centered in this neighborhood, making the interference terms especially strong here, and it might then also contribute the slight forward emphasis of the angular distribution at 1.67 Mev.

The angular distributions at 2.82 and 2.98 Mev, in the way they bend down at the ends, show indication of the presence of a power of $\cos\theta$ at least as high as the fourth in the angular distribution. This requires the penetration of d or f deuterons, depending on the parity of the compound state, and this is not unexpected at these high bombarding energies. It is thus very satisfactory that the simplest angular distribution should appear at the lowest bombarding energy.

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Low Energy Cross Section of the $D-T$ Reaction and Angular Distribution of the Alpha-Particles Emitted*, **

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The thick-target yield of the reaction

$$T+D\rightarrow\alpha+n+17.6 \text{ Mev}$$

has been measured, using a heavy-ice target, and observations have been made on the angular distribution of the α-particles. Experiments have been conducted in the region 15-kev to 125-kev incident triton energy. Within this range the angular distribution appears to be isotropic in the center-of-gravity system. The cross section for the reaction as a function of energy has been evaluated from the thick-target yield measurements. It appears to rise more rapidly with energy than is required by a simple Gamow function.

INTRODUCTION

THE experiments described in this paper are analogous to the D−D experiments which have been discussed elsewhere,[1] and the reader is referred to this earlier paper for most of the details of apparatus and procedure. Certain modifications have been made necessary by difficulties peculiar to this experiment, *viz.*, (a) the small amounts of tritium available, and (b) the steepness of the excitation function for the reaction, which makes a factor of about $2\cdot 10^4$ between the thick-target yields at the highest and the lowest energies employed. These modifications are described later in the present paper.

Measurements were confined to observations on the α-particles from the nuclear reaction. They have an energy of 3.5 Mev and a range of 2.1 cm for zero bombarding energy. They were detected with the aid of proportional counters, plus amplifying equipment.

The cross section for the reaction has been evaluated in the usual way. If the thick-target yield per unit of beam current at bombarding energy E is denoted by $N(E)$, then one has

$$\sigma(E)=(1/A)\cdot(dN/dE)\cdot(dE/dx),$$

where the constant A contains the product of the number of incident tritons per unit of beam current and the number of deuterium nuclei per cm^3 of the target. dE/dx is the rate of energy loss of the tritons in the target. Some discussion of the energy loss of hydrogen nuclei in D_2O has been presented by us elsewhere.[1,2] Numerical values were arrived at (and presented graphically in reference 1) for dE/dx in D_2O vapor. By suitable adjustment of the constant A, these values can be inserted in the above formula to determine $\sigma(E)$. One finds

$$\sigma(E)=2.38\cdot 10^{-6}\cdot(dN/dE)\cdot(dE/dx) \text{ barn},$$

where $N(E)$ = thick-target yield per microcoulomb of incident tritons,
dN/dE = change of $N(E)$ per kev change of bombarding energy, and
dE/dx = rate of energy loss in kev per cm of tritons in D_2O vapor at 1 mm of pressure, 15°C.

* This document is based on work performed at Los Alamos Scientific Laboratory of the University of California under Government Contract W-7405-eng-36.

** Professor H. H. Staub, now at Stanford University, joined in the direction of this research in its later stages. Considerable contributions were also made by M. J. Poole, F. G. P. Seidl, and H. L. Wiser.

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[1] Bretscher, French, and Seidl, Phys. Rev. **73**, 815 (1948).

[2] A. P. French, Phys. Rev. **73**, 1474 (1948).

EXPERIMENTAL METHOD

A. Ion Beam

In the absence of a continuous circulating device, the normal type of ion source consumes several cc of gas per hour. The amount of tritium available for experiments was only a few cc. Accordingly, it was necessary to dilute the tritium with hydrogen in order to lengthen the period during which measurements could be made. The degree of dilution employed was 1:100. The ion sources used in these experiments gave monatomic, diatomic, and triatomic beams, the diatomic ions composing about 90 percent of the whole. With such sources, fed with a tritium-hydrogen mixture, one has the following tritium-containing ions:

$$T^+, HT^+, H_2T^+, T_2^+, HT_2^+, T_3^+.$$

With a concentration of one percent tritium in hydrogen, the only important ions are T^+ and HT^+, and, of the two, HT^+ has by far the higher intensity. Moreover, it is the only ion of mass 4, so that there is no uncertainty in interpreting yield measurements made with the mass-4 beam. (There is one qualification to this assertion. If the ion source has been previously run for a considerable time with deuterium, the D_2^+ ions contribute to the mass-4 current. It is in this case necessary to run for a while with pure hydrogen before beginning any experiments with tritium.)

The maximum triton energy obtainable with the mass-4 beam is, however, only $\frac{3}{4}$ of the total bombarding energy. In order to make full use of the high voltage equipment, measurements were also made with the mass-3 beam. Although the current in this beam was principally due to H_3^+, experiment showed that the triton content of the beam was independent of the energy, and could be found by comparing the disintegration yields produced by mass-3 and mass-4 beams having the same triton velocity (i.e., for $E_T = \frac{3}{4}E_{HT}$).

B. Measurement of Beam Current

In consequence of the dilution of the tritium, the target currents of analyzed HT were sometimes only a few units of 10^{-8} amp. Measurement of these currents with a galvanometer was unreliable, because any instrument sensitive enough to measure such currents has too long a period to enable it to follow small rapid variations of intensity. Use was therefore made of a current integrator specially designed for the purpose.*** Its calibration did not exhibit any deviations due to leakage currents, even for input currents as low as $5\cdot 10^{-9}$ amp. (For circuit diagram, see Fig. 3, reference 1.)

*** Designed and constructed by M. J. Poole.

C. Counting

Since the HT^+ beam on the target was much weaker (by a factor of the order 100) than the deuteron beams used in the $D-D$ experiments, it was necessary to sacrifice some of the geometry of the detecting counters at the lower energies. At higher energies, the greater yield of the $T+D$ reaction compared to the $D+D$ compensated for the deficiency in beam current, and it became possible to employ the arrangement described in the $D-D$ paper.

Figure 1 shows the counter and target arrangement designed for the low energy work (15 to 40 kev). The counter was provided with 5 holes, covered with a mica window of 1 cm in stopping power. The window was supported to withstand pressure from both sides. The counter was filled to 30 cm of pressure ($A+3$ percent H_2) before being mounted in position. (This is the same procedure as was used for the $D+D$ experiment, but is more troublesome here because the window is much weaker.)

Difficulty was experienced because of the closeness of the counter to the target. The arc filament in the ion source was run on a.c. current, and this led to a ripple in the magnitude of the beam current, which was picked up by the unshielded body of the counter. The effect was much reduced by mounting a grounded copper screen (see Fig. 1) between the counter and the target, but it remained impossible to run a target current of more than about $0.1\mu A$.

The fraction of 4π subtended by the counter windows at the target spot was calculated.**** The calculation is necessarily crude, because one does not know the distribution of current intensity over the cross section of the beam. Accordingly, the fraction was also obtained experimentally by making measurements of the $D+D$ yield with the same set-up. An extra thickness of mica window was superimposed so that only the 3.0-Mev protons from the $D+D$ reaction could enter the counter. The values so obtained could be compared directly to the $D+D$ yields observed with good geometry. The solid angle fraction thus deduced agreed within ten percent of the calculated value. This agreement was considered satisfactory; the experimental value of the fraction was used in converting observed counting rates into total yields in 4π.

D. Recovery of Tritium

Various schemes were considered for the recovery of the tritium after use. In the end it was decided to adopt the simplest possible arrangement, namely, to collect the gas in an inverted burette after it had passed out to the atmospheric side of the forepump

**** We are indebted to Dr. E. J. Konopinski for the evaluation.

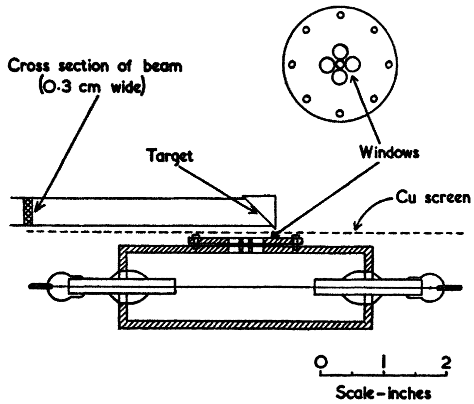

FIG. 1. Experimental arrangement for the yield measurements at lower energies.

of the vacuum system. CO_2 was used to flush out the dead volume above the oil in the forepump after a run with tritium had been completed.

FURTHER REMARKS ON THE EXPERIMENTAL METHOD

A. Target Contamination

In measurements at these low energies, the formation of a thin oil film on the surface of the target can easily render the results worthless. This is especially so in the case of the T+D reaction, where the excitation function is very steep. To take a specific example, an oil layer of thickness only 1 microgram per cm^2 would reduce the energy of a 30-kev triton beam by about 0.4 kev, and this would reduce the thick-target yield of the reaction by nearly ten percent. At an oil vapor pressure of 10^{-6} mm, such a layer would build up in about a minute. The need for a very clean vacuum system is therefore apparent.

To lessen target contamination as far as possible, several auxiliary cooling traps were installed in the vacuum system. These were kept filled with liquid nitrogen for a few hours before the target itself was cooled.

Two possible checks on target contamination could be applied. The first was simply to observe the change with time of the reaction yield for a given bombarding energy. The second check was more exacting. With a given bombarding voltage, the yield was measured as a function of the angle between the face of the target (which could be rotated) and the direction of the incident beam. If an oil film existed, it would thereby be made to present a varying thickness to the triton beam, and the yield would be changed. No evidence for target contamination exhibited itself in either of these tests.

B. Measurement of High Voltage

The steep rise of the excitation curve for the T+D reaction also imposes severe demands on the measurement of the bombarding voltage. Considerable attention was therefore paid to this point. On the low energy H.T. set, the voltmeter consisted of two 20-megohm precision resistors in series with a good quality 1-milliamp. meter. For the higher energy set a special resistance stack of 300 1-megohm precision resistors in series was constructed. The voltage across the bottom 1-megohm resistor was applied to a 30-microamp. meter in series with 16.5 megohms of precision resistors. The meters for both sets were carefully calibrated. The ratio of the two arms of the 300-megohm potential divider on the larger set was measured and was found to change by only 2 parts in 1000 before and after running the set at 125 kev for an hour.

SUMMARY OF OBSERVATIONS

A. Angular Distribution

The measurements on the excitation function were made with the counter in one fixed position. For higher energies, with the arrangement having good geometry, the angle of observation (measured by the angle between the direction of the incident beam and the radius joining target to counter window) was 90°. With the lower energy arrangement there was a spread of angle in the neighborhood of 90°. In order to convert these measurements into total yields it was necessary to know the angular distribution of the α-particles. This could be done only with the counter with good geometry, which could be rotated about a vertical axis through the target.

Observations on the angular distribution were made at two energies, 35 kev and 75 kev. Because of the low yields at 35 kev, and the consequent heavy consumption of tritium required to achieve good statistical accuracy, no detailed measurement was attempted. Observations were, however, made at six angles between 45° and 150°. It was considered that the results justified sufficiently the assumption that, for 35 kev and lower energies, the angular distribution was isotropic.

A much more careful study of the angular distribution was made for 75-kev bombarding energy. The results are shown in Fig. 2. It may be seen that the deviations from isotropy are not more than a few percent, and they may well be due to slight errors of alignment in the experimental set-up.

B. Excitation Function

Given the result of the preceding section, that the angular distribution is isotropic in the center-of-gravity system, it at once becomes legitimate to

TABLE I. Evaluation of the solid angle subtended by the counter window at the target (in the fraction F of 4π).

E	$A(E)$	$1+\frac{1}{3}A(E)$	$N(E)$	$C(E)$	$C(E)$ $[1+\frac{1}{3}A(E)]$	F
22.1	0.23	1.08	$1.89\cdot 10^3$	$1.94\cdot 10^1$	$2.10\cdot 10^1$	0.0111 ± 0.0008
27.0	0.24	1.08	$5.35\cdot 10^3$	$4.03\cdot 10^1$	$4.35\cdot 10^1$	0.0081 ± 0.0004
32.2	0.25	1.08	$1.22\cdot 10^4$	$8.15\cdot 10^1$	$8.80\cdot 10^1$	0.0072 ± 0.0003
40.0	0.26	1.09	$2.87\cdot 10^4$	$2.42\cdot 10^2$	$2.64\cdot 10^2$	0.0092 ± 0.0003
Mean value of $F=0.0088\pm 0.0008$						

determine the excitation function of the reaction by making measurements at one angle only. There is, in general, a correction by which the observed number of particles in the laboratory system is converted to an equivalent number per unit solid angle in the center-of-gravity system. If the angle of observation is chosen to be 90°, the correction is never more than one percent for energies less than 150 kev. Since this represents the conditions of the measurements here described, the correction has been ignored. The yield of particles in 4π is then given simply by the observed counting rate divided by the fraction of 4π subtended by the counter windows. This simple result holds even for the counter with bad geometry, since the α-particles are detected in almost equal numbers at angles both greater and less than 90°.

Reference has already been made to the artifice of extending the excitation curve to higher energies than are attainable with the HT^+ beam. Figure 3 shows how the method is applied. On a "Gamow" plot, of log $N(E)$ *vs.* $E^{-\frac{1}{2}}$, the yield curves are almost straight lines. By making observations on yield per microcoulomb of beam as a function of energy for both mass-3 and mass-4 beams, one obtains two parallel lines, as may be seen from the figure. The fact that the lines are parallel shows that the T content of the mass-3 beam does not change with energy. The distance between the lines on the logarithmic plot determines the factor by which one must multiply the mass-3 yields to obtain the yield per microcoulomb of T^+.

The precise means of determining the solid angle fraction for the low energy arrangement perhaps merits more detailed description: Counts were made on protons from the D+D reaction at four different energies. Let $C(E)$ be the count per microcoulomb of incident deuterons at energy E. Now the angular distribution of protons from the D+D reaction is given by

$$n(\theta)=n(90°)[1+A(E)\cos^2\theta]$$

in the center-of-gravity system. $n(\theta)$ and $n(90°)$ refer to numbers of protons per unit solid angle. The count at 90°, as with the T+D reaction, is almost unaffected by the conversion from the center-of-gravity to the laboratory system. This being so, it may readily be verified that the total yield of protons, corresponding to an observed count $C(E)$ at 90°, is given by

$$N(E)=(1/F)\cdot C(E)[1+\tfrac{1}{3}A(E)],$$

where F is the fraction of 4π subtended by the counter windows at the target. $N(E)$ and $A(E)$ have been independently determined,[1] so that one can at once determine F from the above equation. In Table I the results are set out fully. The errors quoted for individual values of F in the above table are those attributable to statistical fluctuations because of the low counting rates obtained with the D+D reaction. The total yield of the T+D reaction corresponding to an observed count $C'(E)$ in the counter is $(1/F)C'(E)$, i.e., 114 $C'(E)$, correct to ± 9 percent.

In Fig. 4 and in Table II below the collected values of thick-target yields are presented, log$N(E)$ being plotted as a function of $E^{-\frac{1}{2}}$. This method of presentation is convenient because, as has already been mentioned, it results in an almost linear plot. This has been used in deriving the value of dN/dE. A curve of E *vs.* $E^{-\frac{1}{2}}$ is also shown in Fig. 4, so that $N(E)$ as a function of E may be read from the figure without difficulty. Values of $N(E)$ obtained

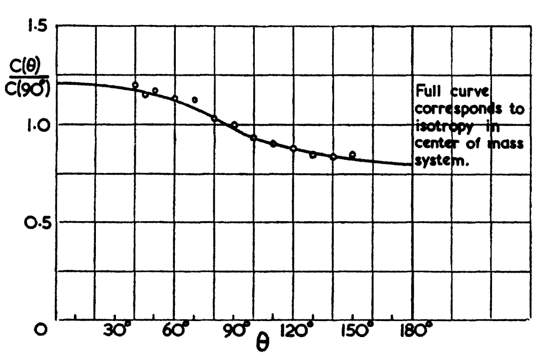

FIG. 2. Angular distribution of α-particles from a thick target at 75-kev incident triton energy.

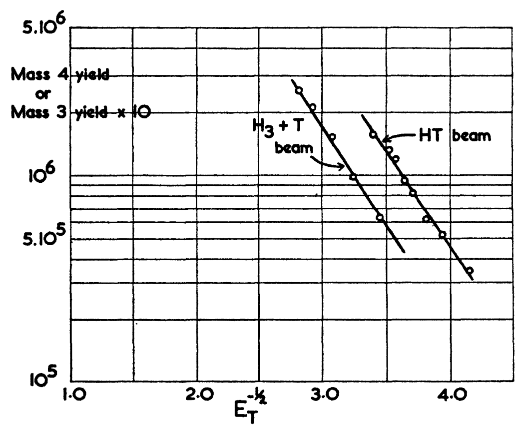

FIG. 3. Comparison of yields per microcoulomb of target current produced by mass-3 and mass-4 beams, respectively.

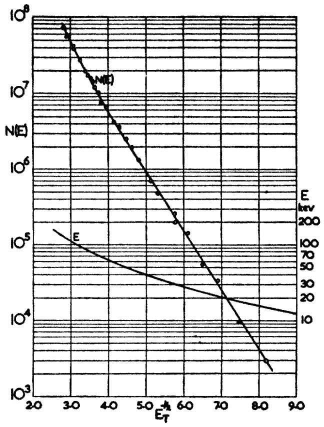

FIG. 4. Semilogarithmic plot of the thick-target yield of α-particles per microcoulomb of incident tritons, as a function of $E_T^{-\frac{1}{2}}$ (in (Mev)$^{-\frac{1}{2}}$).

TABLE II. Thick target yields, $N(E)$.

E kev	$E^{-\frac{1}{2}}$ (Mev)$^{-\frac{1}{2}}$	$N(E)$	E kev	$E^{-\frac{1}{2}}$ (Mev)$^{-\frac{1}{2}}$	$N(E)$	E kev	$E^{-\frac{1}{2}}$ (Mev)$^{-\frac{1}{2}}$	$N(E)$
15.0	8.16	$2.90\cdot10^3$	47.5	4.59	$1.97\cdot10^6$	80.8	3.52	$1.65\cdot10^7$
18.1	7.44	$9.61\cdot10^3$	50.9	4.44	$2.47\cdot10^6$	84.4	3.44	$1.76\cdot10^7$
21.1	6.89	$3.34\cdot10^4$	54.9	4.27	$3.64\cdot10^6$	87.1	3.39	$1.95\cdot10^7$
24.1	6.44	$5.42\cdot10^4$	58.2	4.15	$4.20\cdot10^6$	95.0	3.25	$2.75\cdot10^7$
27.2	6.06	$1.45\cdot10^5$	64.3	3.94	$6.41\cdot10^6$	105.6	3.08	$4.01\cdot10^7$
30.2	5.76	$2.22\cdot10^5$	69.1	3.80	$7.56\cdot10^6$	116.0	2.94	$5.87\cdot10^7$
36.4	5.25	$4.92\cdot10^5$	72.3	3.72	$1.02\cdot10^7$	118.8	2.90	$5.77\cdot10^7$
38.8	5.08	$6.92\cdot10^5$	75.3	3.64	$1.16\cdot10^7$	126.7	2.81	$7.20\cdot10^7$
43.7	4.79	$1.28\cdot10^6$	79.2	3.55	$1.49\cdot10^7$			

with the two different counter geometries (above and below 40 kev) appear to join up quite smoothly.

ERRORS

The counting errors at the lowest energies are about three percent, and at the higher energies are negligible. The geometry of the counter used at low energies is known within about nine percent; for the other counter it is better known—to about two percent. The current measurements with the integrator are probably good to two percent. The error due to the presence of neutral particles in the beam is, in general, not more than one percent; any errors due to target contamination or secondary electron emission were together not more than one percent.[1] The bombarding voltage is known within one percent. The combination of these factors leads to an aggregate error in the thick-target yield amounting to $\pm3\frac{1}{2}$ percent at high energies and about ±10 percent at low energies.

In translating the thick-target yields into cross sections one introduces a further small error (perhaps three percent or so) in differentiating the yield curve to find dN/dE. But the associated values of dE/dx are very uncertain, and it is impossible to estimate a probable error for the cross sections which are evaluated in the next section.

CROSS SECTION. COMPARISON WITH THEORY

It has been noted earlier that the cross section at any energy is given by

$$\sigma(E)=2.38\cdot10^{-6}\cdot(dN/dE)\cdot(dE/dx)\text{ barns},$$

where dN/dE is in α-particles per microcoulomb per kev, and dE/dx is in kev per cm in D_2O vapor at 1 mm pressure, 15°C. dN/dE has been found by obtaining graphically the slope of the yield curve. When plotted, the relation between $\log(dN/dE)$ and $E^{-\frac{1}{2}}$ appears to be accurately linear.

In Table III, which follows, the evaluation of $\sigma(E)$ is set out. Values of dE/dx are taken from Fig. 8 of reference 1. It is possible that their use leads to an overestimate of the cross section.[2] $\text{Log}\sigma(E)$ *vs.* E. is plotted in Fig. 5, and Fig. 6 shows $\log[E\cdot\sigma(E)]$ *vs.* $E^{-\frac{1}{2}}$.

This latter is a test of the simple Gamow formula, which for low energies becomes

$$\sigma(E)=\text{const.}1/E\cdot\exp[-2\pi e^2/\hbar v]$$
$$=\text{const.}1/E\cdot\exp[-1.72E_{\text{Mev}}{}^{-\frac{1}{2}}].$$

The slope corresponding to the theoretical exponent is indicated in Fig. 6. It may be seen that the values of $E\cdot\sigma(E)$ lie on a curve, which rises progressively more steeply, as the energy increases, than is demanded by the Gamow plot. This is interesting if one compares it with the analogous plot for the D+D reaction (see Fig. 10, reference 1). Here the

TABLE III. Values of the cross section $\sigma(E)$ in barns.

E kev	$E^{-\frac{1}{2}}$ (Mev)$^{-\frac{1}{2}}$	$dN/dE\cdot10^{-4}$	dE/dx kev per cm vapor at 1 mm pressure	$\sigma(E)$ barns	$E\cdot\sigma(E)$ kev$\times$barns
15	8.16	0.152	0.29	$1.05\cdot10^{-3}$	$1.56\cdot10^{-2}$
17.5	7.56	0.330	0.32	$2.51\cdot10^{-3}$	$4.40\cdot10^{-2}$
20	7.07	0.630	0.34	$5.10\cdot10^{-3}$	$1.02\cdot10^{-1}$
25	6.33	1.68	0.39	$1.56\cdot10^{-2}$	$3.90\cdot10^{-1}$
30	5.77	3.55	0.43	$3.63\cdot10^{-2}$	1.09
35	5.34	6.25	0.48	$7.14\cdot10^{-2}$	2.50
40	5.00	9.90	0.53	$1.25\cdot10^{-1}$	5.00
45	4.71	14.7	0.57	$2.00\cdot10^{-1}$	9.00
50	4.47	20.0	0.61	$2.90\cdot10^{-1}$	14.5
55	4.27	26.1	0.66	$4.10\cdot10^{-1}$	22.5
60	4.08	33.3	0.70	$5.55\cdot10^{-1}$	33.3
65	3.92	42.0	0.73	$7.30\cdot10^{-1}$	47.5
70	3.78	50.2	0.75	$8.96\cdot10^{-1}$	62.6
75	3.65	60.0	0.78	1.11	83.1
80	3.54	68.5	0.80	1.30	104
85	3.43	80.0	0.82	1.56	132.5
90	3.33	91.0	0.84	1.82	164
95	3.24	103	0.86	2.11	200
100	3.16	115	0.88	2.41	241
105	3.08	129	0.90	2.76	289
110	3.02	138	0.92	3.02	332
115	2.96	151	0.93	3.34	384
120	2.89	164	0.95	3.71	445
125	2.83	177	0.96	4.04	505

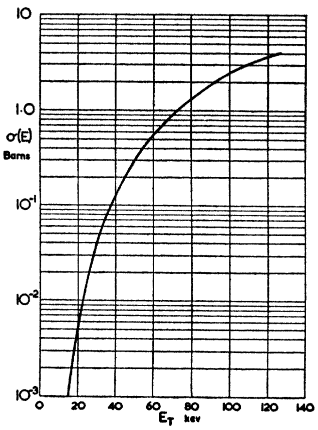

FIG. 5. Semilogarithmic plot of the T+D cross section as a function of incident triton energy.

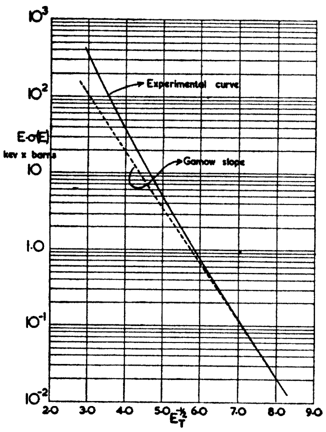

FIG. 6. Comparison of the energy dependence of $\sigma(E)$ with that to be expected from a simple Gamow penetration formula.

Gamow plot appears to be accurately a straight line. Since the same values for dE/dx were used in the two cases, the uncertainty in the energy-range relationship does not enter into this comparison.

The obvious inference is that a low energy resonance occurs in the T+D reaction. To gain some idea of the position and width of such a resonance, a Gamow formula modified by a resonance factor was assumed, of the form:

$$\sigma(E)=[1/E][A/((E_r-E)^2+\Gamma^2)]\cdot\exp[-1.72E^{-\frac{1}{2}}].$$

The best fit to the experimental curve was obtained with the following values of the parameters:

$A=325\times10^8$ (kev)$^3\times$cm^2,
Resonance peak—$E_r=124.3$ kev,
Half-width——— $\Gamma=71.7$ kev.

These values may give a rough idea of the true state of affairs, but it should be remembered that in deriving them one makes use of the rather doubtful values of dE/dx.

There exists a convenient way of expressing the results, independently of the precise energy-range relation in the target. The method is to compare the T+D and D+D cross sections at equal bombarding particle velocities. It may be assumed that a triton of energy E_{T} loses energy at the same rate as a deuteron of energy $E_{\mathrm{D}}=\frac{2}{3}E_{\mathrm{T}}$. One may therefore write:

$$(\sigma DT/\sigma DDp)_v=(dN/dE)_{DT,E}/(dN/dE)_{DDp,2/3E}.$$

Using the values of $(dN/dE)_{DDp}$ obtained from the experiments on the D+D reaction, the cross-section ratio has been evaluated as a function of energy. The results are tabulated in Table IV and are plotted in Fig. 7. (The first two points are dubious because they involve an extrapolation of the D+D measurements.) Now the Gamow penetration factor, $\exp[-(2\pi e^2)/\hbar v]$, is the same for T−D and D−D interactions under the conditions of the above comparison. The change of cross-section ratio with energy therefore suggests that the term preceding the exponential of the cross-section formula varies in a different manner for T+D and D+D reactions. If one assumes that the $1/E$ factor in this term holds good for both, then the difference is due entirely to the T−D resonance. If one ignores the two points below the 30-kev T energy (i.e., the points which involve an extrapolation of σ_{DDp}), the rest of the curve is consistent with a resonance at $E_r=343$ kev, and with half-width $\Gamma=80$ kev approximately. It will be seen that this differs greatly from the result of the first analysis, but the methods employed in the two cases are so different that this is not surprising. In the first instance, experimental knowledge is lacking in dE/dx; in the second, theory cannot assert positively that the $1/E$ in the cross-section formula is, in fact, valid for both the D+D and the T+D reactions. Moreover, it should always be borne in mind that the Gamow theory applies to the total cross section of an interaction and that only the proton-producing branch of the D+D reaction has been considered here.

It is probable that, if the D+D cross section could be accurately evaluated at a high energy,

TABLE IV

E_T kev	E_D kev	$(dN/dE)_{DT}$	$(dN/dE)_{DDp}$	$(\sigma_{DT}/\sigma_{DDp})_v$
15	10.0	$1.52\cdot10^3$	~10.0	~152
20	13.3	$6.30\cdot10^3$	~49	~129
30	20.0	$3.55\cdot10^4$	$3.04\cdot10^2$	117
40	26.7	$9.90\cdot10^4$	$8.00\cdot10^2$	124
50	33.3	$2.00\cdot10^5$	$1.55\cdot10^3$	129
60	40.0	$3.32\cdot10^5$	$2.42\cdot10^3$	137
70	46.7	$5.01\cdot10^5$	$3.40\cdot10^3$	148
80	53.3	$6.85\cdot10^5$	$4.35\cdot10^3$	158
90	60.0	$9.10\cdot10^5$	$5.39\cdot10^3$	169
100	66.7	$1.15\cdot10^6$	$6.20\cdot10^3$	186
110	73.3	$1.38\cdot10^6$	$7.10\cdot10^3$	195
125	83.3	$1.77\cdot10^6$	$7.80\cdot10^3$	227

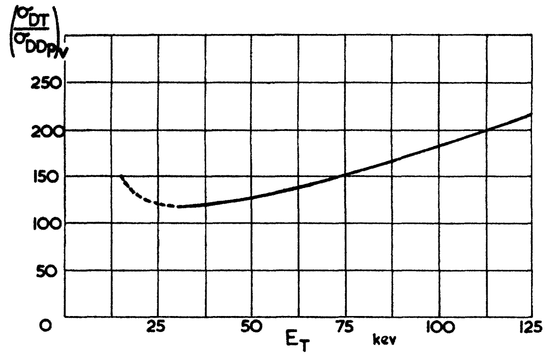

FIG. 7. Ratio of cross sections for the reactions $T(D, n)\alpha$ and $D(D, T)p$ for equal bombarding particle velocities.

where dE/dx is better known, an extrapolation would be possible with the help of theory to the low energy region corresponding to these experiments. With the aid of the ratios given in Table IV, one could then find the true T+D cross sections. A direct extrapolation from high energies for the T+D cross section would be more difficult on account of the uncertainty introduced by the resonance in this reaction.

CONCLUSION

The experiments described in this paper were designed for the determination of the cross section of the T+D reaction at low energies. The values given for the cross section as a function of energy should, however, be accepted with reserve, because of the very great uncertainty involved in estimating the rate of energy loss of the bombarding tritons in the heavy-ice target. The values of thick-target yields are considered to be fairly reliable and might be used for the evaluation of the cross section, should better measurements of the energy-range relation for slow protons or tritons become available.