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YIELD RATIOS OF THE ISOMERIC PAIR $Ce^{137m/137}$ FORMED BY La^{139}(d, 4n) Ce^{137} REACTION

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Abstract: The variation of the yield ratio between the isomeric pair formed in the reaction La^{139}(d, 4n)$Ce^{137m/137}$ for deuteron energies up to 27 MeV has been measured.

1. Introduction

Nuclear isomers being different states of the same isotope we can expect different relative yields of the isomeric pairs from different nuclear reactions or excitation energies [1–3]. By studying those relationships at variable excitation energies, an indication of the reaction mechanism may be obtained.

The purpose of the present work was to study the cross section ratio of the isomeric states $Ce^{137m}(\frac{11}{2}-)$ and $Ce^{137}(\frac{3}{2}+)$ for the (d, 4n) reaction on La^{139} (99.91 %, $\frac{7}{2}+$), bombarding with deuterons ranging between 18 and 27 MeV.

We have chosen such an isomeric pair and such a nuclear reaction in order to have the same spin difference between the target nucleus and the excited and fundamental levels of the isomeric pair.

2. Experimental

2.1. IRRADIATIONS

The targets for the experience were prepared by using the stacked foils technique. Some La_2O_3 powder was suspended in an nitrocellulose-amyl acetate solution and slurried onto thin copper foils, which were then folded over and stacked together.

The deuteron energy at each sample of the stack was calculated from the range-energy curves of Aaron, Hoffman and Williams [4].

The irradiations were performed with the internal beam of the 180 cm diameter synchrocyclotron of the C.N.E.A. at the orbit corresponding to 28.1 MeV energy.

The maximum uncertainty in the beam energy was estimated at ± 1.2 MeV for 28.1 MeV.

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The modification of the curvature radius inside the target was not enough to change the thickness of the absorber traversed by the particles.

Due to the variation of the flux across the different samples of the stack, the excitation functions of the single isomers were not determined.

2.2. CHEMICAL SEPARATIONS

The irradiated sample of La_2O_3 was transferred mechanically into a beaker.

It was dissolved in 10 ml of concentrated HNO_3; Ce^{III} carrier was added, and after oxidyzing to Ce^{IV} with saturated $KBrO_3$ solution, $Ce(10_3)_4$ was precipitated with KIO_3 (ref. [5]).

The precipitate was dissolved in H_2O_2 with drops of concentrated HNO_3 and afterwards $Ce(OH)_3$ was precipitated with NaOH. The hydroxide was dissolved in HNO_3 and Ce^{IV} reprecipitated as above, adding previously La^{III} as hold-back carrier.

The cycle $Ce(OH)_3$, $Ce(OI_3)_4$ was repeated twice so as to make the La impurity negligible.

2.3. COUNTING METHODS

The decay scheme [6]) is sketched in fig. 1.

Two lines are prominent in the gamma spectrum, one at about 255 keV and one at 445 keV. The first one is attributed to a transition of 34.1 h Ce^{137m}

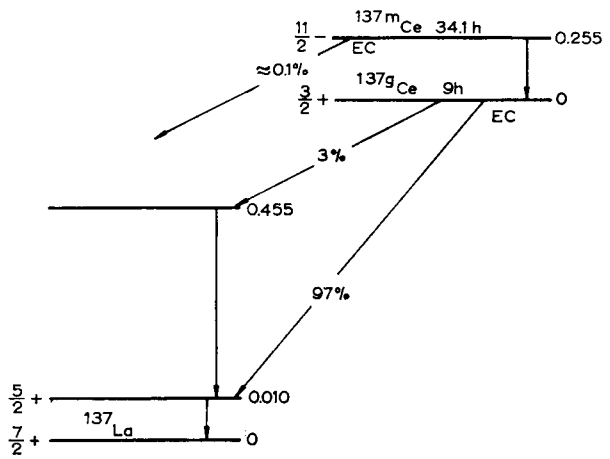

Fig. 1

decaying to Ce^{137}; the 445 keV line arises from the decay of the second excited state of daughter La^{137}.

Measuring the relative intensities of the 255 keV and 445 keV gamma rays the abundances of the 34.1 and 9.0 h levels can be determined.

The radiations of the sample were detected with a 2.54 cm × 2.54 cm sodium

iodide (Tl activated) crystal coupled to a one-channel pulse height analyzer [7]). The same geometry used in the determination of the efficiency curve was maintained during the measurements.

To prevent piling-up effects, the X-ray of the La was absorbed with a Sn foil of 0.581 g/cm^2 followed by one of Mo of 0.153 g/cm^2. The low values for the (d, 4n) reaction cross section resulted in low intensities which made the measurements difficult.

Fig. 2 shows as an example the gamma spectrum of the $Ce^{137m/137}$ corresponding to 26.9 MeV deuteron energy, some hours after the end of irradiation.

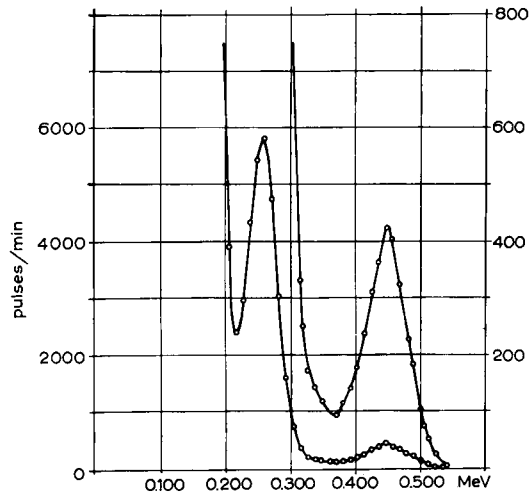

Fig. 2.

The areas under the 255 and 445 keV peaks were graphically integrated. Making the counting corrections and those corresponding to the disintegration scheme, the relative intensities of the 34.1 and 9.0 h levels were calculated for each deuteron energy.

The values of the cross-section ratios (σ_m/σ_g) for the excited and fundamental levels for different deuteron energies are given in table 1. The errors in σ_m/σ_g are of the order of 20 %.

Fig. 3 shows the curves of the variation of σ_m/σ_g, with deuteron energy.

3. Discussion

In the present case, either because the spin of the target nucleus is exactly in the middle between those of Ce^{137m} and Ce^{137}, or because the threshold for the reaction occurs only at 18 MeV, both isomeric states can be equally reached. However, as in other reactions [2, 3, 8, 9, 11]), statistical considerations may indi-

cate that the spin of the compound nucleus increases with energy [12]). Thus, the slope of the curve in fig. 3 can be qualitatively understood.

TABLE 1

Values of the cross-section ratios for the excited and fundamental levels for different deuteron energies

E (MeV)	$\sigma_m\ \sigma_g$
18.8±0.2	0.03
21.8±0.3	0.09
22.7±0.3	0.15
23.5±0.2	0.34
24.4±0.3	0.38
25.1±0.2	0.59
25.9±0.2	0.46
26.9±0.3	0.76
27.7±0.3	0.67
27.9±0.2	0.68

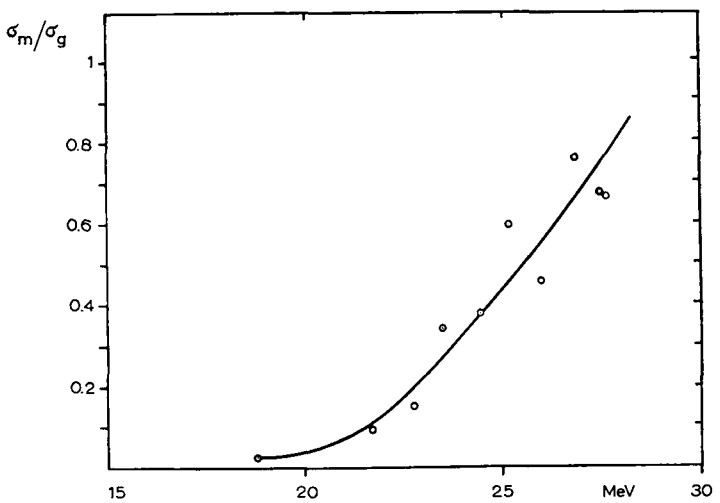

Fig. 3

The available deuteron energies do not allow decision whether there is an asymptotic value of σ_m/σ_g (ref. [13])).

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