Study of Alpha-Particles Emitted by CsI(Tl) Bombarded with Fast Neutrons.* F. Gabbard, T. Young and J. L. Beach+,
University of Kentucky

ABSTRACT

Alpha particles and protons emitted from CsI(Tl) bombarded by fast neutrons in the energy range 12.4 - 18.2 Mev have been observed. A 1" x 1/4" crystal and a 1" x 1/8" crystal, both right-circular cylinders, were used as target and detector while mounted on a Dumont 6467 phototube. Alpha particles were separated from protons using a circuit due to Biggerstaff et al.[1] The excitation function for the sum of the $Cs^{133}(n, \alpha)$ and $I^{127}(n, \alpha)$ reactions was measured for the above energy range. The sum of the cross sections is 2.8 ± 0.3 mb at 12.4 Mev and increases monotonically to 11 ± 1 mb at 18.2 Mev. Spectra of the emitted alpha particles will be presented. As previously observed by Bormann and Langkau[2], the alpha-particle spectra are not well represented by the statistical model and some sort of direct reaction mechanism or mechanisms appear(s) to be important. The observed spectra will be compared with calculations based on the statistical model.

[1] J. A. Biggerstaff, R. L. Becker and M. T. McEllistrem, Nuclear Instr. and Methods, 10, 327 (1961)
[2] M. Bormann and R. Langkau, Z. fur Naturforschg. 16A, 444 (1961)
*Supported in part by the U.S. Atomic Energy Commission.
+N.S.F. undergraduate research assistant.

American Physical Society
1963 Southwestern Meeting
Houston, Texas
February 28-March 2, 1963

DISCLAIMER

One means of studying reaction mechanisms in medium and heavy nuclei is by observation of the spectra of nuclear particles emitted as a result of the nuclear reaction being studied.

This paper describes measurements of alpha-particle spectra for alpha-particles emitted from CsI bombarded with fast neutrons. Even though there are two elements contributing to the spectrum, statistically they may be treated as two nuclei of mass 130 and Z of 54 since they differ in A by only 6 units and in Z by only two units. The Q-values for (n, α) reactions in Cs and I are 4.20 and 4.29 Mev respectively.

The technique used to measure the alpha-particle spectra was to observe the pulses produced in CsI(Tl) crystals by fast neutron bombardment.

SLIDE 1

Slide 1 shows a block diagram of the electronic hookup. The crystal attached to a 1" phototube was placed in the neutron flux. A dynode pulse was taken from the phototube and fed to a pulse shaper circuit whose output tells us whether the pulse was produced by a proton, alpha particle or electron. This circuit was developed by Biggerstaff, Becker, and McEllistrem[1]). An anode pulse is used for pulse height determination

---

1.) J. A. Biggerstaff, R. L. Becker, and M. T. McEllistrem, Nuclear Instr. Methods 10, 327 (1961).

SLIDE 2

Slide 2 shows a "typical" shape spectrum. The lower peak is produced by alpha particles, the upper peak by protons. The alpha particle energy range was from 8 to 20 Mev while the protons ranged from 5 to 17 Mev in this spectrum. The shape circuit measures the shape of the input pulse and as you see is not very sensitive to pulse size. For measuring the alpha-particle spectra a single channel analyzer was set with its window over the α-peak and the output of the single-channel was used to gate the 512 channel analyzer.

SLIDE 3

Slide 3 shows alpha spectra for six (6) different neutron energies: 13.1, 14.1, 15.5, 16.5, 17.4 and 18.2 Mev. The neutron source was a Zr-T target bombarded with neutrons from the 2 Mev Van de Graaff accelerator at Kentucky. One sees immediately that these spectra do not have the shape to be expected if the alpha-particles were evaporated from a compound nucleus in a manner prescribed by the statistical model. The next slide shows a more quantitative picture of this fact.

SLIDE 4

This slide shows a plot of $\ln \frac{E_x^2 N}{E_\alpha \; _c}$ vs $\sqrt{E_x}$ where $E_x = E_n + Q - E_\alpha$ represents the excitation energy in the residual nucleus, N in the number of alpha-particles observed, E_α is the energy of the emitted alpha-particles and $_c$ is the reaction cross section for alpha-particles as given by Igo[2].

George Igo, Phys. Rev. 115, 1665 (1959).

This plot is the usual plot for checking the yield of particles:

$$N(E_\alpha)\ dE_\alpha = \text{const.}\ E_\alpha\ {}_c\ (E_\alpha)\ W\ (E_x)\ dE$$

for agreement with the statistical model. In this case, the level density $W(E_x)$ was assumed to have the form:

$$W\ (E_x) = \text{const.}\ E_x^{-2}\ \exp\left[2\sqrt{a E_x}\right]$$

One interpretation which can be made of this graph, although it is certainly not the only one, is that the straight portions near the right of the slide are evidence of $(n, n\ \alpha)$ reactions; just to the left of this are straight portions due to compound-nucleus, statistical model α-particle emission and further to the left still and corresponding to higher α-particle energies is the curved portion containing α-particles emitted from direct-interactions of some variety. If one buys this interpretation, which is admittely risky, then the value of a for the "statistical model part" extracted from the middle straight portion of the curves is $(16.0 \pm 3.1)\ \text{MeV}^{-1}$. This is a "reasonable" value by comparison with other investigators[3].

3.) D. W. Lang, Nuclear Phys. 26, 434 (1961)

SLIDE 5

The final slide shows the excitation curve for the CsI(n, α) reactions between 12 and 18 MeV. The cross section is seen to increase monotonically from 2.1 mb at a neutron energy of 12.4 MeV to 7.0 mb at 18.2 MeV. Also shown are the results of Bormann[4]. Bormann's measurements of the cross section are

4.) M. Bormann, Z. Naturforschg 17a, 479 (1962)

lower than ours by a factor of 2-1/2 at 12.4 Mev and about a factor of 0.8 at 18 MeV. The reason for the descrepancy is not known. It should be noted that the cross section measured is the sum of the cross sections for Cs and I.

Bormann has done a more complete study of the CsI(n,α) reactions and these results are published in reference 4.).