

YIELD RATIOS FOR THE ISOMERIC PAIR ^{121m}Te , ^{121}Te PRODUCED IN $^{121}\text{Sb}(d,2n)^{121}\text{Te}$ NUCLEAR REACTION

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Abstract—The cross-section ratio for the isomeric pair ^{121m}Te , ^{121}Te produced in the $^{121}\text{Sb}(d,2n)^{121}\text{Te}$ nuclear reaction has been determined experimentally for deuterons from 9 up to 28 MeV.

NUCLEAR reactions are usually considered as proceeding by intermediate formation of a compound nucleus at low energies, ≤ 30 Mev.

If energetically possible the nucleus emits one or more particles and generally the residual nucleus remains in an excited state from which it reaches the ground or isomeric state through a gamma cascade.

At low energies of the nuclear projectile the spins of the target nucleus and of the isomers are the most important factors for determining the population ratio of the isomeric states. The isomer whose spin is closest to the spin of the compound nucleus will be favoured. At higher energies, where the compound nucleus is produced with a wider spin range, this effect is not so remarkable.⁽²⁻⁶⁾

The statistic theory suggests that the above mentioned ratio should approach the statistical weights ratio of the isomeric states.^(7,8)

In this work, the ratio of the yields of the isomeric pair Te^{121m} , ^{121}Te , formed in the $^{121}\text{Sb}(d,2n)^{121}\text{Te}$ nuclear reaction is studied as a function of the energy of the bombarding particle.

EXPERIMENTAL

a. Bombarding procedure

Samples of antimony oxide were irradiated in the internal beam of the 180 cm synchrocyclotron of the C.N.E.A. (Buenos Aires) with deuterons from 9 up to 28 MeV energy.

The experiment was performed using the stacked foil technique. The Sb_2O_3 was slurred on silver foils of approximately 30 mg/cm^2 which were then folded over and stacked together. The deuteron energy on each sample of the stack was calculated from RICH and MADEY range-energy curves.⁽⁹⁾

The exposure was performed at the orbit corresponding to 28.1 MeV. The maximum spread of the beam was estimated to be ± 1.2 MeV, for 28.1 MeV energy. The modification of the curvature across the target was not enough to change the thickness of the absorber traversed by the particles.

Owing to the flux variations throughout the different thickness of the target the excitation function of each single isomer was not determined.

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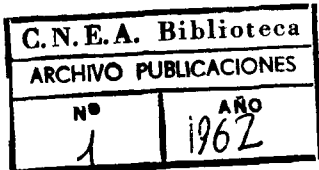
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The stable isotopes for antimony are: ^{121}Sb (57.25 per cent) and ^{123}Sb (42.75 per cent). On account of the different cross-sections for the $(d,4n)$ and $(d,2n)$ reactions the ^{121}Te activity from $^{123}\text{Sb}(d,4n)^{121}\text{Te}$ reaction is negligible in regard to the $^{121}\text{Sb}(d,2n)^{121}\text{Te}$ reaction activity.

b. Chemical separation

The irradiated antimony tri-oxide was dissolved in 6N HCl and tellurium carrier was added. After the reduction with HBr, metallic tellurium was precipitated with hydrazinehydrochloride.

The precipitate was dissolved and reprecipitated several times always using antimony as hold-back-carrier.

c. Counting procedure

The decay scheme⁽¹⁰⁾ of ^{121}Te is sketched in Fig. 1.

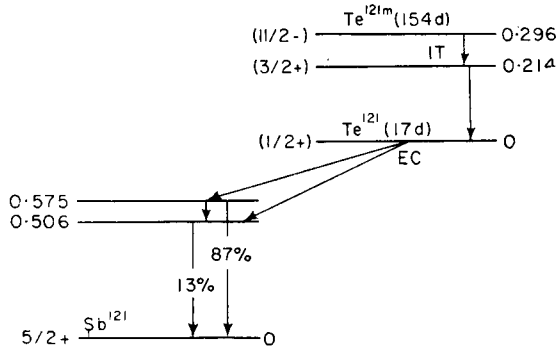


FIG. 1.—Disintegration scheme of $^{121m/121}\text{Te}$

By measurement of the 0.214 and 0.575 MeV γ -rays, the populations of the 154 and 17 days half-lives levels respectively can be determined.

The γ -spectra were obtained with a 2 in. \times 2 in. NaI (TI) scintillation counter coupled to a one channel pulse height analyser.

Fig. 2 shows as example the gamma spectrum of $^{121m/121}\text{Te}$ corresponding to a 18.7 ± 0.3 MeV deuteron energy measured 72 days after irradiation. Peaks corresponding to 0.575, 0.506, 0.214 and 0.159 MeV energies are observable. The two first peaks correspond to radiation emitted in the ground level disintegration of the ^{121}Te ; the 0.214 MeV ray to the de-excitation of the isomeric state and the 0.159 MeV ray is from ^{123}Te produced in the $^{123}\text{Sb}(d,2n)^{123}\text{Te}$ reaction.

The areas under the 0.214 and 0.575 MeV photopeaks were integrated graphically. Counting corrections and those corresponding to the disintegration scheme were made in order to calculate the relative intensities of the two levels under investigation.

RESULTS AND DISCUSSION

The values of the cross section ratios for the excited $[(11/2) -]$ and ground $(\frac{1}{2} +)$ levels with contribution of the intermediate level $(\frac{3}{2} +)$, for different deuteron energies, are given in Table 1.

The $\sigma(11/2)/(\sigma_{\frac{1}{2}} + \sigma_{\frac{3}{2}})$ (indicated as σ_m/σ_g) represent an average of data obtained at different times from the end of irradiation. The listed errors are the deviation of the single values from the average.

In Fig. 3 the σ_m/σ_g ratio is shown as a function of the deuteron energies. A slight increase in the population of the highest spin level is noticeable with growing deuteron energy. This is in agreement with earlier experimental work⁽²⁻⁸⁾, i.e. at low deuteron energies the states of the residual nucleus closest to the spin of the target nucleus are the most favoured.

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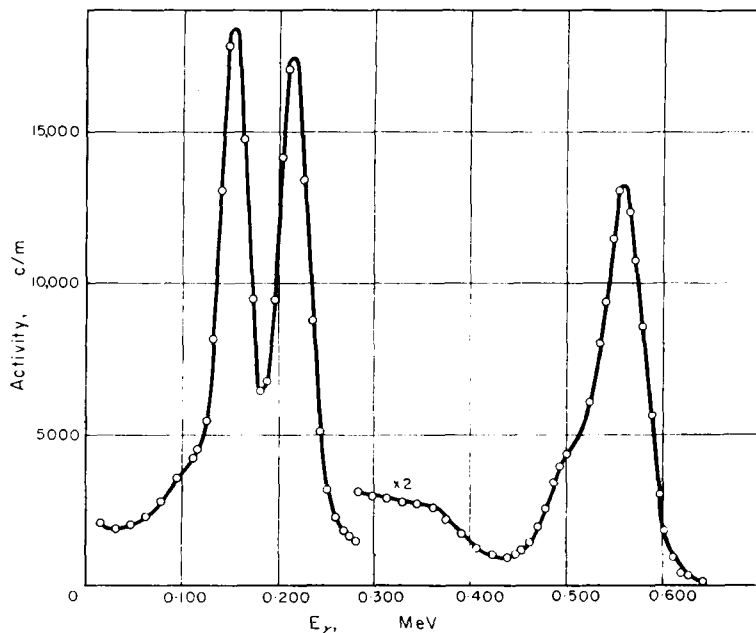


Fig. 2.— γ -spectrum of $^{121m/121}\text{Te}$ corresponding to 18.7 MeV deuteron energy, measured 72 days after the end of irradiation.

TABLE 1.

Deuteron energy (MeV)	σ_m/σ_h
27.30 ± 0.1	0.793 ± 0.087
25.80 ± 0.2	0.747 ± 0.064
24.20 ± 0.2	0.653 ± 0.079
22.80 ± 0.2	0.720 ± 0.093
21.50 ± 0.1	0.720 ± 0.060
20.30 ± 0.1	0.623 ± 0.024
18.70 ± 0.3	0.653 ± 0.032
16.60 ± 0.2	0.603 ± 0.009
14.30 ± 0.3	0.560 ± 0.015
11.70 ± 0.3	0.470 ± 0.025
9.20 ± 0.2	0.560 ± 0.095

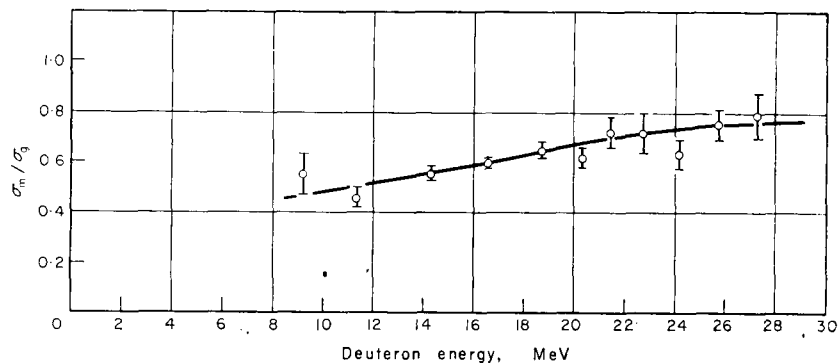


FIG. 3.— σ_m/σ_g ratio as a function of the deuteron energies.

It is not possible to conclude if this ratio tends to the limit $(2I_m + 1)/(2I_g + 1 + 2I_i + 1)^{(7,8)}$, were I_m , I_g and I_i are the spins of the metastable, ground and intermediate states respectively.

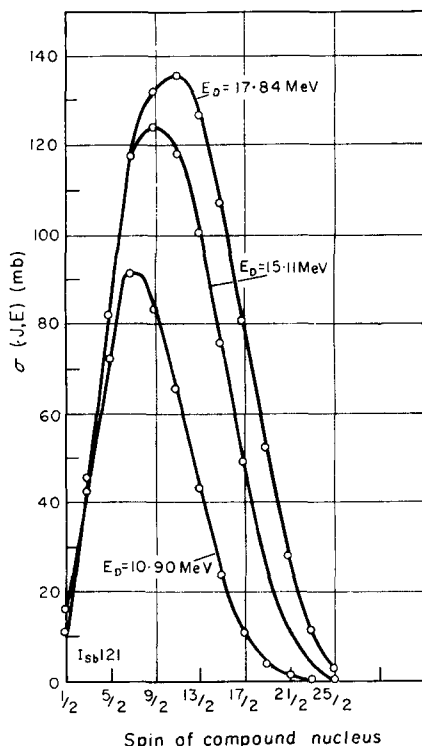


FIG. 4.—Distribution of angular momentum in compound nuclei for deuteron energies of 10.90, 15.11 and 17.80 MeV

Assuming that every particle penetrating into the potential barrier is captured, the angular momentum distribution of the compound nucleus was calculated from:

$$\sigma(J, E) = \pi \lambda^2 \sum_{S=|I-s|}^{I+s} \sum_{l=|J-S|}^{J+S} g(S) \frac{2J+1}{2S+1} \cdot T_l(E)$$

where $T_l(E)$ is the barrier transmission coefficient of a particle with orbital angular momentum l and energy E .

S is the spin entrance-channel.

J is the angular momentum of the compound nucleus.

I is the spin of the target nucleus.

s is the spin of the deuteron.

$g(S)$ is the statistical weight for S .

Fig. 4 shows such distribution for incident deuteron energies of 10.90 MeV, 15.11 MeV and 17.84 MeV (in the centre-of-mass system).

The trend observed from the curves in Fig. 4 agrees with the experimental results sketched in Fig. 3.

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