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INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

Conclusions and Recommendations of the two IAEA Experts Meetings on $\alpha(^{239}Pu)$ and $\bar{\nu}$ data Studsvik, Sweden, 10-12 June 1970

by

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Summary

The two meetings were initiated and organized by the Nuclear Data Section and attended each by about 15 people. The generous financial support and excellent organizational arrangements made by the Swedish authorities deserve particular mentioning and acknowledgement.

Both α (^{239}Pu) and $\bar{\nu}$ for the main fissile nuclei are of crucial importance for nuclear reactor design; there are still intolerable discrepancies in the available experimental information. Both meetings had therefore the task

1. to review the present status of the available information;

2. to identify discrepancies and possible sources of systematic errors in the experimental results;

3. to work out detailed recommendations regarding the experimental, compilation and evaluation work needed for improving the confidence level of the data concerned.

Although both meetings suffered a bit from the fact that they had to be prepared on a rather short time scale, the discussions were fruitful and conclusive. Both meetings succeeded, in particular in initiating close future cooperation between the experimentalists concerned and the Nuclear Data Section with the aim of working out improved evaluations for $\bar{\nu}$ and α (^{239}Pu) data.

Furthermore, the meetings served as preparatory meetings to the Helsinki IAEA Conference on Nuclear Data for Reactors, 15-19 June 1970, and allowed thorough discussions of a number of contributed papers in advance of the conference. Summaries of the high-lights of these papers and of the results of both meetings were reported at the conference by the two meeting chairmen, Mr. D.W. Colvin/U.K. ($\bar{\nu}$ meeting) and Mr. S.I. Sukhoruchkin/USSR (α meeting).

More details on both meetings and lists of recommendations can be found in the enclosed report.

1. The Consultants Meeting on $\bar{\nu}$ values for the main fissile isotopes, Studsvik, 10-11 June 1970

Participants:

D.W. Colvin	U.K.	(Chairman, Consultant)
H. Condé	Sweden	
W.G. Davey	U.S.A.	
J.A. Farrell	U.S.A.	
M. Fréhaut	France	
G.C. Hanna	Canada	
L. Hjärne	IAEA	(part-time only)
B. Holmqvist	Sweden	
V.A. Konshin	IAEA	
D.S. Mather	U.K.	
J.J. Schmidt	IAEA	(Scientific Secretary)
M. Soleilhac	France	(Consultant)
S.I. Sukhoruchkin	U.S.S.R.	(Consultant)
A. de Volpi	U.S.A.	
T. Wiedling	Sweden	

The discussions centered on the following subjects:

1. brief review of the 2200 m/sec $\bar{\nu}$ data for U^{235} and Pu^{239};
2. status of the $\bar{\nu}$ (Cf^{252}) standard;
3. review of a number of recent experiments on the energy dependence of $\bar{\nu}$ for U^{235} and Pu^{239};
4. integral measurements of $\bar{\nu}$ for U^{235} and Pu^{239} in the Swedish fast critical facility FRO.

The review report on "Energy-dependent $\bar{\nu}$ values for U^{235}, Pu^{239}, U^{233}, Pu^{240}, Pu^{241} and the status of $\bar{\nu}$ for spontaneous fission isotopes" (INDC (NDS)-19/N, draft) prepared by V.A. Konshin and F. Manero from the Nuclear Data Section contains an almost complete summary of the recently available information and therefore served as basic background document in the discussions.

The following high lights were brought out:

The discrepancy of about 2% between the $\bar{\nu}$ (Cf^{252}) values from both manganese and boron pile measurements on the one hand and from liquid scintillator measurements on the other hand is still not solved. According to Mr. Soleilhac the γ-ray detection efficiency in liquid scintillator measurements might depend upon the multiplicity of prompt fission neutrons, upon the size of the liquid scintillator tank, and also upon the number and the geometrical arrangement of the photomultipliers used for γ-detection. If the "γ-ray efficiency effect" is true, then corrections of previous liquid scintillator $\bar{\nu}$ values for this effect would tend to reduce the mentioned discrepancy. The Agency was asked to stimulate further experimental investigations of this effect.

Most of the recent detailed experiments show a structure in the energy dependence of $\bar{\nu}$ below about 2 MeV deviating from the generally assumed linear behaviour. This is particularly true of U^{235} and, to a less extent, of Pu^{239}. Contrary to this, in the particularly careful recent Australian work by Mr. Boldeman a much weaker structure in U^{235} $\bar{\nu}$ values was found. This point most importantly needs clarification by further experimental and theoretical work.

Preliminary results were reported on the Swedish spectral $\bar{\nu}$ measurements. Because of their close relationship to actual fast reactor $\bar{\nu}$ values and for the purpose of checking microscopic $\bar{\nu}$ values these measurements were felt to be very valuable and worth of being pursued vigorously.

The discrepancy between the spin-dependent resonance $\bar{\nu}$ results of Weinstein/US and Ryabov/USSR for U^{235} and Pu^{239} is still not solved. The meeting strongly encouraged further experimental work for clarification of the resonance spin dependence of $\bar{\nu}$ for both nuclei.

Recommendations and observations of the $\bar{\nu}$ meeting are summarized in Appendix 1 of this report. The Agency is particularly asked through its Nuclear Data Section:

1. to continue and improve the compilation of $\bar{\nu}$ data and associated physics information (rec. 1);
2. to promote the evaluation of energy dependent $\bar{\nu}$ data (rec. 2);
3. to encourage further investigations of the γ-ray efficiency in liquid scintillator work on the Cf^{252} $\bar{\nu}$ standard (rec. 3).

Recommendations 4-12 set forth very detailed needs for further experimental and theoretical work on $\bar{\nu}$ data.

Observation 13 expresses the satisfaction of the participants with the extensive Australian $\bar{\nu}$ programme initiated upon the encouragement of the IAEA at its first $\bar{\nu}$ meeting in June 1965.

Observation 14 contains some criticism regarding the preparation and attendance of the $\bar{\nu}$ meeting. This actually reflects the difficulties connected with the short time scale available for the technical preparation of the meeting and with budgetary restrictions.

2. The Experts Meeting on the status of α (Pu^{239}) data, Studsvik, 12 June 1970

Participants:

J.Y. Barré	France	
W.G. Davey	U.S.A.	
J.A. Farrell	U.S.A.	
H. Häggblom	Sweden	
E. Hellstrand	Sweden	
L. Hjärne	IAEA	
K.M. Jirlow	Sweden	
V.A. Konshin	IAEA	(Scientific Secretary)
J.L. Rowlands	U.K.	
G. de Saussure	U.S.A.	
J.J. Schmidt	IAEA	
S.I. Sukhoruchkin	U.S.S.R.	(Chairman)
A. de Volpi	U.S.A.	
T. Wiedling	Sweden	

The goal of this meeting was to review the status of the Pu^{239}-α-values which are of crucial significance for the fast reactor development. During the one day's session the latest differential measurements - those of Gwin (ORNL, USA), Sowerby (Harwell, UK), Czirr (Livermore, USA), Farrell (LASL, USA), Ryabov (Dubna, USSR), Sukhoruchkin (Moscow, USSR) and their co-workers - were thoroughly discussed.

Similarly to the $\overline{\nu}$ meeting, a review report covering the present status of the α (Pu^{239}) values had been prepared by V. Konshin as a basis for the discussions (INDC (NDS)-17/N, draft). This report includes all the recent data which the NDS had received as a result of the existing international cooperation in the nuclear data field.

Considering these results, the meeting came to the conclusion that in spite of the fact of having as many as six individual data sets for α (Pu^{239}) measured in different laboratories with different techniques, the alpha problem is still unsolved. Probably with the existing techniques the upper limit of attainable accuracy in α-values (about 10-15%) is almost achieved, whereas the differences between different measurements are often larger than this. Therefore what seems to be needed now is a thorough evaluation of all existing measurements with due account for systematic errors and the derivation of recommended α-values for the reactor physicists. Close cooperation between the experimentalists directly involved in the α-measurements through the IAEA Nuclear Data Section would be of highest value for this purpose. This was actually one of the main recommendations of the meeting, which are attached as Appendix 2 to this report. The other recommendations of the meeting were directed to the experimentalists and are concerned with technical questions such as standardization of energy intervals for α-averaging, search for possible systematic errors in the experiments, an appeal for investigation of different physical effects - such as the spin dependence of $\overline{\nu}$-values in resolved resonances, etc.

The experts finally recommended that the NDS publish an enlarged and improved review of all available α-data with all relevant physics information before the end of the year.

Appendix 1

Recommendations and observations of the IAEA Consultants Meeting on $\bar{\nu}$-values for fissile nuclei, Studsvik, Sweden, 10-11 June 1970

1. The Agency, through its Nuclear Data Section, should continue its compilation effort in $\bar{\nu}$ along the lines of its paper by Konshin and Manero, INDC(NDS)-19/N. This work should be completely brought up to date and checked with all originators of data, as part of the EXFOR effort. A complete description of all necessary experimental details should be included, in particular to provide information to allow elucidation of the consequences of a possible variation of the γ-ray efficiency with the number of emitted fission neutrons in liquid scintillator $\bar{\nu}$ measurements (in points 3 and 10 below called "γ-ray efficiency effect").

2. The Agency should use its good offices to promote evaluation of $\bar{\nu}$ as a function of energy, in a manner similar to that used for the review by Hanna et al. (Atomic Energy Review, Vol. VII, no. 4, p. 3, 1969). This could suitably be begun after successful completion of the Nuclear Data Section's compilation but setting the mechanism up should not await this work. The evaluation would be that of world experts on $\bar{\nu}$.

3. The Agency should use its good offices to persuade all experimentalists with large liquid scintillators to carry out detailed investigations of the γ-ray efficiency effect, and the Agency's Nuclear Data Section should collate and circulate the information, in view of its great importance for the absolute values of $\bar{\nu}$.

4. The Agency should take note of the very valuable experiment of Condé and Widén described in paper CN-26/59 and of the Meeting's findings that this should be pursued with all possible vigour; the Meeting was concerned that limitations on reactor time may limit successful conclusion of the experiment.

5. Further investigations should take place on the causes of the disparity between the results of Weinstein et al. and Ryabov on $\bar{\nu}$ in the resonance region; re-assessment of the data as well as new experiments are suggested.

6. Further experiments should be carried out to resolve the disquieting findings of Boldeman of Australia that, contrary to the results of almost all other experimentalists, there exists no structure in $\bar{\nu}$ for U^{235} in the low energy region. Particular attention should be paid to energy standards and energy spreads.

The meeting regretted that Boldeman could not be present to discuss his experiment in more detail, and compare it with the experiments of earlier workers.

7. Further measurements are required for the actinide elements to confirm recent USSR work reported to the meeting, which has provided the first data on some of these isotopes, in particular californium and curium.

8. More data are required in the low energy region, less than 200 keV, for U^{235} and Pu^{239}, as well as for Pu^{240} and Pu^{241}.

9. The requirement, stated some time ago, for information on delayed gamma rays from fission, particularly for Cf^{252}, should be again brought to the attention of experimentalists; this is of greatest importance for the $\overline{\nu}$ standard Cf^{252}.

10. If the γ-ray efficiency effect can be shown to be genuine, there may be a requirement to study gamma rays from fission, as a function of the number of neutrons emitted. Again this is particularly true for Cf^{252}.

11. More information is required on the vexing question of fission fragment counting to resolve the discrepancies between the measurements of White and Axton, and perhaps those of De Volpi.

12. More theoretical approaches are required to the question of variation of $\overline{\nu}$ with energy, which might act as guides to the experimentalists in interpreting data.

13. The Agency should note the satisfaction of the Meeting that encouragements given to Australian workers at its first panel meeting on $\overline{\nu}$ in June 1965 have been followed up by a most extensive and detailed programme of studies on $\overline{\nu}$ by the group at Lucas Heights.

14. The Agency should take note of the opinion of the meeting that its work might have been more successfully prosecuted if the papers submitted to it had been available well in advance, and that the discussion would have been improved had more experts been present (e.g. Axton/UK, Boldeman/Australia, and Smirenkin/USSR. As a large quantity of material was submitted to the Meeting and to the Second IAEA Conference on Nuclear Data for Reactors at Helsinki, more time should have been provided for the rapporteur to deliver the findings of the meeting at the Conference.

Appendix 2

Recommendations of the IAEA Experts Meeting on the Status of $\alpha(Pu^{239})$ Data, Studsvik, Sweden, 12 June 1970

1. The intervals, in which average experimental α values ($=\overline{\sigma_\gamma}/\overline{\sigma_f}$) are given, should be standardized to

100 eV between 0.1 keV and 10 keV
1 keV between 10 and 20 keV
2.5 keV between 20 and 30 keV
5 keV between 30 and 50 keV and
10 keV above 50 keV,

in order to alleviate the comparison of the results of different measurements. The interval lengths have been chosen such that they are large compared to the experimental energy resolution, and small enough in order to reproduce still the fluctuating behaviour due to intermediate structure effects particularly above 1 keV.

2. The average experimental α values in the energy intervals mentioned under 1 as well as the directly measured data, from which these averages are deduced, i.e. fission and capture cross sections or effective fission and capture rates together with the detailed experimental characteristics should be sent by each experimenter concerned to the Nuclear Data Section of the IAEA. In particular, each experimenter should provide the Nuclear Data Section with those cross-section values, capture and fission resonance areas and half widths, he used in the normalization of his measurements.

3. The Agency, through its Nuclear Data Section, should collect all these data and experimental conditions and publish an improved review of all available α data before the end of the year. All known experiments have been performed outside the service area of the Nuclear Data Section. Therefore the correspondence between Nuclear Data Section and experimenters should preferably proceed through the other neutron data centres unless time schedule and effectiveness require direct contacts. Recommended "best" values of α should then be worked out in close collaboration between experimenters and the Nuclear Data Section in a similar way as in the IAEA thermal fission constants review.

4. Each experimenter is asked to provide for a split-up of the total measurement errors in statistical and systematic errors.

5. The available α measurements can be divided into two classes, those which depend and those which do not depend upon $\overline{\nu}$. Possible systematic deviations between both classes of measurements should be investigated more closely. In particular, it is recommended to study more conclusively and systematically the spin dependence of $\overline{\nu}$ in resolved resonances.

6. The influence of geometrical self-shielding and multiple scattering on the interpretation of α measurements with thick samples in the unresolved resonance region should be investigated more thoroughly in experiment and theory.

7. In order to verify the α values above 10 keV it is desirable to perform new measurements for energies above 10 keV with other methods than in the two available measurements from Los Alamos and Oak Ridge which use Van de Graaff accelerator and liquid scintillators.

8. It is recommended that for energy calibration in α measurements which involve the time-of-flight method, a common set of energies of isolated resonances is agreed upon, such as resonances in Al, Mn, etc. used for such calibrations.

9. Finally, the possibility of checking the α results obtained by time-of-flight methods by measurements with filtered neutron beams (2 keV resonance in Sc, 28 keV resonance in Fe^{56}) should be explored more thoroughly.