neutron inelastic scattering. In addition, Cranberg and Levin[11] have observed the inelastically-scattered neutron group for an incident neutron energy of 2.5 Mev, which clearly identifies the process involved as inelastic scattering.

The data obtained using enriched scatterers show conclusively that at $E_n = 4.1$ Mev there are 926-kev gamma rays produced in both Zr^{92} and Zr^{94}. From the relative sizes of the scatterers and observed photopeaks, one can state that the intensities of the two gamma rays are roughly equal, but it is impossible to assign an energy difference to these gamma rays from these data.

From the large-scatterer data, an upper limit of 2.5% is placed on the energy separation of the two 926-kev gamma rays. This figure is based on the observed values of $(8.3\pm0.6)\%$ and $(8.0\pm0.7)\%$ for the half-widths of the 850-kev and 926-kev photopeaks, respectively, and the expected variation in half-width of a composite photopeak as a function of the separation of its two equal components. This variation was determined empirically by a graphical addition of two separated, equal photopeaks.

[11] L. Cranberg and J. S. Levin, Bull. Am. Phys. Soc. Ser. II, 1, 56 (1956).

Without yield curves for these enriched samples one cannot assign unambiguous level schemes for Zr^{92} and Zr^{94}, but the threshold measurements on normal Zr indicate that at least one isotope has a level at 926 kev. From the threshold data of Day *et al.*[2] and the lack of any sudden rise, except at threshold, in the excitation curve for the 926-kev gamma rays, one can exclude the possibility that the 926-kev gamma ray in the other isotope comes from a cascade process. Thus, one can conclude that the first excited state in both Zr^{92} and Zr^{94} lies at 926 kev. This assignment is not unreasonable, based on the nuclear systematics of even-even nuclei,[12] and is in agreement with the known[7] first excited state of Zr^{92}.

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[12] G. Scharff-Goldhaber, Phys. Rev. 90, 587 (1953).

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Test of the Statistical Assumption in Nuclear Reactions*

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The angular distribution of protons inelastically scattered from A^{40}, leading to the excitation of the 1.47-Mev level, has been measured at bombarding energies of 9.8, 9.0, and 8.5 Mev. An attempt is made to relate these data to the possibility of correlations in the phases of the levels excited in the compound nucleus.

THE angular distributions of nucleons inelastically scattered from nuclei, leading to the excitation of single levels of the nuclei, will be symmetric about a scattering angle of 90° providing: the reaction goes through the compound nucleus (compound nucleus assumption), many overlapping levels are excited in the compound nucleus (continuum assumption), and the phases of the levels excited by different partial waves are random (statistical assumption).[1,2] The observed departure from symmetry of such angular distributions, in situations where the continuum assumption would probably be satisfied, is usually attributed to a violation of the compound nucleus assumption—i.e., to the presence of direct interactions.[3,4] However the departure from symmetry could be due to a violation of the statistical assumption.

It may be possible to distinguish between these alternatives by measuring angular distributions at several closely spaced bombarding energies.[5] Large changes in the angular distributions for small changes in the bombarding energy would be difficult to explain if the departure from symmetry were due only to a violation of the compound nucleus assumption. This is because the direct interaction angular distributions do not depend in a sensitive manner on the bombarding energy,[3,4] and because the incoherence of the direct interaction and compound nucleus processes (a result of the continuum and statistical assumptions) prevents the existence of interference terms which might have a sensitive dependence on bombarding energy. However, large changes in the angular distributions for small changes in the bombarding energy would be easy to

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[1] L. Wolfenstein, Phys. Rev. 82, 690 (1951).
[2] B. T. Feld *et al.*, U. S. Atomic Energy Commission Report NYO-636, 1951 (unpublished).
[3] Austern, Butler, and McManus, Phys. Rev. 92, 350 (1953).
[4] Hayakawa, Kawai, and Kikuchi, Progr. Theoret. Phys. (Japan) 13, 415 (1955).
[5] R. M. Eisberg, in Brookhaven Conference on Statistical Aspects of the Nucleus, BNL-331, 1955 (unpublished), p. 85.

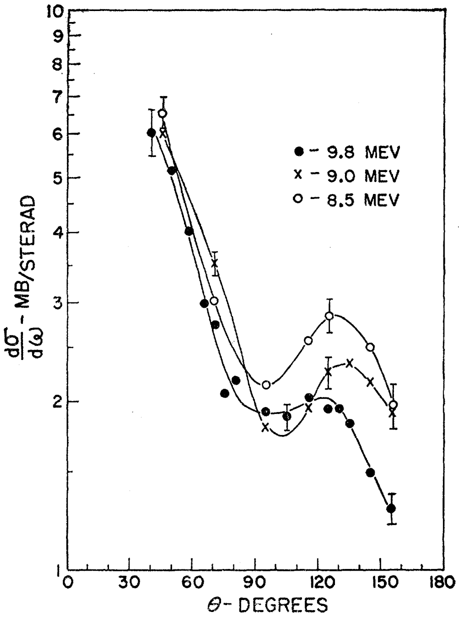

FIG. 1. Angular distribution of protons inelastically scattered from ${}_{18}A^{40}$, leading to the excitation of the 1.47-Mev level, at bombarding energies of 9.8, 9.0, and 8.5 Mev.

explain if the departure from symmetry were due to a violation of the statistical assumption. This is true since, if the angular distribution depends in detail on the phase of every level excited in the compound nucleus because the phases are not random, then the angular distribution resulting from the excitation of a particular group of levels in the compound nucleus could be very different from the angular distribution resulting from the excitation of a nearby group of different levels.

We have measured the angular distribution of protons inelastically scattered from ${}_{18}A^{40}$, leading to the excitation of the 1.47-Mev level, at bombarding energies of 9.8, 9.0, and 8.5 Mev. A^{40} was chosen because, although it is probably of high enough atomic number so that the continuum assumption is satisfied for the compound nucleus, still the spacing of the lowest levels of the target nucleus is large enough to allow adequate resolution of a single group of inelastically scattered protons. The bombarding energy was varied by passing the incident beam through polyethelene absorbers. There was a spread of approximately 200 kev in the bombarding energy as a result of the thickness of the target, straggling in the absorbers, and the energy spread of the incident beam.

Figure 1 shows the three angular distributions. The flags represent an estimate of the over-all accuracy of the data. It is apparent that there are changes in the angular distribution for small changes in the bombarding energy. It should be pointed out that the observed changes represent a lower limit to the effect which would be seen if the bombarding energy were well defined. This is because the 200-kev spread in the bombarding energy performs an average over bombarding energy which can only tend to diminish the dependence of the angular distribution on the mean bombarding energy.

It is not possible to draw definite conclusions from these data about the validity of the statistical assumption. The spacings and widths of the levels in the compound nucleus ${}_{19}K^{41}$ have not been measured at the excitation attained in this experiment (16-Mev excitation at 9.8-Mev bombarding energy). Although it would seem probable that the levels of K^{41} form a continuum at this excitation, one cannot be sure. Additional difficulty in interpreting these data arises from the lack of detailed knowledge about the properties of the direct interaction process. The available experimental and theoretical information, most of which is at a bombarding energy of 17 or 31 Mev, indicates an insensitive dependence on bombarding energy of the direct interaction angular distribution. However, little is known about the process in the energy range investigated here.

Despite the uncertainties of interpretation, it is felt that these data do provide some evidence of a violation of the statistical assumption.[6,7] Certainly the results are sufficiently positive to indicate the advisability of obtaining data in more favorable cases. If this type of experiment were performed with equipment of high-energy resolution it would be possible to choose a case in which there was no question about satisfying the continuum assumption. High-energy resolution would also remove the averaging effect, due to a spread in beam energy, which exists in the present experiment.

[6] *Note added in proof.*—A recent compilation of experiments on the inelastic scattering of protons, leading to the first state of Mg^{24}, shows an even stronger dependence of the angular distributions on the bombarding energy than does the $A^{40}(p,p')A^{40*}$ experiment. [P. C. Gugelot and P. R. Phillips, Phys. Rev. **101**, 1614 (1956).] These authors consider the effect to be most likely due to a violation of the continuum assumption.

[7] *Note added in proof.*—Recent calculations on the direct interaction, which include distortion of the incoming and outgoing waves, appear to give a more sensitive dependence of the direct interaction angular distributions on bombarding energy than do the original forms of the theory [C. A. Levinson (private communication)]. Calculations have not been made for the case of $A^{40}(p,p')A^{40*}$.