the cross section is quite small in the angular region beyond 60°. Therefore, a background correction was made, when necessary, to data taken above 60° in the laboratory system. This correction fluctuated a great deal from run to run; it averaged about 4 percent. This effect was negligible for data obtained at angles less than 60°.

Errors in the data resulting from the finite size of the entrance slits and counter slits were negligible for this experiment.

RESULTS

The differential cross sections for the elastic scattering of deuterons by tritons in the center-of-mass system of coordinates are listed in Table I. Values of the cross section multiplied by the wave number squared of the incident particle are also included. The probable errors associated with these data (also listed in Table I) vary with angle. The error in $\sigma(\beta')$ was determined by consideration of errors in pressure measurement (± 1 percent), charge collection (± 1 percent), temperature ($\pm \frac{1}{3}$ percent), geometry (± 0.5 percent), uncertainty in measurement of tritium concentration, statistical error of each run, corrections to the data, and a consideration of the internal consistency of the data. The large error reported in data at 44.3° and 126.4° was associated with experimental difficulties which occurred in taking these data.

Figure 5 contains the results of this study in graphical form. Squares and triangles represent data obtained by counting scattered deuterons and recoil tritons, respectively, in resolved pulse-height distributions, while circles represent cross sections obtained after subtracting the expected recoil proton yield from a combined yield of recoil protons and scattered deuterons as is discussed above. The errors illustrated are probable errors. The point of the ordinate representing zero cross section for each energy is indicated on the right side of Fig. 5.

The incident deuteron energies were corrected for loss of energy in the entrance aluminum window and in the target gas. The energies are reliable to ± 20 kev at all energies except the lowest two which are considered reliable to ± 30 kev.

The authors are pleased to acknowledge the advice of Dr. J. H. Williams and the assistance of Dr. J. M. Blair and Mr. R. J. S. Brown, Mr. H. D. Holmgren, and Mr. J. L. Yarnell during the course of the experiment.

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The Angular Distribution of Alpha-Particles from the Reaction of Deuterons with Tritons*

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The distribution, as a function of angle, of the alpha-particles produced in the reaction of deuterons on tritons has been measured using a monoergic beam of deuterons from the Minnesota electrostatic generator. The alpha-particles were detected in the angular range of 40° to 140° in the center-of-mass system of coordinates for an incident deuteron energy of 2.21 Mev in the laboratory. The center-of-mass differential reaction cross section was flat at 8 millibarns from 40° to 90° and rose to about 13 millibarns at 140°.

INTRODUCTION

INFORMATION on the production of neutrons in the reaction of deuterons on tritons is best obtained by measurements on the yield of the associated alpha-particles. The reaction has been studied at Los Alamos[1] with incident deuterons in the energy range of 1 Mev to 2.5 Mev, and over an angular interval of 45° to 90° in the laboratory system. Interest in the reaction for theoretical considerations and as a possible source of fast monoergic neutrons caused an attempt to be made to extend the measurements on the alpha-particle yield to a wider angular range. The availability of an apparatus which allowed measurements in the angular range of 26.8° to 120° in the laboratory system of coordinates made such an investigation possible. Only one energy of incident deuterons was used, this being 2.21 Mev.

EQUIPMENT

A collimated beam of monoergic deuterons produced by the electrostatic generator was allowed to pass through a small volume scattering chamber filled with hydrogen and tritium gas. The alpha-particles produced in the reaction were detected as a function of angle by a movable proportional counter. The chamber and associated current and pressure measuring instruments have been discussed before.[2,3] The tritium handling system was discussed in the previous article.[4]

* This program assisted by the joint program of the ONR and AEC.

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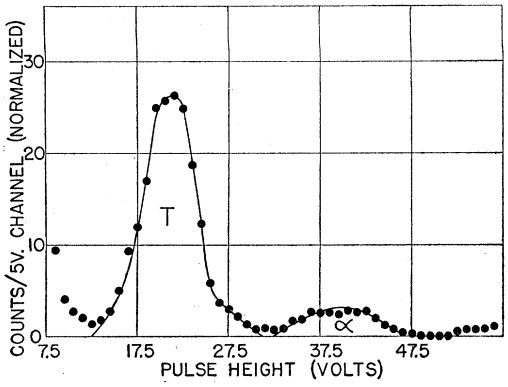

FIG. 1. Pulse-height distribution observed at 49.8°. The yields are plotted normalized per mm Hg and per microcoulomb of charge collected. The abscissa is in volts. Particle groups are recoil tritons and alpha-particles. The counter window was 0.18 mil Al.

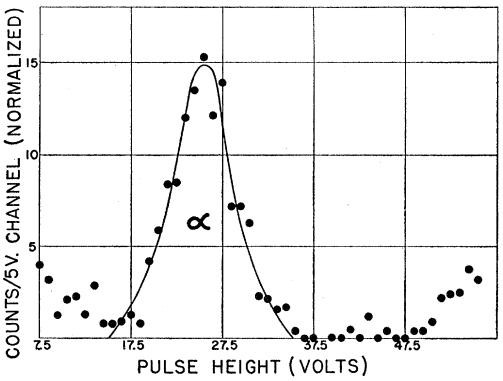

FIG. 2. Pulse-height distribution observed at 100°. All particles except the alpha-particles have been stopped in the counter window (0.5 mil Al).

METHOD

At low angles, the scattered deuterons and recoil protons and tritons had sufficient velocity so that the pulse heights associated with them were much smaller than those coming from the alpha-particles. It was no problem to separate and identify the latter. As the angle of detection was increased, the pulse height from the scattered particles became larger as the particles became slower. The alpha-particles also became slower, and produced larger pulses, but because of the large Q value associated with the reaction, the percentage change was not so great. When the angle of observation was increased to 70° (laboratory), the alpha-particles produced pulse-height distributions in the proportional counter which could not be separated from the pulses of the scattered deuterons. At this point it was possible to adjust the stopping power of the counter window to transmit only the more energetic alphas. Examples of the pulse-height distributions mentioned above are shown in Figs. 1 and 2. Figure 1 is for the counter fitted with a thin window (0.18 mil Al), and Fig. 2 is with a thick window (0.5 mil Al).

The use of a thin window made it possible to obtain a measured value for the concentration of hydrogen contaminant in the tritium sample. The method by which this was done was described in detail in reference 4. Since no concentration measurements could be made while the thick window was in place, the percentage of tritium in the gas sample was measured immediately before the thicker window was substituted for the thin window and immediately after the thin window was replaced. A careful account had been kept throughout the course of the deuteron-tritium scattering experiment[4] of the percentage of hydrogen contaminant as a function of the number of times the tritium sample had been cycled through the uranium. The percentage of tritium in the total gas sample was a monotonically decreasing function of the number of cyclings and averaged very close to 1 percent less tritium per cycling. The data taken with the thicker window required only four cyclings of the gas, so there should have been a 4 percent decrease in the tritium concentration. The measurements before and after inserting the 0.5-mil Al window showed only a 2 percent decrease. Similar fluctuations had been observed before, and it appeared that our concentration estimates could be in error by as much as 2 percent.

At least two measurements were taken at each angle. The statistical error on the large angle data amounted to as much as 5 percent because the chamber geometry was not designed for the measurement of the yields associated with cross sections as small as 10 millibarns.

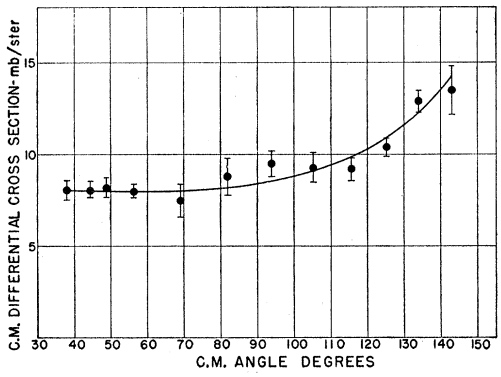

TABLE I.

$\theta_{c.m.}$°	38.0	44.6	48.7	56.1	69.0	81.9	93.9	105.1	115.5	125.1	133.9	143.0
$\sigma_{c.m.}(\theta)$ mb/sterad	8.1	8.1	8.2	8.0	7.5	8.8	9.5	9.2	9.2	10.4	12.9	13.5
$\pm\Delta\sigma_{c.m.}(\theta)$ mb/sterad	0.6	0.4	0.5	0.4	0.9	1.0	0.7	0.8	0.6	0.5	0.6	1.3

FIG. 3 and Table I.

Differential cross section per unit solid angle for the production of alpha-particles from the reaction $T(d, \alpha)n$, as a function of the center-of-mass angle. The deuteron energy was 2.21 Mev. The indicated errors are composite estimates from all causes.

RESULTS

The data have not been subjected to any corrections. The error estimated for the measurement of the beam current was 1 percent. The geometry measurement was good to $\frac{1}{2}$ percent. The concentration of tritium molecules in the gas sample could be estimated to 2 percent. In other experiments using the chamber, 3 percent to 5 percent corrections were necessary to correct the test p-p and p-He^4 scattering data to agree with published results. It was not felt that any correction could be made with confidence on the reaction data. For these reasons an estimated error of ± 8 percent is attached to the results.

Figure 3 and Table I show the cross sections for the production of alpha-particles as a function of alpha-particle angle in the center-of-mass system of coordinates. The indicated errors are, in the main, determined by the average deviation from the mean of the several runs at a given angle. The results are in general agreement with the Los Alamos data but do not seem to indicate so strong a tendency for the alpha-particle to come off in the forward direction.

We wish to thank Professor J. H. Williams for suggesting this problem and for his interest and advice during the experiment. We also wish to thank the members of the electrostatic generator group for their cooperation in obtaining these data.

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Nuclear Spectroscopy of Ba^{131}

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The spectra of Ba^{131} have been investigated in permanent magnet spectrographs, a solenoidal beta-spectrometer and a thin lens gamma-spectrometer. Gamma-rays of 122, 214, 241, 370, and 494 kev have been confirmed. In the conversion electron spectrum, there is indication of the existence of three low energy gamma-rays: ~65 kev, ~43 kev, and ~108 kev. The K/L ratios, K-conversion coefficients and relative intensities have been estimated.

I. INTRODUCTION

SEVERAL studies have been made on the energies, relative intensities, conversion coefficients, and multipole orders for the gamma-rays emitted by Ba^{131}.[1-6] Gamma-rays with energies of 122, 196, 206, 213, 241, 371, and 496 have been reported,[5,6] but there is disagreement as to their relative intensities and as to which of those around 200 kev are present. This investigation has therefore been undertaken to check and extend the results which have to date been presented.

II. APPARATUS AND PROCEDURE

Permanent magnet semicircular spectrographs, a solenoidal beta-spectrometer and a thin lens gamma-spectrometer were employed for the studies of the conversion electron spectrum and the photoelectron spectrum of Ba^{131}. The two spectrographs (low and high energy) were calibrated with I^{131}. Resolution of about 1 percent can be expected for gamma-rays of 100 kev or higher. The solenoidal spectrometer, which was used to study the conversion electrons, was equipped with a thin-window counter tube which transmitted electrons down to 17 kev. From 17 kev to 45 kev window correction was carried out on the peak height of conversion electrons. The instrument was calibrated with I^{131} and Cs^{137}. Its resolution setting was 1.5 percent. The thin lens spectrometer was used to study the photoelectron spectrum. It was calibrated with I^{131} diluted with common barium such that the geometries of the two samples, Ba^{131} and I^{131} plus Ba, were made substantially identical. The resolution setting was 2.5 percent.

The activity in the form of barium nitrate, pile activated, was obtained from Oak Ridge National Laboratory. Three samples were made. The one for the spectrographs was prepared by placing Ba^{131} on cellulose tape. Because of the low specific activity, a thick sample was required. The sample for the conversion electron spectrum was approximately 8 mm in diameter and 8 mg/cm^2 thick. It was covered with 0.2 mg/cm^2 zapon film. The sample for the photoelectron spectrum was large, having a cylindrical volume of about 1.8 cc and a diameter of 1.7 cm.

The conversion electron spectrum was measured several times so that decay would discriminate the peaks belonging to different radioactive isotopes of barium.

The photoelectron spectrum was measured with a 30 mg/cm^2 lead radiator and with a 21 mg/cm^2 ura-

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