NEW EXPERIMENTAL DATA OF $^{19}F(n,\alpha)^{16}N$ REACTION EXCITATION FUNCTION

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Abstract

The interaction of neutrons with light nuclei is interesting for nuclear reaction mechanics understanding. Fluorine nuclei cross section data are of a great importance due to the usage of fluorine-containing salts in advanced nuclear reactors. Their active zone is filled up with that molten salts, and so fluorine cross-section affects on nuclear chain reaction kinetics. The experimental investigation of $^{19}F(n, \alpha)^{16}N$ reaction cross section in 4-7.35 MeV energy region is represented in this work.

Introduction

The molten salts reactor is one of the most advanced nuclear technologies today. Molten uranium and thorium fluorides are used both as fuel and coolant in these reactors. Such approach allows purification of fuel and its replacement without reactor shutdown. This approach results on heat removal increase and allows to clean and reload fuel without reactor shutdown. With such fuel preferences there are a lot of fluorine nuclei in the active zone of the reactor. And fluorine nuclei are in constant contact with fissioning nuclei and interacting with unmoderated neutrons that appear in heavy nuclei fission. That is why fast neutron with fluorine nuclei interaction may seriously result on reactor kinetics.

The $^{19}F(n,\alpha)^{16}N$ reaction cross section investigation was our aim. There is big discrepancy in experimental data of different authors for this reaction. Different libraries estimations for this reaction cross section also significantly vary one from another. The new direct low-background method, that allows to determine reaction products yield directly, was developed for data uncertainties improvement. The $^{19}F(n,\alpha)^{16}N$ reaction cross section detailed investigation was made with this method.

Experimental method

The $^{19}F(n,\alpha)^{16}N$ reaction cross section investigation presented in this work was carried out on EG-1 accelerator of IPPE. Neutrons were generated in $D(d,n)^3He$ reaction on solid titanium target of 0,97 mg/sm^2 thickness. Measurements were made for 4.0 to 7.35 MeV neutrons energy region.

The measurements were carried out with doubled ionization chamber as detector. One part was ionization chamber with Frisch grid and was used for fluorine-neutron interaction investigation. The other parallel-plate chamber was used for neutron flux monitor by ^{238}U fission fragments registration and counting (Fig.1).

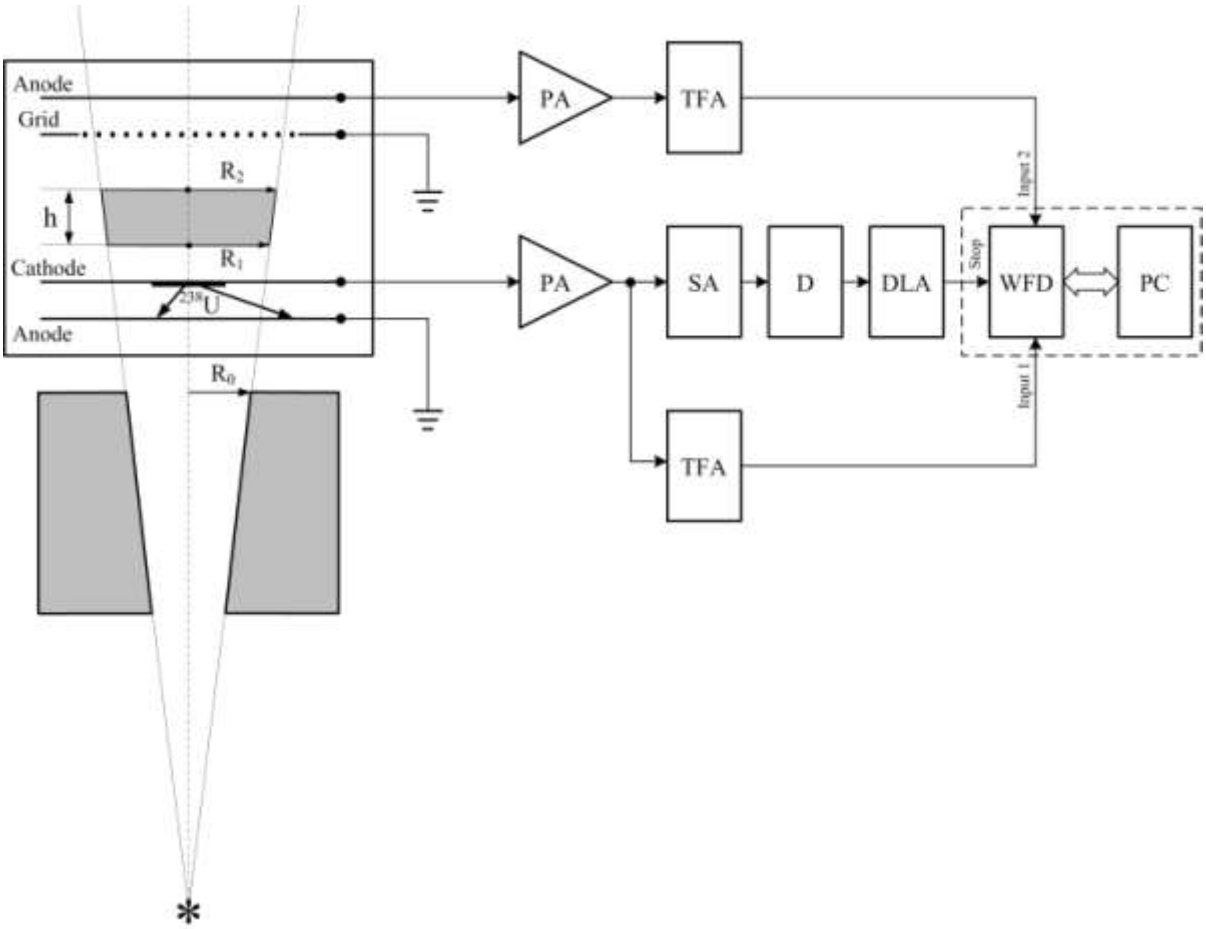

Figure. 1. Scheme of experimental setup. PA – preamplifier, TFA – timing filter amplifier, D – discriminator, DLA – delay line amplifier, SA – spectrometric amplifier, WFD – waveform digitizer.

Signals obtained from different chamber electrodes were amplified and then digitized with LeCroy 2262 waveform digitizer. Further signals processing was made by software with digital signals processing algorithms. Amplitude, moments of beginning and ending of signals from cathode and anode were obtained from processing. Joint analysis of named information allowed to determine energy of charged particle, its birth place of and type of registered particle.

Chambers were filled up with 95%Kr + 5%CF_4 gas mixture. The pressure of mixture is 3 bars. Fluorine in the working gas was a target for incident neutrons. Experimental time shortage was reached by serious increase of investigating nuclei number due to usage of gaseous target. Events for processing were chosen from sensitive volume inside chamber formed by collimated neutron beam (radius) and data from digital signals processing (sell height). Such approach allows effective suppression of wall effect and precise determination of nuclei number inside chosen sell.

The background from parasitic reactions on chamber constructional elements and (n,p) reaction on working gas components was decreased by determination and further separation of registered particle type. Anode signals spectrum before suppression (a) and after suppression (b) is shown on fig. 2. Some of the lines in the obtained spectrum referred to the $^{19}F(n,\alpha)^{16}N$ reaction channels where residual nucleus left in the excited states. It should be noted that named peaks referred to α-particles along-track of neutrons direction.

Spectrometer response function has complicated shape in case of light nuclei investigation. Summary of kinetic energies of reactions products is always equal to summary of incident neutrons kinetic energies and reaction energy.

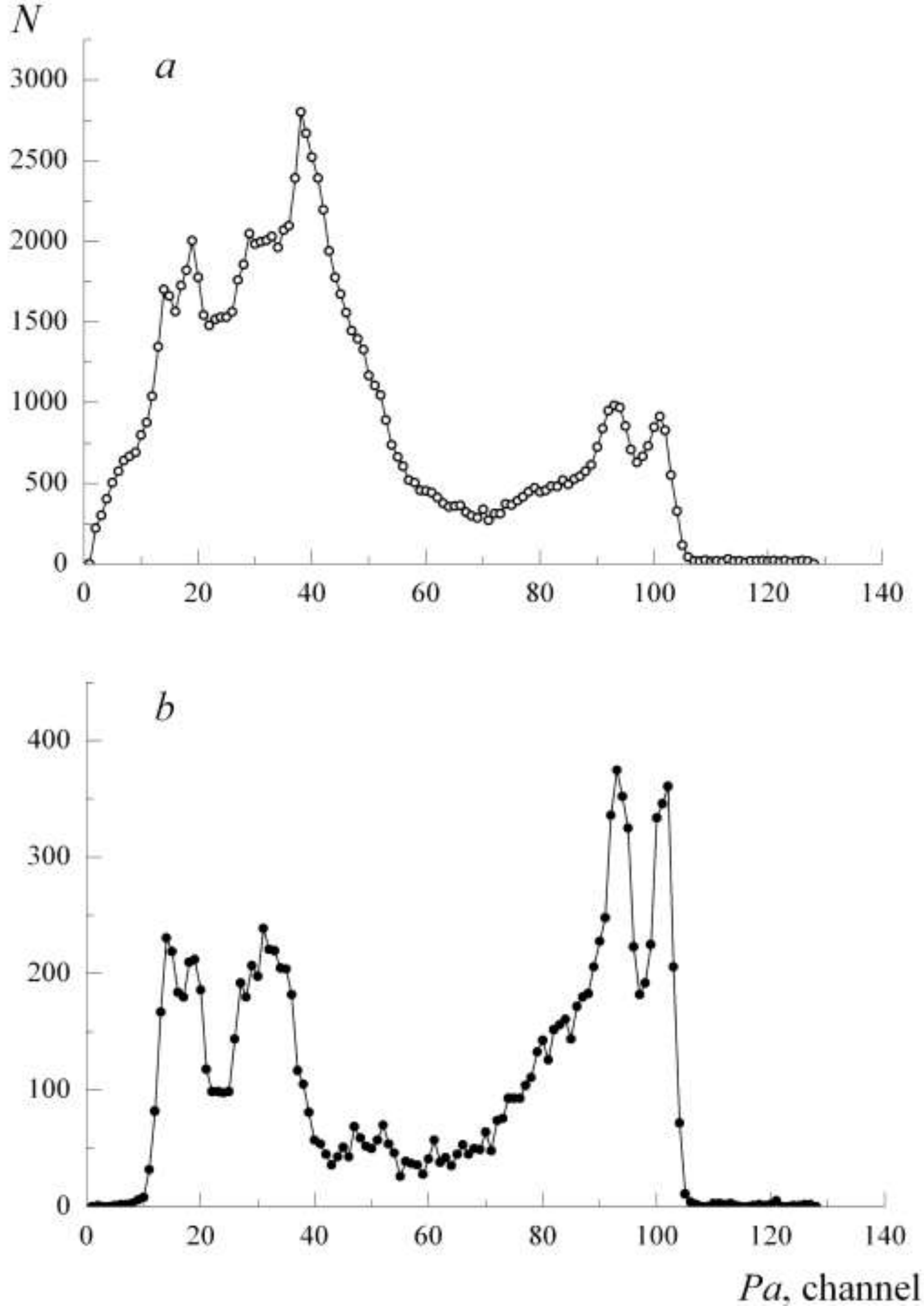

Fig. 2. *a* – anode signals spectrum of ionization chamber; *b* – the same spectrum after event selection.

However, energy distribution between reaction products depends from their emission angles. Signal from α-particle is always equal to its energy as opposed to residual nucleus which has huge amplitude defect and large part of energy is lost in elastic interactions not leading to ionization of filling gas. α-particles emitted along-track of neutrons direction has major part of reaction products kinetic energy, so the residual nucleus has only little part. Such events form clear peak in amplitude spectrum. In case residual nucleus is emitted along-track of neutrons direction significant energy part won't be spent on ionization and signal amplitude will be smaller. Such events will be to the left from mentioned peak and they should also be taken into account.

Residual nucleus scheme is shown on Fig.3. As follows there are a few groups of levels ground state and exited ones from 1^{st} to 3^{rd}. Another one has higher excited states lying above. These two groups are separated with 3 MeV, that allows to separate them in energy spectrum, in spite of effect due to amplitude defect described above. Determination of differential reaction cross-section of each reaction channel (provided with filling of exact excitation level of residual nucleus) is the difficult mathematical task.

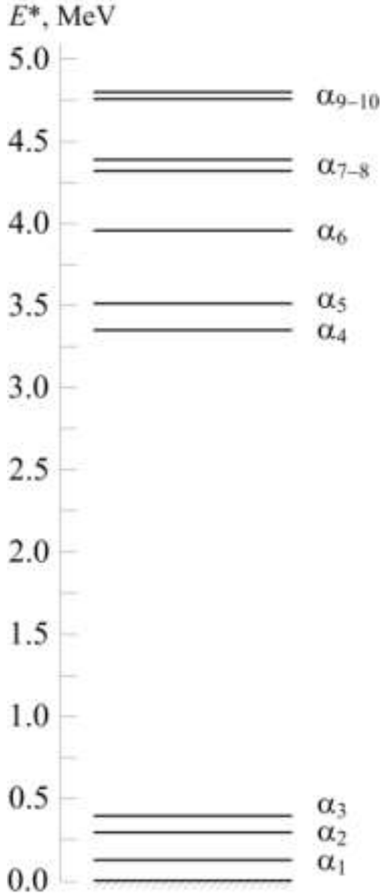

Fig. 3. ^{16}N excitation level scheme.

Results

The obtained preliminary $^{19}F(n,\alpha)^{16}N$ reaction cross section data are shown on Fig.4 and Fig.5. Fig. 4 illustrates comparison of obtained data with available experimental results from literature [1-5]. Fig. 5 illustrates comparison of obtained data with estimated data from different libraries (ENDF/B VII, BROND, and JENDL). The obtained data described fair by all estimations for neutrons with energies from 4.0 MeV to 5.2 MeV. Estimations are higher than obtained data on 20-30% in 5.2 – 6.0 MeV energy region. Generally our data is in a rather good agreement with data from work [1] for neutron energies from 4.0 to 6.0 MeV. There is fast growth of the cross section for energies higher than 6 MeV in our experiment and this growth is not reproduced by evaluations. More over such growth is absent in other authors' experimental data, including data of work [1]. Preliminary analysis has shown that total cross section growth in this energy region caused by filling of higher excitation levels of residual nucleus (α_4 an higher). The cross section of channels referred to lower excitation levels filling is smooth with downward trend with energy increase, and it generally repeat cross section course in work [1].

Carried out analysis of the work [1] has shown, that authors has a big background in low energy part of spectrum. It happened due to a lot of events from $^{10}B(n,\alpha)^{7}Li$ reaction by thermal neutrons take place in this energy region (working gas with admixture of BF_3 was used in that work).

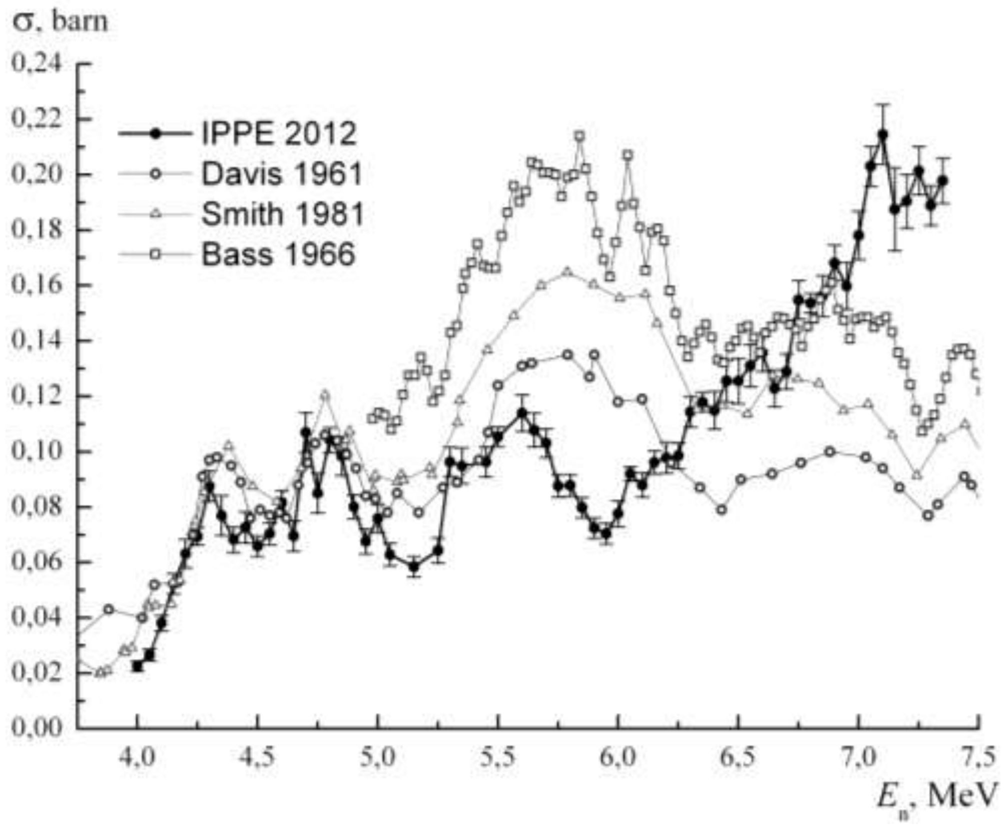

Fig. 4. $^{19}F(n,\alpha)^{16}N$ reaction cross section in comparison with experimental data. Closed circles – present work data, opened circles – data of Davis 1961, opened triangles – data of Smith 1981, opened squares – data of Bass 1966.

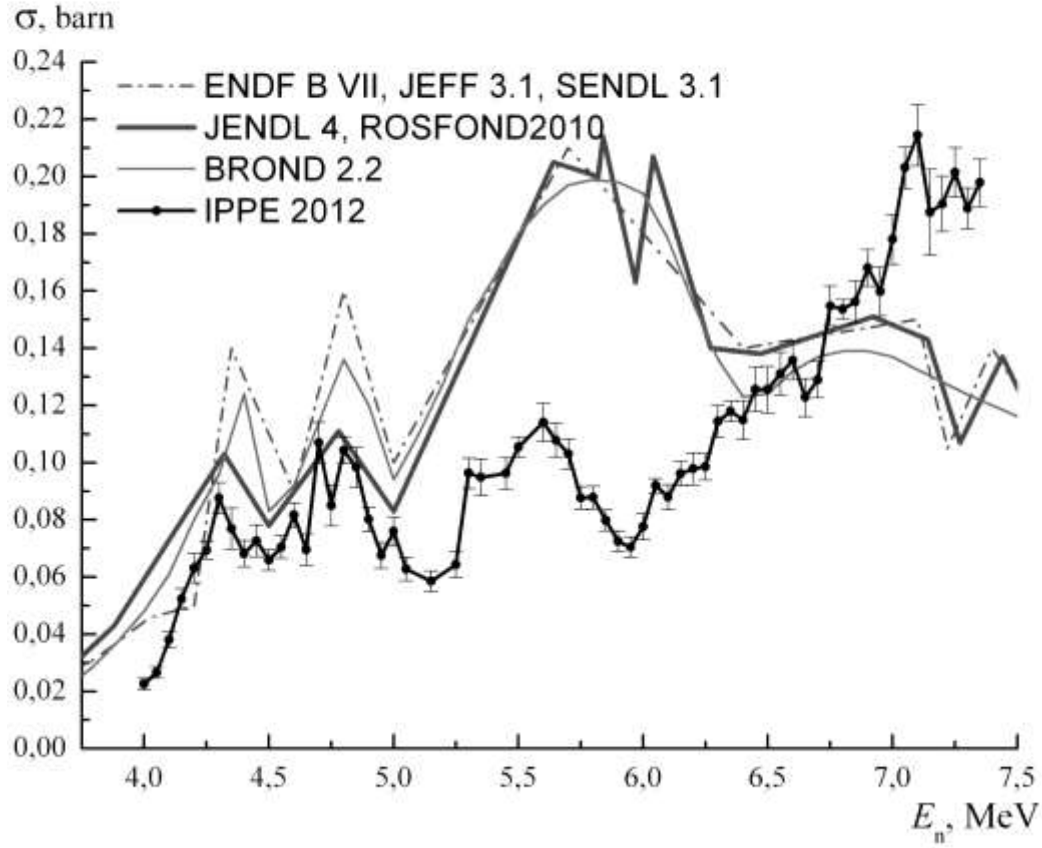

Fig. 5. $^{19}F(n,\alpha)^{16}N$ reaction cross section in comparison with estimated data. Curve with closed circles – present work data, wide curve – JENDL 4, ROSFOND2010, fine curve – BROND 2.2, dash dot curve – ENDF B VII, JEFF 3.1, SENDL 3.1.

Conclusion

The number of new experimental approaches was used in present work to decrease background significantly and to improve reliability of events number determination for $^{19}F(n,\alpha)^{16}N$ reaction. Background suppressing method appreciably exceeds previous methods used for named reaction investigation. The experimental investigation of $^{19}F(n, \alpha)^{16}N$ reaction cross-section in 4-7.35 MeV energy region was carried out. It is shown that obtained data differ from estimations of different libraries much for neutrons with energies more than 5.2 MeV. The obtained data differs from experimental data of other authors. This can be explained by underestimating of reaction channels contributed to low energy part of spectra.

References

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