About the Resonance Self-Shielding for Fission and Capture Cross-Sections of Uranium-235

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Abstract

Unexpected dependence of reactivity of uranium-235 samples on size of fast critical assembly BFS-79 - 5 with softened spectrum was discovered in case uranium-235 samples enriched up to 90 %. For small sample sizes its reactivity's are negative. The analysis of this dependence has shown that values listed in ABBN - 93 can be predicted by calculations under following conditions:

-. the effects of resonance self-shielding for radiative capture must be much lower for low values σ_0 ;

- in accordance with the last microscopic experiments, group neutron cross-section of radiative capture must be larger in the resonance energy region.

Introduction

At carrying out of experiments on indignation of criticality, by entering samples of the various sizes into a critical configuration from highly enriched uranium and диоксида silicon at the Big Physical Stand (assembly BFS-79 - 5) the data which sharply differed from results of the calculations received with the help of settlement model proved by then have been received. All previous experience of good concurrence of results of experiments and calculations with use of this model [1-3] speaks that, basically, the wrong description of experimental dependences probably is connected not to lacks of model as such, and with discrepancy of the nuclear data for in resonant area.

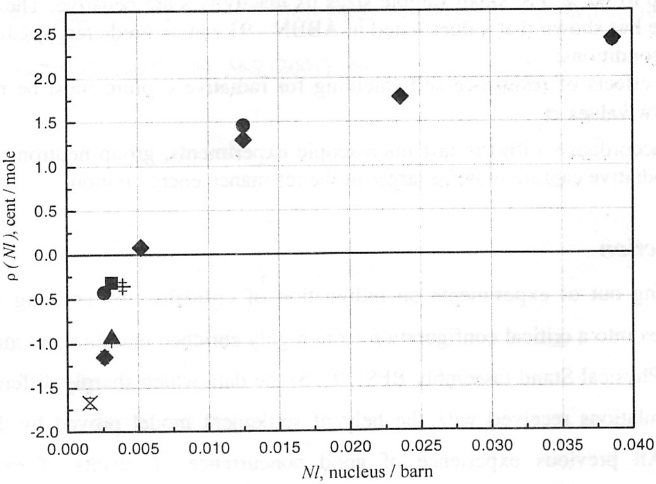
There was, that a reactance brought by samples c by enrichment and thickness, laying in a range, becomes negative (see fig. 1.). With increase in thickness of a sample up to reactance became standard (positive).

Analysis of experimental data

Certainly, first of all, the effect of negative reactance of thin samples is connected to unusual structure and a configuration of an active zone. It has consisted of vertically located matrix of aluminums pipes in external diameter and thickness of the walls established in гексагональной to a lattice with step (a usual configuration of stand BFS)

In pipes tablets of metal uranium with enrichment in external diameter and thickness (weight), in an aluminums environment thickness and tablets thickness have been placed. On two such "fuel" pipes one pipe filled entirely with tablets is necessary.

On fig. 1. results of measurements of factors of reactance of the samples, normalized on unit are resulted. As samples served or hollow cylinders of uranium with external diameter and thickness of the walls, located in intertrumpet backlashes of a regular lattice of pipes, or tablets (disks) of metal uranium in diameter and weight (thickness). The increase was reached{achieved} by addition of two, five and ten tablets (disks) of uranium. A sample of the greatest size - a tablet thickness, such tablets were part of an elementary cell.



◆ disk U (ε^5 = 89.7 %) on against a sample SiO_2;● disk U (ε^5 = 89.7 %) on against a sample U; ▲ cylinder U (ε^5 = 88.6 %) on against a sample SiO_2; ■ cylinder U (ε^5 = 88.6 %) on against a sample U; × disk UO_2 (ε^5 = 36.7 %) on against a sample SiO_2; + disk U (ε^5 = 90.1 %) on against a sample SiO_2.

Fig. 1. Experimental values of reactance of samples of uranium.

The described effect appeared so unusual, that in repeated experiments careful check with use of tablets not only metal uranium, but also samples of dioxide of uranium with close enrichment has been lead{has been carried out}. The found out effect cannot cause doubt.

The program of calculation layer streams and layer values in integral-transport approach has been written. As a whole, behind some difference, it is based on model of program HETERA_M used at creation [4, 8], and other programs, for example, Japanese program

SLAROM [10]. Difference has consisted in redefinition of sections of elastic delay to means of introduction of factors after reception of heterogeneous streams and the subsequent iterative procedure. The result of calculation of such heterogeneous group streams and values has well coincided with calculation and a method of Monte Carlo.

At carrying out of calculations it has been established, that the maximum of capture of neutrons nucleus at a spectrum of assembly BFS-79 – 5 falls at an interval энергий. By the way, this area энергий plays rather small role both in reactors on fast, and on thermal neutrons and consequently was not exposed to serious check in macroscopical experiments earlier.

The basic components of reactance answering to absorption and a birth of neutrons conveniently to present as:

$$\langle \rho_R(N\ell)\rangle = \langle \sigma_f^5(N\ell)\rangle \cdot \left[\frac{\langle \nu^5 \rangle}{k_{eff}} \langle \varphi_\chi^+ \rangle - \langle 1+\alpha^5(N\ell)\rangle \langle \varphi_a^+ \rangle \right] \quad (1)$$

where $\langle\ \rangle$ - a symbol of averaging on a site of a sample and group.

The negative size $\langle \rho_R(N\ell)\rangle$ can be received, having increased α^5 $(\alpha = \sigma_c/\sigma_f)$ and size of average value of absorbed neutrons $\langle \varphi_a^+ \rangle$. (As cross-section of divisions ^{235}U are well-known, the increase α^5 can be received, having increased values of group sections of capture). Both these requirements are mutually inconsistent - the increase in capture reduces $\langle \varphi_a^+ \rangle$. They can be coordinated if to assume, that with increase in the size of a sample corresponding factors resonant самоэкранировки capture decrease so, that for values $\sigma_0 = 25\ barn$ this reduction stronger, than increase in capture. At such decision direct data works [6]:

Table 1. Experimental values of size an alpha for [6].

Energy *(eV)*	$\alpha(0)$	$\alpha(0)_{ABBN-93}$	$\alpha(0.5\ mm)$	$\alpha(0.5\ mm)/\ \alpha(0)$
1000 - 465	0.49±0.05	0.44	0.29±0.06	0.59±0.14
465 - 215	0.45±0.05	0.43	0.28±0.06	0.62±0.15
215 - 100	0.75±0.07	0.59	0.48±0.10	0.64±0.15
100 - 46.5	0.66±0.06	0.48	0.45±0.10	0.68±0.16
46.5 - 21.5	0.78±0.07	0.61	0.53±0.11	0.68±0.15
21.5 - 10.0	1.02±0.08	0.92	0.53±0.12	0.52±0.12
10.0 - 4.65	1.17±0.08	0.79	0.67±0.15	0.57±0.13

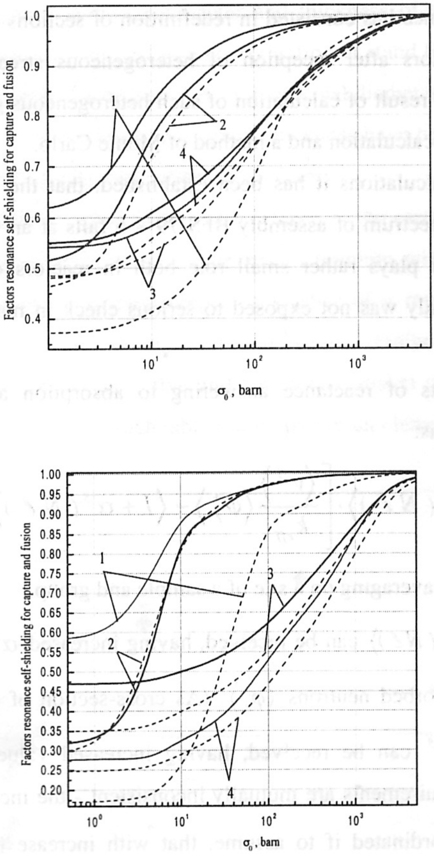


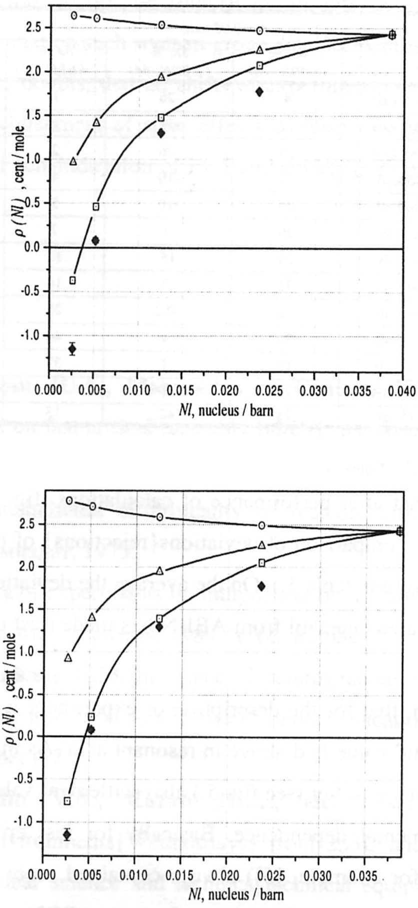
Fig. 2. Factors resonance self-shielding for capture and fusion for various versions ABBN in 18 and 21 power groups.

a) б)

_ f_f; - - f_c; 1 – The corrected variant; 2 – ABBN – 93; 2 – ABBN – 78; 2 – ABBN – 64

As a result of carrying out of calculations the corrected variant of change of the nuclear data has been chosen from the point of view of the description of considered experiment. On fig. 2 as the typical example, is shown shift for factors resonant самоэкранировки capture and division concerning standard systems of constants ABBN in 18 and 21 power groups.

On fig. 3 the result of calculations with such factors resonance self-shielding for capture and fusion is shown



a) б)

◆ Experimental dependence; –□– The basic variant (ABBN – 78); –△– The resonance self-shielding for capture and fusion are changed; –O– The resonance self-shielding for capture and fusion and neutron cross-section of capture are changed;.

Fig. 3. Comparison of dependence of reactance from the sizes of samples U with enrichment of 89.7 % located against a layer with, designed for two kinds of structure of a cell *(a) 11 layers, б) 14 layers* SiO_2*).*

Table 2. Size $\delta\sigma = (\sigma_{corrected.} - \sigma_{ABBN}) / \sigma_{ABBN}$.

$t = 0.03$ mm					
G	E_n	$\delta\sigma_c$ % (ABBN -78)	$\delta\sigma_c$ % (ABBN -64)	$\delta\sigma_c$% (ABBN -93)	$\delta\sigma_c$%* [6]
11	10.0 - 21.5 кэВ	4	-26	1	-
12	4.65 - 10.0 кэВ	12	-34	1	-
13	2.15 - 4.65 кэВ	24	-26	2	-
14	1.0 - 2.15 кэВ	22	-10	4	-
15	465 - 1000 эВ	25	-10	5	11
16	215 - 465 эВ	29	-1	7	5
17	100 - 215 эВ	29	15	12	27
18	46.5 - 100 эВ	32	-5	16	28
19	21.5 - 46.5 эВ	12	-0.2	25	11
20	10.0 - 21.5 эВ	20	-4	44	28
21	4.65 - 10.0 эВ	15	-2	37	48
22	2.15 - 4.65 эВ	29	35	7	-
23	1.0 - 2.15 эВ	28	42	13	-

*) $\delta\sigma = (\sigma \text{Grigoriev} - \sigma_{ABBN-93}) / \sigma_{ABBN-93}$.

That fact is indicative, that after performance of calculations (fig. 5. and 6.), we had been lead{had been carried out} comparison of deviations{rejections} of the corrected variant and the data of work [6] (last column table 3.). On the average the deviation{rejection} of sections of the corrected variant in area энергий from ABBN has made (last column table 3.), and the data [6] (see also table 1.).

Calculations have shown, that for the description of experiment it is necessary, that power dependences of a stream and value laid above in resonant area. As in a cell with 14 layers the stream and value of neutrons is softer (see fig. 5.) also settlement values for this structure of a cell are closer to experimental dependence. Basically for fast critical assembly BFS the measured spectrum (see, for example, [5]) always contained more neutrons in the field of small energy, than calculations under all versions of system ABBN.

Conclusion

This work shows necessity of perfection of knowledge on resonant structure of sections of capture in the field of small энергий and small. Certainly, the explanation stated and proved above not the only thing. Probably, here approach{approximation} of narrow resonances, and also, probably is inapplicable, plays a role appreciable distinction in the form делительных and захватных resonances, i.e. in dependence возбуждений, corresponding to processes of division and capture from energy of a neutron.

Carrying out of the specialized experiments on specification of size in resonant area энергий for samples of the big sizes is desirable.

Повидимому, has has washed off use мульти group approach{approximation} and last microdata on. Now the estimation such мульти group displacement is made.

However, one of authors doubts, that all shifts of experimenters - nuclear engineering can be more useful to an establishment of sizes effects of resonance self-shielding neutrons in samples, than a method of self-indication of I.I. Bondarenko, is so brilliant justification itself earlier.

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