$Al^{27}(n,\alpha)Na^{24}$ Reaction Induced by 14.8-Mev Neutrons*

I. KUMABE, E. TAKEKOSHI, H. OGATA, Y. TSUNEOKA, AND S. ŌKI
Department of Physics, University of Kyoto, Kyoto, Japan
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Samples of aluminum foil inserted between two C2 nuclear plates were bombarded with 14.8-Mev neutrons, and the angular and energy distributions of the alpha particles resulting from $Al^{27}(n,\alpha)Na^{24}$ reaction were measured. It was found that the angular distribution of all energy regions in the center-of-mass system is concave upward and approximately 90° symmetrical. Also the curve on a semilog plot of the relative level density calculated from the energy distribution of the alpha particles fits a straight line which would correspond exactly to Maxwellian distribution with a temperature of about 1.45 Mev. The results are compared with the predictions of the statistical theory.

IN the past few years, several experiments have been performed to measure the density of energy levels of nuclei as a function of the nuclear excitation energy. In those experiments, measurements were made of the energy distributions of neutrons and of protons from (n,n'),[1,2] (p,n),[3,4] (p,p'),[5–7] and (α,p)[8,9] reactions on various nuclei. The presence of non-compound-nucleus processes and secondary nuclear reactions throws serious doubt on the interpretation of the results of those experiments and prompts a search for new experiments which might provide less ambiguous information about the energy level density. Experimental data on (n,α) reactions may give more reliable information on the energy level density, since it seems improbable that alpha particles will be emitted by direct interaction. Except for light nuclei, angular and energy distributions of the (n,α) reaction have been observed so far only for zirconium,[10] for which the angular distribution above 120° has not been measured and the energy distribution has not been reported in detail. Our present experiment was therefore designed to measure the distributions of energy and angle of the alpha particles resulting from the incidence of 14.8-Mev neutrons.

The experimental arrangement is shown schematically in Fig. 1. We bombarded samples of aluminum foil (1.8 mg/cm²) inserted between two C2 nuclear plates (thickness 200 μ) with $d-T$ neutrons produced by a Cockcroft-Walton machine. The neutron flux was accurately determined by counting the accompanying alpha particles from the $T(d,n)\alpha$ reaction. Platinum foil (60 mg/cm²) was used to reduce the background. An incident angle of 45 degrees was chosen for the neutrons to reduce the errors arising from the correction of the angular distribution. In order to discriminate alpha

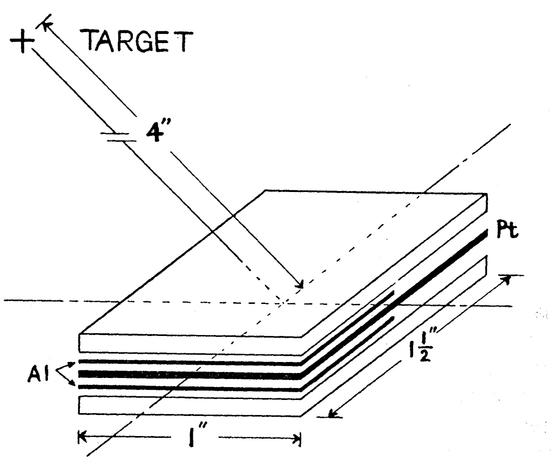

FIG. 1. Experimental arrangement.

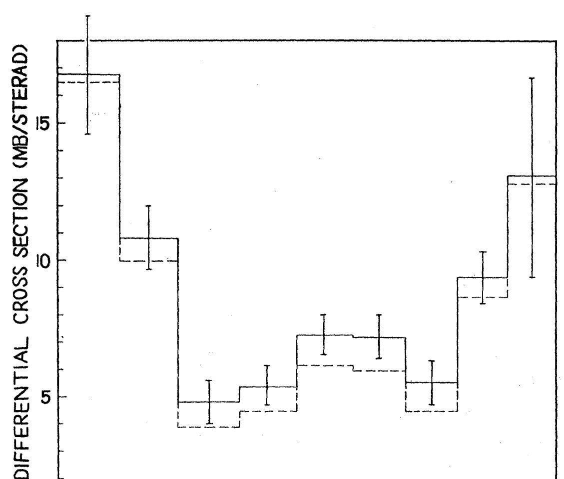

FIG. 2. Angular distribution of alpha particles from the $Al^{27}(n,\alpha)Na^{24}$ reaction. The dashed line shows the observed angular distribution, while the solid line shows the corrected angular distribution.

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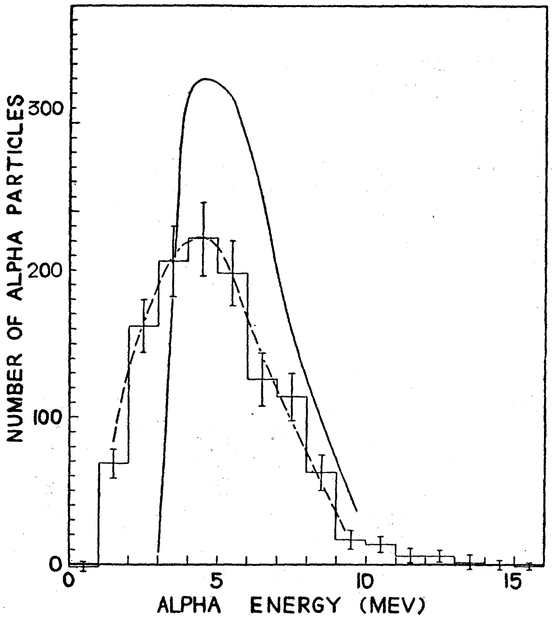

FIG. 3. Energy distribution of alpha particles from the $Al^{27}(n,\alpha)Na^{24}$ reaction. The histogram and dashed curve show the observed energy distribution, while the solid curve shows the corrected energy distribution.

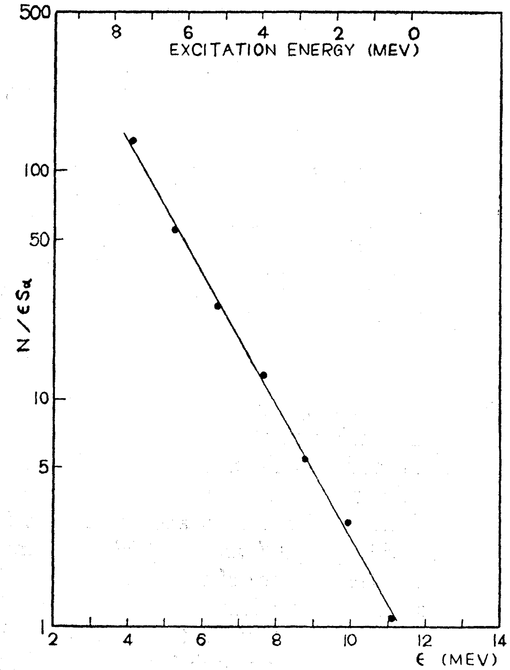

FIG. 4. The relative level density $\omega = N/(\epsilon S_\alpha)$ of Na^{24}.

particles from protons in the emulsion, the plates were processed by the temperature method[11] using low *p*H (6.6) amidol developer,[12] and for the hot stage, we chose the values of 15 minutes and 18°C for the suitable time and temperature respectively after several trials. In the right half of the emulsion in Fig. 1, the background tracks were measured.

The angular distribution in the center-of-mass system of the alpha particles from the (n,α) reaction for the entire energy region is shown in Fig. 2. We divided the uncorrected angular distribution into two energy regions, namely, a high-energy region (>6 Mev) and a low-energy region (<6 Mev), and it was found that the angular distributions for these two regions are similar to each other. Therefore we assumed that the angular distributions for various energy regions are all the same. Thus the correction for the energy loss of alpha particles in the aluminum sample was carried out for the uncorrected energy distribution in Fig. 3, using the angular distribution. Then, making use of this corrected energy distribution, the correction for the absorption loss of alpha particles stopped in the aluminum sample was carried out for the uncorrected angular distribution. The final results obtained by the successive corrections are shown by the solid line in Fig. 2 and by the solid curve in Fig. 3. Although there appears to be slight peaking in the forward direction, the deviation from symmetry about 90° lies within the statistical error. The total cross section is 92±15 mb, which is in fairly good agreement with values obtained by other authors.[13–15] Figure 4 shows the result presented by plotting the measured energy spectrum divided by ϵS_α,[16] where ϵ is the total energy (in Mev) of both the outgoing alpha particle and the recoiling Na^{24} particle, and S_α is the cross section, including the effects of barrier penetration for a nuclear radius of $1.5\times10^{-13}A^{\frac{1}{3}}$ cm, for the formation of the compound nucleus in the same state of excitation by the reverse reaction, in which particles of energy ϵ strike the excited residual nucleus. The data fit a straight line which would correspond exactly to a Maxwellian distribution with a temperature of about 1.45 Mev.

The approximate 90° symmetry of the angular distribution of the alpha particles indicates the fact that most of the reactions probably occur through the formation of the compound nucleus. However, the angular distribution is inconsistent with the isotropic pattern predicted by the statistical theory, while the observed energy distribution is found to agree well with that predicted by the evaporation theory,[17] although the temperature is fairly low as compared with that obtained by other authors.

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