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EVALUATION OF THE NUCLEAR CONSTANTS OF ^{240}PU FOR COMPILING A COMPLETE FILE

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EVALUATION OF THE NUCLEAR CONSTANTS OF ^{240}Pu FOR COMPILING A COMPLETE FILE

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ABSTRACT

The authors evaluate the neutron cross-sections for ^{240}Pu in the energy region from 10^{-4} eV to 15 MeV on the basis of available experimental data and theoretical concepts of nuclear structure. The evaluated data are presented in the SOKRATOR format and have been transmitted to the Obninsk Nuclear Data Centre.

The neutron cross-sections for ^{240}Pu are important from the point of view of planning and operating fast reactors, as the fuel may contain ~20-30% ^{240}Pu. Even so, there are few experimental data on the cross-sections of interaction between neutrons and ^{240}Pu nuclei, and evaluation must therefore necessarily be based to a considerable extent on theoretical notions. Interest in the ^{240}Pu nucleus has led to the emergence of new experimental data on σ_t, σ_f, $\sigma_{nn'}$, $\sigma_{n\gamma}$, and therefore evaluations made more than five years ago can now be considered outdated.

The present paper outlines the results of evaluating the nuclear constants for ^{240}Pu. They are described in greater detail in the report presented in the Bulletin of the Nuclear Data Centre.

In the thermal region of neutron energies for ^{240}Pu, there are measurements of σ_t and $\sigma_{n\gamma}$ at the thermal point, and also measurements of σ_t by a number of authors for the region from 10^{-2} to 10 eV.

Recently, fairly reliable work was published by Lounsbury et al. [1] on measuring $\sigma_{n\gamma}$ and by Lander et al. [2] on measuring the amplitude of coherent scattering $a_{coh} = (0.35 \pm 0.01)10^{-12}$ cm. This quantity for the even-even ^{240}Pu nucleus gives the scattering cross-section $\sigma_s = 4\pi a^2_{coh} = 1.54 \pm 0.09$ barn.

As the distance between the levels is rather large (~14 eV in the case of the ^{240}Pu nucleus, the cross-section at the thermal point can be calculated accurately from the first resonance parameters. On the basis of self-consistent evaluation of the resonance parameters, taking into account all available experimental data, including the thermal point, the following first resonance parameters were obtained: $E = 1.056 \pm 0.002$ eV, $\Gamma_n = 2.3543 \pm 0.0800$ MeV, $\Gamma_\gamma = 32.24 \pm 1.60$ MeV, $\Gamma_f = 0.0057 \pm 0.0030$ MeV, $\sigma_p = 4\pi R^2 = 9.247$ barn. The cross-section values calculated using these parameters agree with the most accurate measurements of σ_t and σ_γ in the thermal region with an accuracy of the order of 0.5%, and the cross-section values themselves at an energy of 0.0253 eV are: $\sigma_t = 288.43$ b, $\sigma_\gamma = 286.84$ b, $\sigma_s = 1.54$ b, $\sigma_f = 0.05$ b.

In the resonance region of neutron energies there are sufficiently reliable data on σ_t and $\sigma_{n\gamma}$. The reason for the discrepancies in $\sigma_{n\gamma}$ that existed for some time has now been removed (cf. Ref. [3]). The series of resonance parameters that have been re-evaluated are no longer contradictory. The great distance between levels simplifies the evaluation procedure and permits evaluation of the resonance parameters not from the experimental data themselves, but from the series of resonance parameters provided by the authors. 1 keV was taken as the upper limit of the resolved resonance region. In this energy region, all the resonances (70 in number) were regarded as S-wave resonances. Fission widths Γ_f are assigned to all resonances, reflecting the existence of a fission structure (see Ref. [4]). Analysis revealed the following values for the mean resonance parameters: $\bar{D} = 13.5 \pm 0.5$ eV, $\bar{\Gamma}_\gamma = 30.7 \pm 2.6$ MeV, $S_o = (1.10 \pm 0.16) \times 10^{-4}$ eV$^{-\frac{1}{2}}$, $\bar{\Gamma}_f = 3.34 \pm 1.00$ MeV. The cross-sections in the unresolved resonance region (1-142 keV) were obtained taking into account the double-humped structure of the fission barrier. With the evaluated mean resonance parameters, all types of cross-section - σ_t, σ_f, σ_γ, $\sigma_{nn'}$ - can be calculated. A more detailed paper [8] on this topic has been presented at this conference.

Measurements of the ^{240}Pu fission cross-section are relative (mainly to ^{235}U). We did not begin to evaluate the ratio σ_f (^{240}Pu)/ σ_f (^{235}U) directly from the experimental data, because there were not sufficient experimental data on the subject to understand the behaviour of such a curve in the area of inflections due to the opening of the channels (n,n'f) and (n,2nf) in ^{235}U. For this reason, we derived σ_f(^{240}Pu) using the σ_f(^{235}U) we had evaluated.

The $\sigma_f(^{240}Pu)$ curve we obtained smoothly fitted the σ_f values obtained from the unresolved resonance region. The agreement between the values for the ratio obtained from various measurements is within the margin of error cited by the authors.

Our evaluation of $\bar{\nu}(^{240}Pu)$ is based mainly on the data of Frehaut et al. [5]. Considering that $\bar{\nu}_p(^{252}Cf) = 3.733$, the evaluated dependence of ν_p on energy takes the form $\nu_p(^{240}Pu) = 2.8378 + 0.14585\ E$. The total cross-section $\sigma_t(^{240}Pu)$ was measured only up to 1.5 MeV [6]; the curve evaluated above follows the data of σ_t for ^{239}Pu, as it should according to the predictions of the optical model.

The evaluation of the inelastic scattering cross-section for ^{240}Pu was based mainly on theoretical calculations in view of the small quantity of experimental data. The level scheme of the ^{240}Pu nucleus is known up to an energy of 1.6 MeV. $\sigma_{nn'}$ was calculated in the region both of resolved and of overlapping levels of the target nucleus, account being taken of the competition of radiation capture and fission. Besides the processes taking place across the compound nucleus, the contribution of direct excitation of the first level was taken into account by calculation with the SSROT program [7]. This also enabled us to obtain the angular distributions of the inelastically scattered neutrons for the entire neutron energy region. The correctness of the calculation of competition from fission was verified by comparing calculated and experimental data on σ_f. The excitation cross-section of the first level (43 keV, 2^+) near the threshold, corresponding to the compound-process, was calculated from the mean resonance parameters given in Ref. [8] because the double-humped fission barrier structure had to be taken into account. The evaluated data on $\sigma_{nn'}$ (^{240}Pu) agree well with the experimental data given by Smith et al. [6].

The angular distributions of the elastically scattered neutrons for ^{240}Pu were evaluated using the data of Smith et al. [6] in the region below 1.5 MeV.

In the energy region above 1.5 MeV, elastic scattering is determined mainly by the scattering on the nucleus potential, as the contribution from scattering which occurs across the compound nucleus is close to zero. For this reason, the evaluated angular distributions for ^{240}Pu in this energy region were obtained using information on adjacent nuclei.

The cross-sections of the (n,2n) and (n,3n) reactions were calculated on the basis of a statistical model of the nucleus and compared with the cross-sections for ^{238}U.

The evaluated data for ^{240}Pu are presented in the Soviet format for evaluated data, SOKRATOR, and have been transmitted to the Obninsk Nuclear Data Centre.

REFERENCES

[1] LOUNSBURY, M., et al., IAEA Conf. on Nuclear Data for Reactors, Helsinki, 1 (1970) 287.

[2] LANDER, D.H., MUELLER, M.H., Acta Cristallographia, 27 B (1971) 2284.

[3] MOXON, M.C., et al., UKNDC (72) (1972) 37.

[4] MIGNECO, E., THEOBALD, J.P., Proc. of Conf. on Neutron Cross-Section and Techn., (1968) 527.

[5] FREHAUT, J., et al., Proc. of Second All-Union Conference on Neutron Physics, Part 3 (1974) 153.

[6] SMITH, A.B., et al., Nucl. Sc. Eng. 47 (1972) 19.

[7] IGNATYUK, A.V., et al., Byull. Inf. Tsentra Yad. Dannym 15 (1974) 59.

[8] ANTSIPOV, G.V., et al., Proc. Third All-Union Conference on Neutron Physics, Kiev, May 1975.