LETTERS TO THE EDITORS

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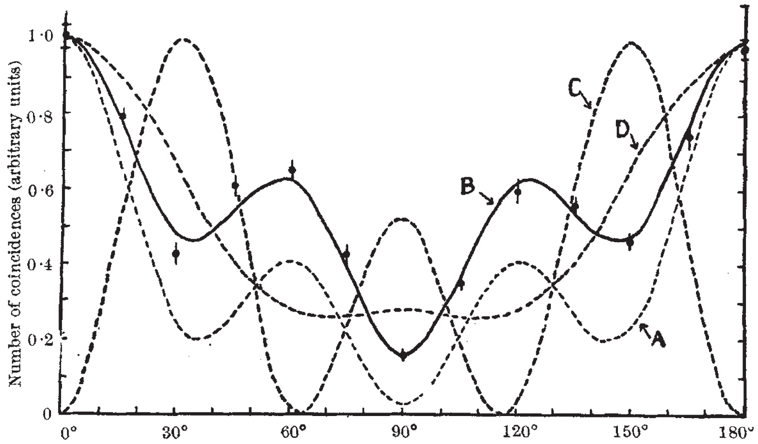
Angular Correlation Between α-Particles and γ-Rays in the Reaction $F^{19}(p,\alpha\gamma)O^{16}$

WE have studied the correlation between the directions of emission of alpha-particles and gamma-rays at the 340-keV. resonance in the following reaction :

$$F^{19} + p \rightarrow Ne^{20*} \rightarrow O^{16*} + \alpha \rightarrow O^{16} + \gamma + \alpha.$$

Both alpha-particles and gamma-rays were observed in the plane perpendicular to the proton beam. The alpha-particles were detected in a proportional counter with a window sufficiently thick (approximately 6·5 mm. air equivalent) to exclude protons scattered from the calcium fluoride target. The 6·1-MeV. gamma-rays emitted from the oxygen-16* nuclei were detected in a lead-walled Geiger counter. Coincidences between the alpha-particles and the gamma-rays were measured as a function of angle between the counters.



Angle θ between α-particle and γ-ray counters

The results are shown by the experimental points in the accompanying graph. It can be seen that there are terms as high as $\cos^6\theta$ and that there is approximate symmetry about the 90° direction. The presence of a $\cos^6\theta$ term requires that the orbital momentum l of the alpha-particle and the angular momentum j of the oxygen-16* nucleus must both be at least 3. In order to make a more detailed interpretation, it is first necessary to know the orbital momentum of the incoming protons. Evidence that this is zero is provided by the isotropy (with respect to the incident protons) of the alpha-particles[1] and gamma-rays[2].

If we assign to l and j their lowest possible values, namely, 3, and further assume the total angular momentum $J = 1$ for this resonance-level of neon-20*, we get the theoretical result indicated by curve A. When a correction is made for the finite solid angles subtended by the detectors ($\sim \frac{1}{50} \times 4\pi$), curve B is obtained. The close agreement between this curve and the experimental results supports the above assignment of angular momenta. The assignment $J = 0$ to the resonance-level which requires j and l to be equal leads for any value of j to an angular correlation function which is zero at $\theta = 0°$ and 180°. This conflicts directly with experiment as illustrated by curve C, which is drawn for $j = 3$. It is therefore impossible to attribute the isotropy of the alpha-particles and gamma-radiation, mentioned above, to a $j = 0$ level of neon-20. Two other feasible interpretations have been examined : (i) $J = 1$, $j = 4$, $l = 3$; this gives curve D. (ii) $J = 1$, $j = 3$, $l = 2,4$. Both components $l = 2$ and 4 can be present without producing terms higher than $\cos^6\theta$, and we must therefore consider the distribution produced by a coherent superposition of the $l = 2$ and 4 components. By a suitable choice of amplitude and phase relationships between these two components we can, in fact, produce a distribution function which agrees with experiment ; but this requires the contribution from $l = 4$ to be at least half that from $l = 2$, which is rather improbable.

We may therefore reasonably conclude that : (i) this resonance level of neon-20 is formed by $l = 0$ protons, has $J = 1$, and is probably of even parity because alpha-particle emission to the ground-state of oxygen-16 is not observed[3] ; (ii) since the neon-20* has even parity and is formed by $l = 0$ protons, fluorine-19 also has even parity ; (iii) the neon-20* emits alpha-particles with $l = 3$, leaving an excited oxygen-16 nucleus with $j = 3$ and odd parity.

Even parity for the ground-state of fluorine-19, and an excited state of oxygen-16 with $J = 3$, odd parity at 6·1 MeV., are both compatible with the alpha-particle model of the nucleus. The even parity of fluorine-19 is also in agreement with the central field model, which gives for this nucleus the configuration $^4S^{12}p^3d$. This model gives for the low excited states of oxygen-16 the configuration $^4S^{11}p^1d$, which includes the possible terms $^3D_3$, $^1F_3$ and $^3F_3$, all of the type $j = 3$, odd parity.

A difficulty that arises from these results is the interpretation of the observed width and cross-section of this resonance-level in neon-20. Measurements[4,5] indicate a combined width for alpha-particle and proton emission of 3·2 keV., made up of one width of 40 eV. and the other of 3·16 keV. The larger of these two widths (usually attributed to the alpha-particle) is difficult to reconcile with the small barrier-penetrability to be expected for either protons of such low energy or alpha-particles of such high angular momentum. This may indicate the inadequacy of some of the approximate methods used to calculate penetrability factors for particles of non-zero angular momentum[6].

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