ALPHA-PARTICLES FROM THE REACTION $^7Li(p,\gamma)^8Be^*(\alpha)^4He$

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Summary

The α-particle spectrum from the reaction $^7Li(p,\gamma)^8Be^*(\alpha)^4He$ has been determined in coincidence with γ-rays. The results indicate that, apart from the broad $2\cdot9$ MeV level, there are no additional levels between the ground state and 7 MeV with intensities greater than 3 per cent. of the $2\cdot9$ MeV level. It is shown that the shape of the $2\cdot9$ MeV level can be fitted satisfactorily by a dispersion formula if a large value for the reduced width of the level is assumed.

I. Introduction

Several states in ^8Be at excitations up to 15 MeV have been reported by various observers; but, so far, the only ones which seem to be present with any degree of certainty (Ajzenberg and Lauritsen 1959) are the narrow 0^+ ground state ($\Gamma\sim5$ eV), the broad 2^+ level at $2\cdot9$ MeV ($\Gamma\sim1\cdot2$ MeV), and a broad 4^+ level at $11\cdot6$ MeV ($\Gamma\sim6\cdot7$ MeV). These levels correspond well with the only three states expected in this region of excitation on the basis of either a simple shell model or an α-particle model of ^8Be.

Nevertheless, the evidence for other even states in ^8Be at $4\cdot1$, $5\cdot3$, and $7\cdot5$ MeV is considerable (Titterton 1954; Ajzenberg and Lauritsen 1955), and it was with a view to obtaining further evidence on the possible existence of these levels that the present experiment was performed.

II. Apparatus

Alpha-particles from the 441 keV resonance in the $^7Li(p,\gamma)^8Be^*(\alpha)^4He$ reaction were detected in coincidence with γ-rays using the apparatus shown in Figure 1. A 20 keV thick target of separated ^7Li on a water-cooled copper backing was bombarded by a collimated beam of 450 keV protons from the Canberra 600 keV Cockcroft-Walton accelerator. The α-particles were detected at 90° to the proton beam by a $1\frac{1}{8}$ by $\frac{1}{2}$ in. CsI crystal which had been thinned down to $0\cdot005$ in. in order to avoid an excessive background count arising from the passage of high energy electrons. To reach this detector, α-particles from the target had to pass through a slit 1 mm wide, after which they were deflected by a magnetic field of 5400 G produced by a set of six permanent magnets of the magnetron type. The purpose of the magnetic field was to prevent the intense $8\cdot8$ MeV α-particle group from the $^7Li(p,\alpha)^4He$ reaction, and also direct light from the target, from reaching the detector. Furthermore, scattered protons were sufficiently deflected not to reach the crystal. To protect the phototube

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from the stray field of these magnets it was necessary to introduce a 7 in. long by $1\frac{1}{2}$ in. diameter " Perspex " light pipe and to surround the cathode end of the phototube with a soft-iron shield.

The γ-ray detector used was a 5 in. diameter by 4 in. long NaI(Tl) crystal coupled to an EMI 6099 phototube. This crystal was placed opposite the α-particle counter and adjacent to the " Perspex " window shown in Figure 1.

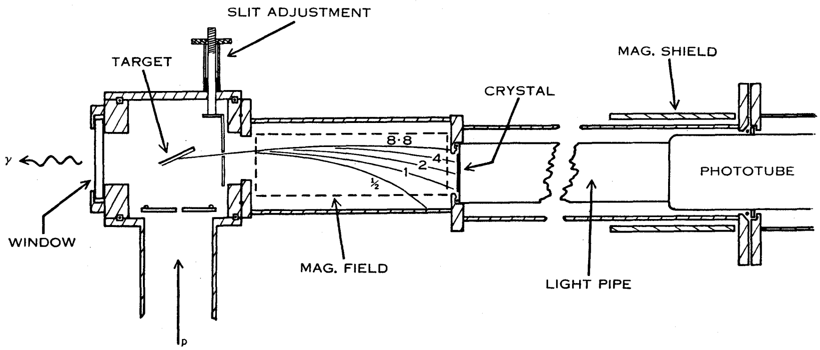

Fig. 1.—Diagram of apparatus.

III. Experimental

Pulses from the two detectors were fed through amplifiers into a Garwin-type coincidence unit (Garwin 1950) with a resolving time of $0\cdot1$ μsec, which responded to γ-ray pulses of greater than 4 MeV, and α-particle pulses of greater than $\frac{1}{2}$ MeV. The output from this unit was used to operate the gate circuit in a 70 channel Sunvic kicksorter, thus enabling the coincident α-particle spectrum to be determined. To avoid the effects of deterioration in the target after prolonged bombardment the target backing was moved slightly every 2 hr so that the beam struck an unused section. The procedure adopted was to run for an hour and then obtain a background count under the same conditions by inserting a $2\cdot4$ μsec delay in the γ-ray channel. Then the target was raised and, before the next run, the gain of the α-counter checked by moving the slit inwards a short distance and determining the pulse height of the $8\cdot8$ MeV α-particles from the $^{7}Li(p,\alpha)^{4}He$ reaction. In all, seven separate targets were used and the final result comprises spectra recorded over a total bombardment time of 82 hr using a beam current of 5 μA. Except at very low α-particle energies the background count was small compared to the total number of coincidences and the resultant spectrum obtained after subtraction of this background is shown in Figure 2.

The calibration of the α-particle energy scale was determined by substituting a ThC$''$ α-source for the target and recording the spectra obtained when various thicknesses of aluminium foil were interposed between the source and the slit. In this way it was also possible to determine the resolution of the α-particle counter as a function of α-particle energy. The use of a long light pipe limited the resolution obtainable, which was found to vary between 25 per cent. at $E_{\alpha}=1$ MeV and 15 per cent. at $E_{\alpha}=4$ MeV. The detection efficiency of the crystal was constant between these limits of α-particle energy.

IV. Results

A statistical analysis of the data in Figure 2 indicates that no additional levels with widths less than $0 \cdot 5$ MeV are present in ^{8}Be at excitations between 2 and 7 MeV with intensities of more than 3 per cent. of the total number of excited ^{8}Be nuclei.

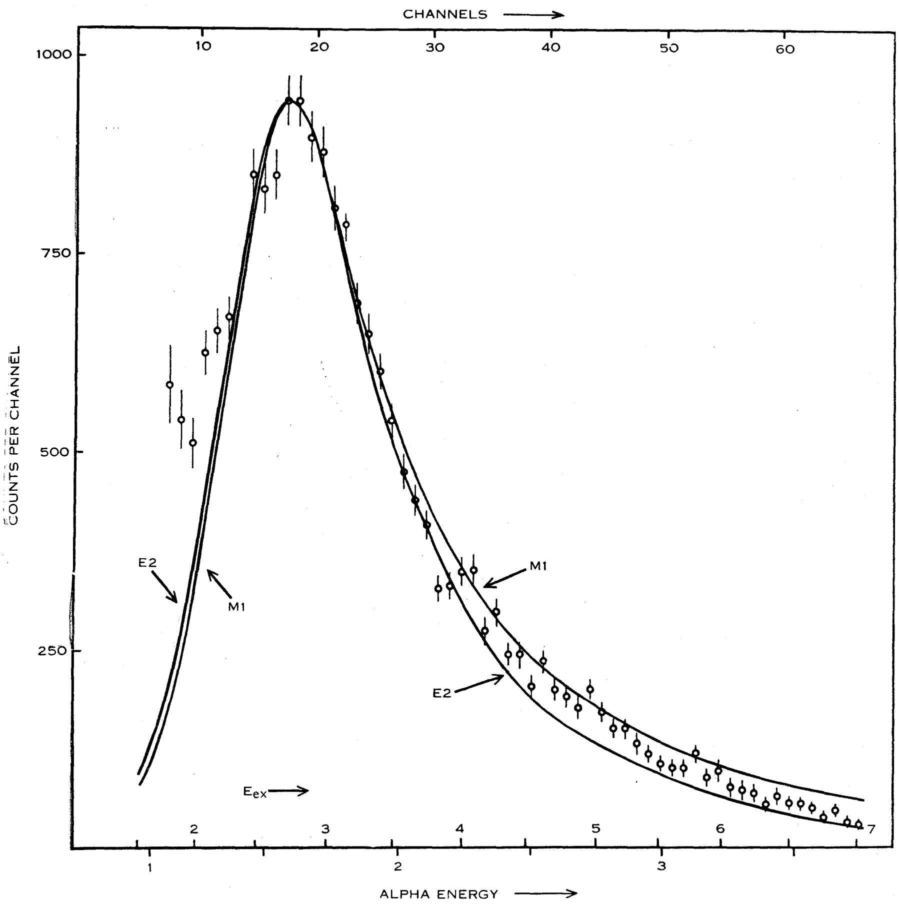

Fig. 2.—Coincident α-particle spectrum with background subtracted. The full curves are theoretical fits to the data, assuming $M1$ and $E2$ radiation is involved.

The $2 \cdot 9$ MeV state appears to have a significant high energy tail, and an attempt was made to account for this by fitting the data with a Wigner-Eisenbud single-level dispersion formula (Wigner and Eisenbud 1947) of the form

$$N(E) = \text{const.}\ \frac{[17 \cdot 6 - E]^{2l+1}\Gamma(E)}{[E_0 + \Delta(E) - E]^2 + [\Gamma(E)/2]^2},$$

where E is the energy of excitation in ^{8}Be and E_0 is a constant. The first term in the numerator of this expression is proportional to the probability of γ-ray transitions from an initial state at $17 \cdot 6$ MeV to a final state at E MeV ($l=1$ for magnetic dipole and $l=2$ for electric quadrupole radiation). The variation of the functions Γ and Δ with energy cannot be neglected in such a broad resonance at low excitation (Thomas 1951). Both Γ and Δ were calculated from tables of Coulomb wave-functions (Bloch *et al.* 1951) assuming a value of the ^8Be radius of $4\cdot48\times10^{-13}$ cm (Christy and Latter 1948). In order to fit the data it was necessary to assume in these calculations a value for the reduced width of $\gamma=11\cdot9\times10^{-13}$ MeV cm and a value of $E_0=5\cdot95$ MeV. By using these values and by numerically folding the experimental resolution into the theoretical curves (a small correction in such a broad peak) the two curves shown in Figure 2 for $M1$ and $E2$ radiation were obtained. The fit is satisfactory and the results are consistent with other evidence (Boyle 1956) that mixed $M1$ and $E2$ transitions are involved. The value of the reduced width is considerably larger ($\theta^2=3\cdot4$) than the Wigner single-particle limit ($3\hbar^2/2\mu R$) in agreement with results found in the $^{10}B(d,\alpha)$ reaction (Treacy 1953).

V. Acknowledgments

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