ANALISIS SISTEMATICO DE LAS SECCIONES EFICACES DE FISION DE LOS ISOTOPOS DEL URANIUM Y DEL PLUTONIUM

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RESUMEN
Se analizan las secciones eficaces de fisión inducida por neutrones, de 10 núcleos actínidos, en los marcos del modelo de la doble barrera de fisión, obteniéndose las alturas de las barreras de estos núcleos. Se obtiene una adecuada correspondencia en el ajuste de las secciones experimentales considerando la ruptura de la simetría axial de la barrera interna y de la simetría de masa de la barrera externa. Los valores obtenidos para las alturas de las barreras se comparan con otros resultados. La tendencia de la sistemática fue observada en las alturas de las barreras de los isótopos observados, cuya dependencia isotópica refleja las fluctuaciones par-impar. Se analiza también la diferencia E_A - E_B y la nueva cantidad auxiliar τ, tomando en consideración el incremento del número de neutrones. La densidad de núcleo es calculada en los marcos del método combinado semimicroscópico. (SCH) para todos los puntos extremales del camino de fisión.

ABSTRACT
Neutron induced fission cross section of 10 actinide nuclei is analyzed in terms of the double humped fission barrier model to deduce the barrier heights. Good fits were obtained by assuming the inner barrier axially-asymmetric and the outer one mass asymmetric. The obtained values of barrier heights are compared to other results. Systematic trends were observed in the barrier heights of the studied isotopes, its isotopical dependence presents the odd-even fluctuations. The difference E_A- E_B and a new auxiliary quantity τ with increasing of neutron number is also analyzed. The level density is calculated in the frame of Semimicroscopical Combined Method (SCM) for all extreme points of fission path.

I. INTRODUCTION AND APPLIED METHODS

Fission cross section of actinide nuclei is included among the most important and necessary nuclear data for energetic and technology. So, to improve the available data, it is necessary the continuous development of evaluation methods. On the other hand, the barrier systematic is useful in estimating fission cross sections of actinide isotopes for which no measurements have been made. Furthermore, an analysis of the systematic in fission barrier provides information about saddle point configuration.

The calculation of the fission cross section energy dependence is one of the main sources of information of the fission barrier structure. The used approach on level density calculation is very importan and, in fact, level density values for low energies determine the barrier height.

For deformed nuclei and especially for extreme points of fission path the phenomenological method in level density calculations have many disadvantages. Phenomenological approaches have been developed in several works considering the shell, pairing and collective effects. To take into account these effects, a great amount of experimental information about level densities in a broad energy interval is needed. Therefore, the application of phenomenological formulae for the deformed states in fission or for nuclei far from nuclear stability line is under question.

The disadvantages of the phenomenological models lead to the development of semimicroscopical models for level density calculations. The quantum-statistical models for level density calculations. The quantum-statistical model of nuclear level density calculations has been proposed and investigated by many authors [1-4]. This model takes into account shell and pairing corrections in the framework of the nuclei superfluid model. Nevertheless, it does not give adequate description of level densities at low energies, where it is necessary to consider the discrete structure of spectrum. At low excitation energy the combinatorial method in the frame of BCS model is preferable.

The principal idea of the semimicroscopical Combined Method is as follows: the discrete features of spectrum at low energies are considered. At high energies, when the number of states grows, statistical calculations are carried out. In the first interval level density is calculated in the frame of combinatorial BCS model and in the second one are made in the frame of quatum-statistical superfluid model [1-4]. In both cases same parameters are used. The use of such method guaranties the smooth joining of discrete and continuos parts of the level density.

The use of semimicroscopical approach, makes possible to analyze the fission cross section without resorting to parameter search technique of many physical quantities. The number of parameters to be adjusted is greatly reduced owing to the physical constraints. The remaining adjustable parameters are only the heights of the two barriers. Thus, this systematic analysis of fission cross section of uranium- plutonium isotopes using the SCM is expected to give insight into some characteristic features of inner and outer barriers.

It is assumed in the present analysis that all the reactions proceed via compound nucleus and the Hauser-Feshbach formalism is used.

II. CALCULATION AND RESULTS

Fission cross sections of 10 uranium and plutonium isotopes have been analyzed. The calculations have been made using the double humped fission barrier model. It was assumed that the nuclear shape is axially asymmetric at the inner barrier (A), while it is axially symmetric and mass asymmetric at the outer one (B) [5].

Fission barrier parameters are fitting to give the best correspondence to the experimental data of fission cross section values in the plateau region. Thus, near threshold structures arising from the coupling of class I and class II states have been neglected.

Good agreement with the experimental values for the fission cross sections were achieved. These results prove that the Combined Method is able to make an adequate description of level density in dependence of nuclear deformation for these nuclei.

The use of all available experimental data of fission cross section, allow us to obtain a systematic for fission barrier heights in the frame of explained above theoretical assumptions. The consideration of structural features of nuclei in a more realistic way becomes the obtained semimicroscopical systematic of the barrier more confident than others based in Fermi gas level density form.

The results show good agreement with experimental data, even at low energies. This fact suggests that the used semimicroscopical procedure for discrete and continuous part of level density is adequate. For these nuclei, full damping method is a better approximation.

In table the obtained barrier parameters are compared to other authors.

Tabla 1. Fission barrier heights from fits to experimental data.

	ref.[6]		ref. [7]		This work	
	E_A	E_B	E_A	E_B	E_A	E_B
234_U	6.00	5.80	5.60	5.50	6.00	5.65
235_U	6.00	5.90	6.15	5.90	6.10	5.90
236_U	5.80	5.70	5.63	5.53	5.95	5.75
237_U	6.30	5.90	6.28	6.08	6.22	6.08
239_U	6.30	5.70	6.46	5.16	6.25	6.10
$239P_U$	6.40	5.50	6.30	5.70	6.05	5.90
$240P_U$	6.00	5.30	5.57	5.07	5.90	5.51
$241P_U$	6.15	5.70	6.10	5.50	6.08	5.54
$242P_U$	5.75	5.50	5.60	5.10	5.70	5.30
$243P_U$	5.90	5.60	6.00	5.40	5.98	5.47

III. CONCLUSIONES

The double humped fission barrier model with full damping approximation appears adequate for the analysis of neutron induced fission reactions in the region of ^{233}U to ^{242}Pu.

Good fits of fission cross sections allows us to confirm that the SCM is able to make an adequate description of level density in dependence of nuclear deformation for these nuclei. Therefore, the consideration of class II states can be made using this procedure.

Good fits are obtained for fission cross section assuming that the inner barrier is axially asymmetric and the outer one is mass asymmetric.

The barrier heights, like a quantity $\tau = (E_A-E_B)/m$, where m is the slope in "plateau" region, tend to be peaked around N≈147 (Figs.1-2). This is in agree with the theoretical predictions that exist a subshell region around N=146 or 148. The difference E_A-E_B has a minimun at approximately N≈146. For higher N it obviously increases as general trend. Because the outer barrier is determined by the liquid drop model.

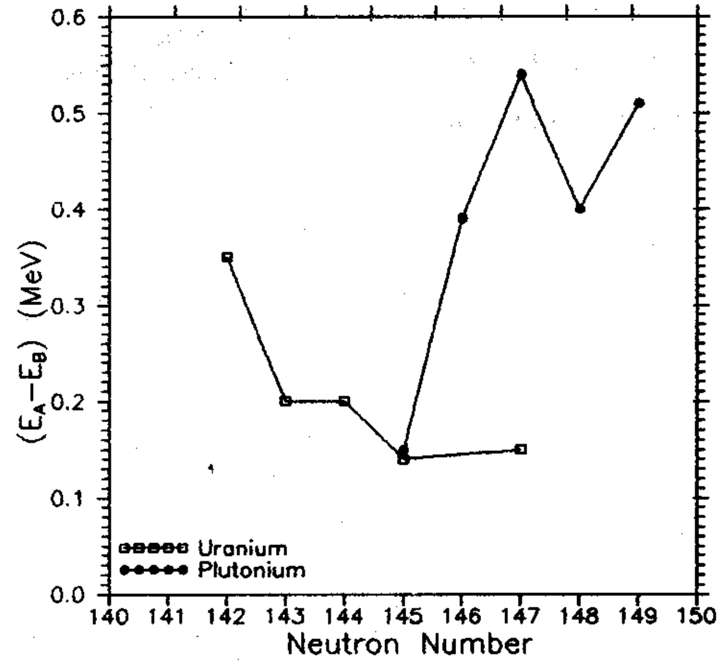

Figura 1. Isotopical dependence of difference between barriers (E_A-E_B).

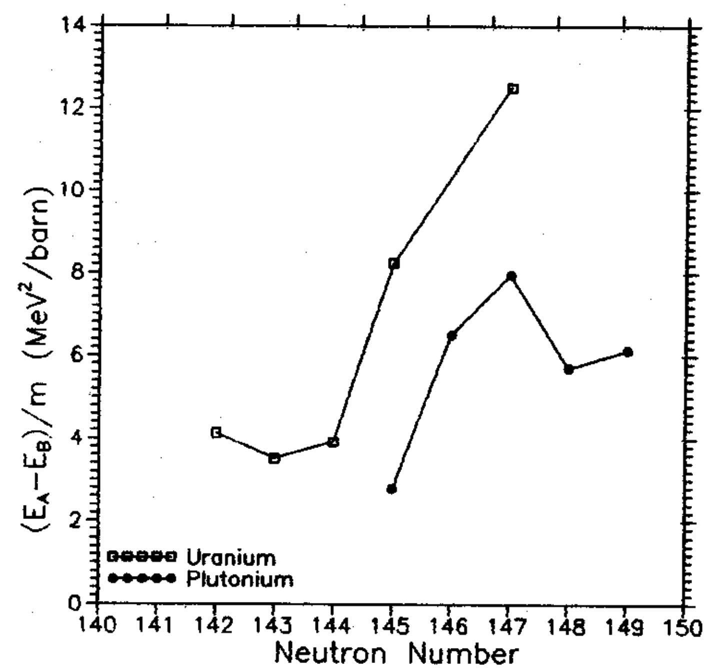

Figura 2. Isotopical dependence of $\tau=(E_A-E_B)/m$.

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