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ÇEKMECE NUCLEAR RESEARCH AND TRAINING CENTER
İSTANBUL - TURKEY

ÇNAEM-R- 187

TOTAL NEUTRON CROSS SECTION OF TERBIUM IN THE THERMAL AND EPITHERMAL ENERGY REGIONS AND DETERMINATION OF THE POTENTIAL SCATTERING CROSS SECTION

Ç.CANSOY, H.ATASOY, and Ş.ZEBİTAY'an

P.K. 1, Hava Alanı, İstanbul, Turkey

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A B S T R A C T

The total neutron cross section of ^{159}Tb has been measured in the energy range from 0.062 to 1 eV with a crystal spectrometer using the Be($10\bar{1}1$) crystal planes as a monochromator. The data in the left wing of the first neutron resonance in ^{159}Tb were fitted directly to the onelevel Breit-Wigner formula using the method of least squares. The parameters obtained from the analysis are $\sigma_p = 7.96 \pm 1.33$ b and $A = 5.50 \pm 0.86$ b X $(eV)^{1/2}$.

Ö Z E T

TERBİYUMUN TERMAL VE EPİTERMAL ENERJİ BÖLGESİNDE TOPLAM NÖTRON TESİR KESİTLERİ VE POTANSİYEL SAÇILMA TESİR KESİTİ

^{159}Tb'un toplam nötron tesir kesitleri, 0.062 eV'dan 1 eV'a kadar olan enerji aralığında Be($10\bar{1}1$) kristal düzlemi monokromatör olarak kullanılarak bir kristal spektrometresinde ölçülmüştür. Deney sonucunda, tek seviyeli Breit-Wigner formülüne en küçük kareler metodu uygulanarak bahis konusu enerji aralığında aşağıdaki rezonans parametreleri tayin edilmiştir:

$$\sigma_p = 7,96 \pm 1,33 \text{ b}, \quad A = 5.50 \pm 0,86 \text{ b X } (eV)^{1/2} .$$

C O N T E N T S

TOTAL NEUTRON CROSS SECTION OF TERBIUM IN THE THERMAL AND EPITHERMAL ENERGY REGIONS AND DETERMINATION OF THE POTENTIAL SCATTERING CROSS SECTION [1]

Ç. Cansoy, H. Atasoy, and Ş. Zebitay'an

I. INTRODUCTION

The experimental values of the total neutron cross section of terbium for the energies between 0.0025 and 0.35 eV are lacking. Therefore, the total neutron cross section of terbium has been measured in the energy range from 0.062 to 1 eV with a crystal spectrometer. In this energy range it is possible to determine the potential scattering cross section σ_p, and this has been done in this paper. On the other hand, the parameter A due to the far away resonances was also determined.

II. EXPERIMENTAL DETAILS

The total neutron cross section of ^{159}Tb has been measured for seventy different neutron energies in the energy range from 0.062 to 1 eV with the ÇNAEM crystal spectrometer [1,2]. This energy range falls in the left wing of the first neutron resonance of terbium. The spectrometer resolution was 1.405 μsec/m using the Be($10\bar{1}1$) crystal planes as a monochromator.

A sample was made by mounting the oxide Tb_2O_3 in an aluminum cell. This sample had an inverse thickness 1/N of 87.92 ± 0.44 b/atom. In calculations of the total neutron cross section of the oxide Tb_2O_3 the cross section of the oxygen atoms in the sample was taken into account and subtracted from the total cross section. According to the data given in BNL-325 [3] this correction term was found to be almost constant and equal to 5.5 b.

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[1] This work was done in 1973 .

III. RESULTS AND ANALYSIS

By the "wings" of a resonance[4], we mean those regions for which $4(E - E_o)^2 \gg \Gamma^2$. For the purpose of this analysis, only those points were used for which the equation $4(E - E_o)^2 \geq 160\,\Gamma^2$ holds. This condition gives $E \leq 2.84$ and $E \geq 3.86$ eV for the 3.35 eV resonance in ^{159}Tb. Therefore, the left wing cross section of this resonance has been measured in the energy range from 0.062 to 1 eV. In wing regions the resolution correction and the Doppler correction are negligible. Consequently the experimental data in the wings can be fitted directly to the one-level Breit-Wigner formula using the method of least squares. On the other hand, for the total cross section one should consider the influence of the absorption peaks in higher energies, which contribute with an additional term $A/(E)^{1/2}$ in lower energies, where A is a constant that can be estimated for the far away resonances. Thus, the data in the left wing of the first neutron resonance in ^{159}Tb were fitted directly to the following formula[4]:

$$\sigma_T = \frac{\left[(1 - K)\sqrt{\frac{E_o}{E}} + K\right]\sigma_o\Gamma^2 + (E - E_o).\mathcal{J}}{4(E - E_o)^2 + \Gamma^2} + \sigma_p + \frac{A}{(E)^{1/2}} \qquad (1)$$

In this equation we seek to solve for the best σ_p and A. The values of the other resonance parameters of ^{159}Tb as recommended in BNL-325[5] are $E_o = 3.35 \pm 0.01$ eV, $\Gamma = 0.08 \pm 0.01$ eV, $\Gamma_n = (0.34 \pm 0.03) \times 10^{-3}$ eV, $J=2$, and $I= 3/2$. Using these values of the parameters, K, $\sigma_o\Gamma^2$, and $g(J)$ have been estimated from the following equations[6]:

$$K = \Gamma_n/\Gamma\,, \qquad (2)$$

$$\sigma_o\Gamma^2 = \frac{10^7\, g\,\Gamma_n\Gamma}{3.841\, E_o}\,, \qquad (3)$$

$$g(J) = \frac{2J + 1}{2(2I + 1)}\,. \qquad (4)$$

The results are K= 0.00425, $\sigma_o\Gamma^2$ = 13.2 bX(eV)^2, and g(J) = 0.625. On the other hand, an approximate value of the parameter $\mathcal{J}$ has been obtained using the relation [6]

$$\mathcal{J} = 4(g\,\sigma_o\Gamma^2\,K\,\sigma_p)^{1/2} \qquad (5)$$

and the trial value of 11 b for σ_p. The result is $\mathcal{J}$= 2.5 bXeV. Using these values of parameters, the quantities obtained from analysis of the data are listed in Table I. The agreement between the experimental points and the Breit-Wigner curve is reasonably good over the entire range. (Fig. 1). On the other hand, the nuclear radius was calculated from the formula

$$\sigma_p = 4\pi R^2, \qquad (6)$$

and using this value of R, the constant r_o was calculated from the formula

$$R = r_o A^{1/3}. \qquad (7)$$

The results are shown in Table I.

Table I

Breit-Wigner Parameters for the Left Wing of Terbium Resonance Derived from Analysis of Experimental Data

σ_p= 7.96 ± 1.33 b
A = 5.50 ± 0.86 b X (eV)$^{1/2}$
$\mathcal{J}$ = 2.11 ± 0.24 b X eV
R = 7.96 ± 0.66 fm
r_o = 1.47 ± 0.12 fm

IV. DISCUSSION

The total neutron cross section of ^{159}Tb has been measured by A. Knorr [5] (Munich, 1965) in the energy range from 0.00022 to 0.00236 eV. Since the total cross section in this energy range is affected by the left wings of all neutron resonances of ^{159}Tb, the parameter A can be obtained accurately from these experimental data. Therefore, the data given by A. Knorr were fitted directly to the formula

$$\sigma = \frac{A}{(E)^{1/2}} + B,$$

and the result is A = 5.49 b X $(eV)^{1/2}$. Comparison between this result and the value given in Table I are in agreement within experimental error. Analysis also gives the value of B = 16.44 b.

Since the total cross section measured by using the ÇNAEM spectrometer covers the vicinity of the minimum of the left wing of the first neutron resonance in ^{159}Tb, the parameter σ_p can be determined accurately. In fact, the value of 8.64 b for σ_p obtained by using the method of neutron diffraction in Ref. 7 is in agreement with the value given in Table I.

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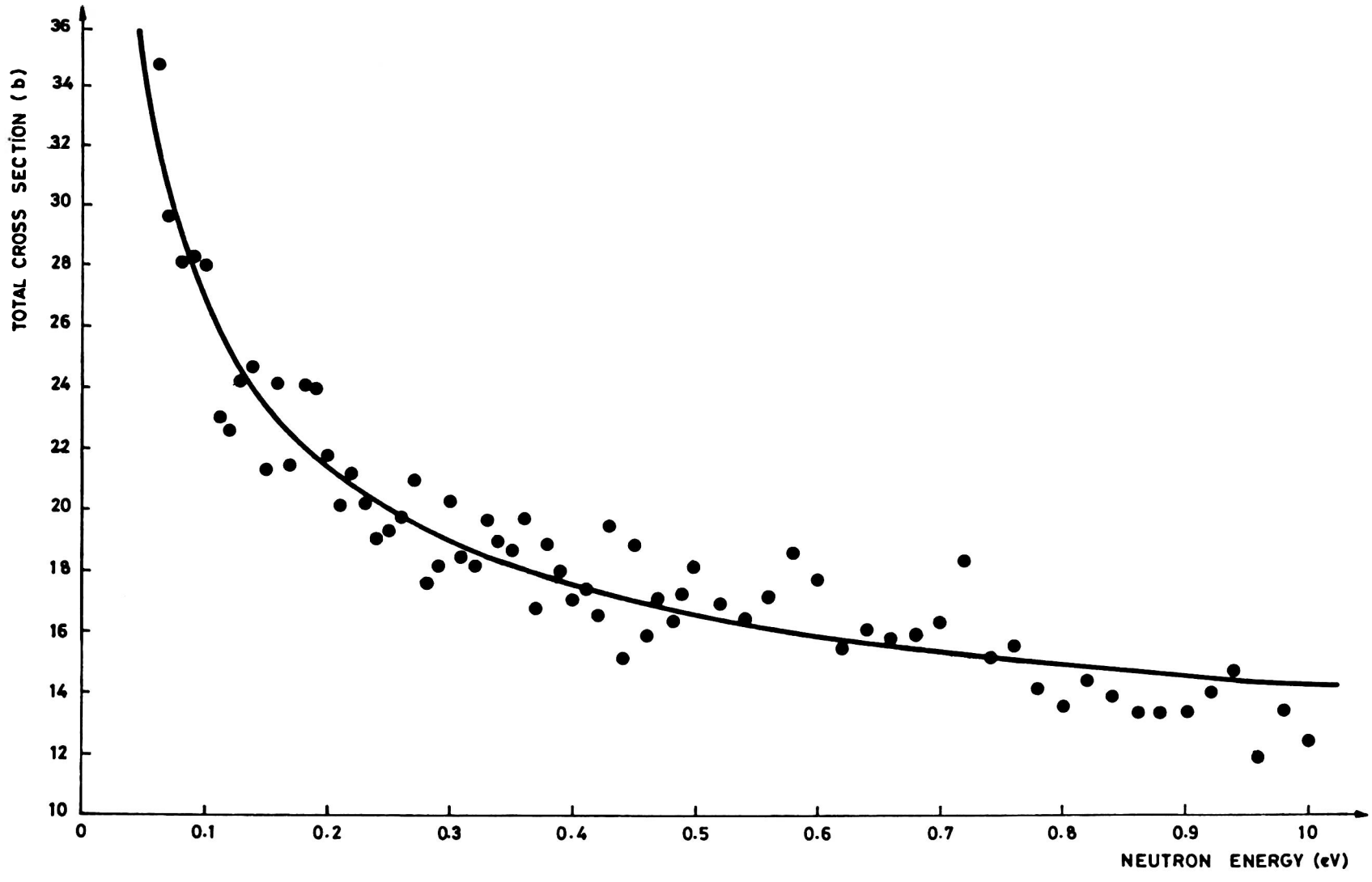

Fig.1_ The total cross section of terbium as a function of neutron energy in the region of the left wing of 3.35 eV resonance.
The curve is fitted Breit-Wigner cross section.