SCATTERING OF 4·9 MeV PROTONS BY ^{27}Al†

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Since 1934 there have been 24 determinations of the level scheme of ^{27}Al. However, even the more recent findings are far from harmonious and the question naturally arises as to how much of the apparent discord is due to target contamination, inadequate resolution, etc., and how much follows from the use of different nuclear reactions where, presumably, selection rules may operate to control transition probabilities. For instance, four of the more recent reports claimed a doublet at ~1 MeV while the remainder found only a single level.

The present work contains a new determination of the ^{27}Al levels below 4 MeV, obtained by scattering 4·90 MeV protons from a thin aluminium target. Scattered particles were recorded at the 45° position on Ilford C2 plates inclined at 3° to the direction of scatter. The scattering chamber has been described elsewhere (Mather 1951). Track ranges were measured and are shown in Figure 1. Eighty-nine per cent. of the tracks are associated with the elastic scattering peak (1) centred at 160 μ, while 11 per cent. had ranges less than 130 μ and were interpreted as due to inelastic scattering. Their positions correspond to the Q values listed in Table 1.

The width due to straggling of 4–5 MeV protons at half maximum is ~4 per cent. (e.g. Dyer 1952), i.e. ~160 keV, which is therefore approximately the limit of resolution achievable with a photographic emulsion at this energy. The observed half width of peak (1) is 175 keV, the difference being due to incident proton beam width and target thickness. The evidence for two groups at ~110 μ comes from the observed width (~300 keV) and the asymmetry of the group. The envelope can be fitted by assuming two levels at 1·01 and ~0·83 MeV respectively, the latter having, perhaps, 40 per cent. of the intensity of the former. The position of the lesser group is uncertain to the extent of $\pm$0·1 MeV. The closeness of these levels will prevent them from being cleanly

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resolved by range measurements in emulsions, which probably accounts for the failure of many observers to detect two levels in this region.

Table 1 also lists intensity estimates for each group based on the relative number of tracks (and calling the total number of charged particle products 100 per cent.). The final column gives absolute values of differential cross

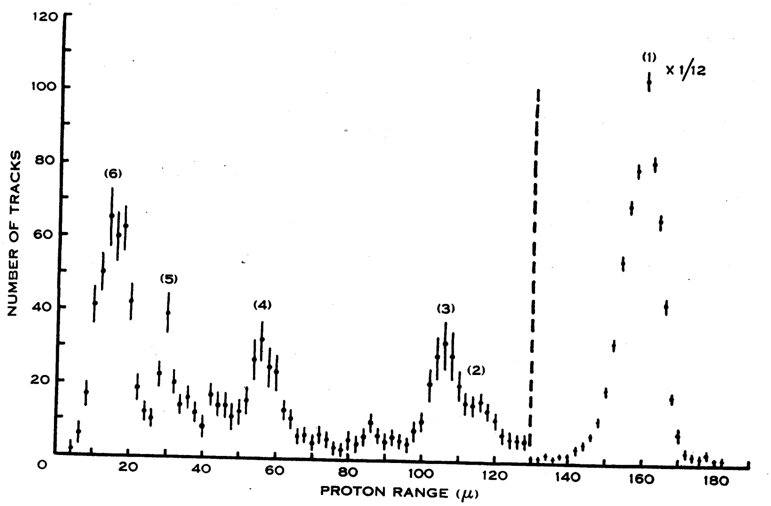

Fig. 1.—Range spectrum of 4·9 MeV protons scattered from a thin aluminium target. The elastic scattering peak (1) has been scaled down 12 times for convenient plotting, change of scale occurring at 130 μ.

sections in the laboratory system at 45° based on the measured track density per unit area of plate and the various constants of irradiation.

TABLE 1

Q VALUES FOR $^{27}Al(p,p')^{27}Al$ AND INTENSITIES OF ELASTIC AND INELASTIC GROUPS AT SCATTERING ANGLE 45°

Excited states =—Q values

Group	Q (MeV)	Intensity Estimate (%)	$d\sigma/d\omega$ (45°) $\times 10^{26}$ (cm^2 sterad^{-1})
(1) Elastic ..	0 (ground)	89·1	6·2
(2) Inelastic ..	—0·83	0·8 (?)	0·056 (?)
(3) ,, ..	—1·01	2·0	0·14
(4) ,, ..	—2·22	1·7	0·12
(5) ,, ..	—3·01	1·2	0·084

(6) Unresolved protons and α-particles

The background between (4) and (5) is severe and may be due to an unresolved group corresponding to an excited state between 2·2 and 3 MeV. Reilley *et al.* (1952) reported a level at 2·78 MeV.

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Group (6) is certainly not single and the impression of a peak may even be spurious. The decline in intensity below 14 μ could be due to loss of short tracks in scanning and failure of low energy particles to escape from the target, together with multiple scattering in the target. The rise in intensity from $\sim$20 μ probably represents the beginning of a group of close levels in ^{27}Al above $3\cdot5$ MeV. The observed group is much too broad for a single level and is also too intense. For instance, a proton of $\sim$1 MeV has less than a 2 per cent. chance of penetrating the Coulomb barrier of ^{28}Si compared with a group (2) proton.

There is a further complication in this region of the spectrum. The ^{27}Al$(p,\alpha)^{24}$Mg reaction which has a $Q\simeq1\cdot5$ MeV in proceeding to the ground state of ^{24}Mg will yield α-tracks in the region below $\sim$25 μ. The escape of a $6\cdot2$ MeV α-particle from ^{28}Si is much more probable than that of a 1 or $1\cdot5$ MeV proton. However, grain density measurements (comparing the tracks with thorium α-prongs which occur naturally in every emulsion) favoured protons as the major source of group (6).

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References

Dyer, A. J. (1952).—*Aust. J. Sci. Res.* A **5**: 104.

Mather, K. B. (1951).—*Phys. Rev.* **82**: 133.

Reilley, E. M., Allen, A. J., Arthur, J. S., Bender, R. S., Ely, R. L., and Hausman, H. J. (1952).—*Phys. Rev.* **86**: 857.