity of 200 V/cm at the target, we recorded two to three coincidences per second with a random-coincidence background of < 0.2/min. The values of a at the two angles of rotation of the target θ (l.s.) were

$$\theta = 35°: a\,(\Omega = 8° - 20°) = 1.025 \pm 0.03,$$
$$\theta = 30°: a\,(\Omega = 2° - 13°) = 1.030 \pm 0.03 \qquad (1)$$

(Ω is the c.m.s. emission angle of the Li^8 nuclei). This value of the asymmetry corresponds to a Li^8 polarization of negative sign. (The positive direction of polarization is in the direction $\mathbf{k}_d \times \mathbf{k}_{Li^8}$.) We note that the value of the asymmetry in β decay of completely polarized Li^8 nuclei is[3] 1.10.

[1)]An idea of the efficiency of the separation of nuclei in a definite solid angle can be obtained from the fact that when the orientation of the target was changed from 90° to 30° relative to the beam, the α-particle counting rate increased twenty-fold.

It can be supposed that the value of the asymmetry observed by us is connected with the small effective value of the polarization of the nuclei and is not a consequence of depolarization effects. Indeed, the fraction of impurity molecules with the purification process employed[4] was $\sim 10^{-9}$ and the concentration of the ions produced by the deuteron beam in the absence of the electric field was $\sim 10^{-8}$, i.e., during the time of transport ($\sim 10^{-2}$ sec) the number of depolarizing collisions is of the order of unity. Hence there should be no depolarization due to impurities, since the time for one collision ($\sim 10^{-13}$ sec) is much smaller than the Larmor period for precession of the nuclear angular momentum in the field of the impurity atoms ($\tau_L \sim 10^{-9}$ sec). For this reason, there should be no depolarization during the passage of the Li^8 atom or ion through the Li_2O layers ($\tau \sim 10^{-13}$ sec). The exchange of electrons with He atoms during the stopping of the Li atoms in the gas appears to be ruled out, since mainly[5] Li atoms (ionization potential 5 eV) and Li^+ ions (ionization potential 75 eV) are emitted from the target, and their velocity is considerably less than the velocity of electrons in He atoms (ionization potential 22 eV).

Finally, the depolarizing action of the walls can apparently be excluded for the following reason. When the flow rate of the helium in the tubing was changed from 20 to 80 m/sec, the α-particle counts increased approximately twenty-fold (the Li^8 lifetime is ≈ 0.8 sec). This effect can be explained only by the fact that practically every collision of a Li^8 nucleus with the wall leads to its adhesion. Only those particles not undergoing collision with the wall reach the counter.

Our attempts to study the polarization in other reactions, for example, in the $B^{11}(d,p)B^{12}$ reaction, were unsuccessful, owing to the γ background.

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