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EXCITATION CURVE FOR THE REACTION ^{181}Ta(n, γ) ^{182}Ta IN THE 0.03 TO 5.1 MeV NEUTRON ENERGY RANGE

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The activation method was applied in measurements of the cross-sections of the ^{181}Ta (n, γ) ^{182}Ta reaction in the neutron energy range from 0.03 to 5.1 MeV. The agreement of the experimental results with those predicted theoretically by the statistical model was good on the assumption that the formula for the γ-ray emission probability depends on the γ-ray absorption cross-section. It was necessary to assume that a giant $E1$ resonance and a *„pigmy"* resonance exist. The agreement was poor when the probability of γ-ray emission was assumed to be proportional to E_γ^3 (E_γ being the energy of γ quanta).

1. *Introduction*

Measurements of the cross-sections of nuclear reaction and their confrontation with the predictions of theoretical models may provide valuable information concerning the mechanism responsible for the course of the investigated processes.

In order to avoid the error associated with inaccurate knowledge of the parameters used in the calculations, it is desirable to investigate various reactions of identical incoming channels. The present paper contains results concerning the reaction ^{181}Ta (n, γ) ^{182}Ta and is a part of a broader investigation of the mechanism of reactions caused by fast neutrons in tantalum [1], [2], [3].

Information hitherto published [4], [5] to [10], on the cross-sections of the reaction of interest to us shows that up to a neutron energy of $E_n \approx 1$ MeV it is described well by assuming the formation of a compound nucleus. It is generally regarded that the contribution of this mechanism drops with an increase of neutron energy, and that to an increasing extent the reaction proceeds by direct interaction.

It seems worthwhile to supplement the experimental data concerning the excitation curve for the reaction ^{181}Ta(n, γ) ^{182}Ta and to analyze the agreement of the results with values calculated on the basis of the compound nucleus model.

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2. *The experimental method*

The cross-section of the reaction ^{181}Ta (n, γ) ^{182}Ta was measured by the activation method. The neutrons were obtained from the reactions ^{2}H (d, n) ^{3}He and ^{3}H (p, n) ^{3}He. Tritium and deuterium were absorbed in zirconium. The target thickness was less than 0.5 mg/cm^2. The protons and deuterons were accelerated in a Van de Graaff generator. The neutron flux was determined by means of the reactions:

^{197}Au (n, γ) ^{198}Au for $E_n = 30$ to 600 keV, [11],
^{63}Cu (n, γ) ^{64}Cu for $E_n = 0.2$ to 1 MeV, [4],
^{64}Zn (n, p) ^{64}Cu for $E_n = 1.9$ to 5.1 MeV, [12], [13].

The cross-sections of these reactions are well known and their products are easy to identify and measure. The activity of ^{182}Ta was identified by measuring the group of gamma rays of energy $E_\gamma = 890$ to 1400 keV which accompany the β decay of the product of the given reaction [14]. The half-life of ^{182}Ta is $T = 115$ days [15]. The gamma activity was measured by a scintillation spectrometer with a 2″×2″ NaI(Tl) crystal.

3. *Result and discussion*

The results of the measurements are presented in Fig. 1 and Table I. The excitation curve obtained in our work is in good agreement with most results of other investigators, [4], and [5] to [10], whose measurements concern particular parts of the neutron energy range encompassed by our investigations. It should be noted that the neutron energy spread, as given in the table, was much less in our experiment than in previous works. According to the decay scheme of the ^{182}Ta adopted after ref. [15], the nucleus has a metastable state which decays in 95 percent by gamma emission to the ground state. The half-life of the

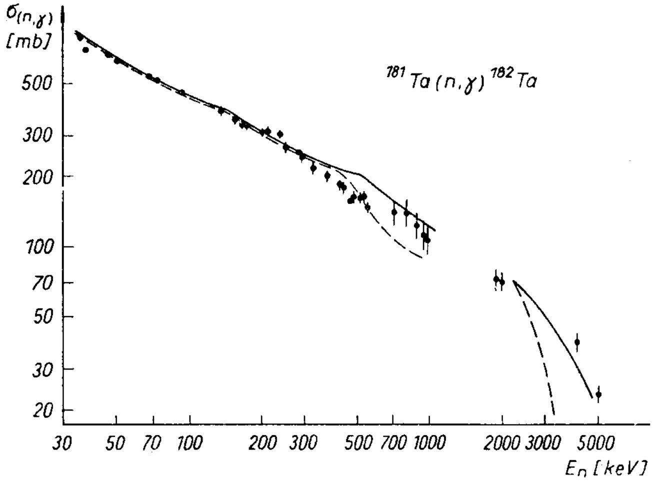

Fig. 1. Comparison of the experimental results with theoretical predictions. Solid line represents the theoretical predictions based on formula (2); dotted line — on formula (1)

TABLE I

Neutron energy (keV)	Measured cross-section (mb)	Neutron energy (keV)	Measured cross-section (mb)
35± 8	798±37	326±34	218±12
37± 8	698±37	370±30	202±12
46±11	657±32	417±36	186±10
50±11	623±32	429±36	183±10
67±13	520±26	465±38	156± 8
74±13	515±26	476±38	164± 8
93±13	456±23	504±40	161± 8
136±22	380±17	512±40	164± 8
154±22	347±18	557±43	144± 7
163±24	333±16	558±43	146± 7
175±24	324±16	712±32	139±29
192±12	310±16	790±34	138±22
207±27	304±15	883±35	123±20
216±27	310±15	955±31	112±18
242±29	299±14	980±28	107±17
251±29	266±14	1900±200	73±10
282±30	249±12	2000±200	70±10
288±30	245±12	4160±150	39± 3
322±34	236±12	5110±150	23± 3

ground state is 115 days. For this reason a measurement of the activity decay with a half-life of 115 days enables the total cross-section of the reaction under study.

It is seen from ref. [8] that for $E_n < 1$ MeV the ratio of the cross-sections for the production of the metastable and ground states is $\sigma_m/\sigma_g \approx 0.01$, so that it may also be expected that for $E_n = 1.9$ to 5.1 MeV the ratio $\sigma_m/\sigma_g < 1$, that is, the total cross-section is too small by less than 5 percent. This error is not taken into account in the measurement errors given in Table 1.

The formula most frequently met with in the literature for the probability of gamma-ray emission from a compound nucleus is

$$P_\gamma \propto \sum_I \int_{E_\gamma} E_\gamma^3\, \varrho(U, I)\, dE_\gamma \tag{1}$$

where: $\varrho(U, I)$ is the level density of a nuclei of spin I and excitation energy. $U = E_n + B - E_\gamma$ (B is the neutron binding energy).

Instead of Eq. (1), Starfelt [16] uses a form associated with the cross section $\sigma_\gamma(E_\gamma)$ for absorption of a quantum by a nucleus

$$P_\gamma \propto \sum_I \int_{E_\gamma} E_\gamma^2 \varrho(U, I) \sigma_\gamma(E_\gamma)\, dE_\gamma. \tag{2}$$

In our calculations, using Eq. (2), we took the gamma-absorption cross-section in a form containing a "*pigmy*" resonance [16] in addition to the giant *El* resonance. The relative contribution, b, of these resonances to $\sigma_\gamma(E_\gamma)$($b = \int\limits_0^\infty \sigma_\gamma^p dE_\gamma / \int\limits_0^\infty \sigma_\gamma^{E1} dE_\gamma$ where $\sigma_\gamma(E_\gamma) = \sigma_\gamma^p + \sigma_\gamma^{E1}$) was assumed to be a parameter in our computation and equaled from 0.002 to 0.02.

The process of inelastic neutron scattering is competitive with the reaction (n, γ) in this energy range. This effect was taken into account in the calculations with consideration for the spins and parities of the concrete levels of ^{181}Ta for $E_n \leqslant 1$ MeV. The probability of neutron emission has been described statistically for $E_n > 2$MeV.

The level density has been taken from ref. [17], and the transmission coefficients for neutrons from ref. [18].

A detailed description of the calculations can be found in refs [19] and [20].

Figure 1 gives a comparison of the experimental results with the predictions based on the compound nucleus model in which Eq. (2) was used for the calculation of P_γ. The conformity is much worse when Eq. (1) is used for this purpose. As can be seen, the experimental results are in good agreement with the theoretical predictions as regards both the shape of the energy dependence and the magnitude. The (n, γ) cross-sections have also been calculated for the nuclei ^{103}Rh, ^{127}I, ^{133}Cs, ^{197}Au. In all cases, satisfactory agreement of theory with experiment was obtained. In the range $E_n > 2$ MeV it was especially important to account for the "*pigmy*" resonance in calculating σ_γ (E_γ).

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