EANDC(US)-157A

INDC(USA)-31G

INDC-448

CHECK LIST OF
NEUTRON CROSS SECTION DISCREPANCIES

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May, 1971

Introduction

The following list of cross section discrepancies is offered to draw attention to the existence of the discrepancies, primarily in the hope of stimulating additional measurements to resolve them.

By "neutron cross section" is meant any piece of microscopic neutron data characteristic of neutron interaction with a single target unit, e.g. nucleus or molecule. Thus, "cross section" is meant to include multiplicities (ν, η, etc.), spectra of emitted particles, infinite-dilution resonance integrals, etc., in addition to actual cross section quantities.

A "discrepancy" is said to exist when two or more direct measurements of the microscopic quantity differ among themselves by substantially more than their combined errors. Integral measurements are usually included only when they are felt to lead unambiguously to microscopic quantities, e.g. infinite-dilution resonance integrals from pile-oscillator studies, or absorption cross sections from thermal die-away experiments with small bucklings. In general, discrepancies between experimental values and theoretical predictions are excluded. There are some so-called cross section "discrepancies" where in fact the only discrepancy is between the accuracy of the actual measurements and the accuracy desired. A case in point is the $^6Li(n,\alpha)$ cross section in the keV range. The existing measurements are in reasonable agreement within the limits of their errors, but these limits are considerably larger than is desired if the reaction is to be used as a standard. Needless to say, such situations do not conform to the present definition of discrepancy. These qualification criteria are obviously subject to interpretation, and in the last analysis the final decision may require an exercise of editorial judgement.

In so broad a field an exhaustive compilation is impossible. Indeed it is intended to list only those of major interest in the various fields of nuclear technology. Frequently the significance of a discrepancy for technology derives not so much from the actual values involved as from the doubt cast on the validity of the measurement techniques. The uncertainties about the variation of $\overline{\nu}$ with E for ^{235}U is a case in point. The sequence of listing is in rough decreasing order of the current degree of alarm and concern over the discrepancy. Necessarily such a ranking is subjective and the order given here represents the joint opinion of the compilers.

The compilers wish to express their gratitude for the assistance of members of the NCSAC and ACRP, and in particular of the Discrepancy Subcommittee of the ACRP. Most of the information about the nature of the discrepancies and their significance to nuclear technology came from these sources. Particular thanks are due to Dr. W.G. Davey whose detailed and thoughtful comments on those discrepancies which affect reactor development have proved invaluable.

5/28/71

Discrepancies of Major Significance to Nuclear Technology

1. Quantity and Nucleus: σ_f for ^{235}U

   Energy Range: 20 keV to 1.5 MeV

   Magnitude of Discrepancy: Up to 10% among recent measurements believed good to a few percent. Data of Poenitz appear particularly low compared to most others. Structure below 100 keV has been confirmed by Bowman, but does not seem to be cause of discrepancies.

   Reason for Interest: Fundamental in fast reactor physics; reference standard for many fast cross section measurements.

   References: There is a voluminous literature on this cross section. The following are some recent references which will lead to most pertinent papers:

   Bowman, C.D. et al., "Structure in the ^{235}U keV fission cross section," Paper V-7, 71 KNOX*

   Kappeler, F. et al., "Accurate measurement of the ^{235}U fission cross section," Paper V-8, 71 KNOX

   Poenitz, W.P., "Interpretation and intercomparison of standard cross sections," Paper 29, 70 ANL

   Moore, M., in Summary of Session IV, "Fission and capture standards," 70 ANL
   (Many individual papers in this EANDC Symposium bear on this particular discrepancy.)

   Poenitz, W.P., "Recent experimental data for heavy nuclei," Vol. II, p. 3 (Paper CN-26/111), 70 HELSINKI

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2. Quantity and Nucleus: α for ^{239}Pu

   Energy Range: 100 eV to 100 keV

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*See appendix for bibliographic details of these conference proceedings.

Magnitude of Discrepancy: Flagrant divergences of yesteryear have been rationalized, but discrepancies up to 20% above 20 keV are still claimed at times. Perhaps the major question to be decided here is whether there is a discrepancy.

Reason for Interest: Vital for fast breeders.

References: The situation with respect to this quantity has been reviewed over and over again to the point of weariness. The following may be consulted:

70 HELSINKI. ^{239}Pu α was a cause célèbre at this conference, including a "consultants meeting" just prior to it. Sukhoruchkin (Vol.I p.307) reported the conclusions of that meeting (in Russian). See also Schomberg et al. (Vol.I p.315), Kurov et al. (Vol.I p.345), Poenitz (Vol.II p.14) and the summary report by Konshin (INDC(NDS)-17/N).

Gwin, R., et al., "Measurement of .... α for ^{239}Pu over the energy range from 0.02 eV to 400 keV," 71 KNOX and NSE, to be published.

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3. Quantity and Nucleus: σ_γ for ^{238}U

Energy Range: 1 keV to 1 MeV

Magnitude of Discrepancy: ORNL and AERE data differ in normalization up to 10% below 30 keV. GRT data above 100 keV seem lower than older data.

Reason for Interest: Fundamental for fast breeders.

References: The literature is voluminous, but the following references will point the way to the most important papers.

71 KNOX. Papers by M.P. Fricke et al. and E.G. Silver et al.

NCSAC-33 (EANDC(US)-150U), Fricke et al., p.69ff, and de Saussure, p.182ff.

70 ANL, Paper 27 by W.P. Poenitz.

See also

Abagyan, L.P., et al., "Cross sections for radiative capture by U-238 nuclei," INDC(CCP)-11/U, 3/71

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4. Quantity and Nuclei: σ_f ratios, primarily $^{239}Pu/^{235}U$ but also for $^{238}U/^{235}U$ and $^{233}U/^{235}U$

Energy Range: 1 keV to 3 MeV

Magnitude of Discrepancy: Various experiments for the $^{239}Pu/^{235}U$ ratio differ by up to 10%, particularly exhibiting different structure. The discrepancy is considerably worse for the $^{233}U/^{235}U$ ratios, but the technological significance is considerably less. The problem of the ^{235}U fission cross section may be at the heart of these discrepancies.

Reason for Interest: Fast breeder reactors.

References: Poenitz, W., "Recent experimental data for heavy nuclei," 70 HELSINKI, Vol.II, p.15

Soleilhac, M., et al., "$\bar{\nu}$ and fission cross section ratios for U-235 and Pu-239 between 0.3 and 1.4 MeV," 70 HELSINKI, Vol.II, p.145

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5. Quantity and Nucleus: $\bar{\nu}$ for ^{252}Cf

Energy Range: Spontaneous

Magnitude of Discrepancy: Data divides into two groups about 2.5% apart.

Reason for Interest: Vital standard.

References: Hanna, G.C. et al., "Review of 2200 m/sec constants for fissile isotopes," Review of Atomic Energy VII, No. 3/4 (1969).

Konshin, V.A., and Manero, F., "Energy dependent $\bar{\nu}$ values and the status of $\bar{\nu}$ for the spontaneous fission isotopes," INDC(NDS)-19/N, 6/70

De Volpi, A., "Absolute source determinations using both techniques," 70 ANL. See also the Summary of Session VI of the same meeting.

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6. Quantity and Nuclei: $\bar{\nu}$ for fissile nuclei, particularly ^{235}U and ^{239}Pu.

Energy Range: Thermal to 14 MeV

Magnitude of Discrepancy: Chief areas of discrepancy appear to be the question of structure in the $\bar{\nu}$ vs E curve for ^{235}U above the resonance region (Soleilhac vs Boldeman) and to a lesser extent in ^{239}Pu.

Reason for Interest: Fast reactor physics.

References: The review literature is massive; see the articles listed under $\bar{\nu}$ for Cf^{252}: Konshin et al., De Volpi, and Colvin.

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7. Quantity and Nucleus: J and $\bar{\nu}$ for ^{239}Pu resonances

Energy Range: 0 to 100 eV

Magnitude of Discrepancy: Question centers over whether resonance $\bar{\nu}$ values correlate with J values. Ryabov, Weinstein, and more recently Weston disagree.

Reason for Interest: Breeder reactors.

References: Ryabov, Yu.V., et al., 69 VIENNA, Paper SM-113; also Report P3-5297, Dubna, 1970

Weinstein, S., et al., 69 VIENNA, Paper SM-122

Weston, L.W., et al., "Neutron Multiplicity for Pu-239 resonance fission," 71 KNOX [also issued as ORNL-TM-3331] (cf also NCSAC-33, p.185, 12/70)

8. Quantity and Nucleus: σ_γ for ^{240}Pu

Energy Range: 20 eV to 600 eV

Magnitude of Discrepancy: Radiative widths measured recently by Hockengurg et al. at RPI are 20% or more higher than those previously deduced from capture and transmission measurements at Geel and Harwell.

Reason for Interest: Fast breeder reactors

References: R.W. Hockenbury et al., "Resonance parameters of Pu^{240} from 20 to 1000 eV," 71 KNOX. See also NCSAC-33, p.203

For earlier literature see
H. Weigmann and H. Schmid, JNE 22, 317 (5/68)

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9. Quantity and Nucleus: Γ_γ for ^{23}Na resonance

Energy Range: 2.85 keV resonance

Magnitude of Discrepancy:

GRT	Γ_γ =	0.35 eV
Harwell		0.60 eV
RPI		0.47 eV

Also BNL measurements (Chrien) indicate (n,γ) spectrum from thermal neutrons is different from the spectrum arising from resonance capture; ~~Harwell (Rae) finds they are similar;~~ (that is wrong)

Reason for Interest: Reactor coolant

Reference: The situation is best summed up in Yamamuro, N., et al., NSE 41, 445 (9/70)

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10. Quantity and Nucleus: $N_f(E_n)$ for fissionable nuclei, particularly ^{235}U

Energy Range: Incident neutron energy to 14 MeV, but mainly for incident energies below 1 MeV

Magnitude of Discrepancy: Spectrum-averaged quantities have been interpreted as indicating average energy is 10% above previous values; dependence on incident energy unclear. Recent microscopic measurements at ANL and KFK of average neutron energy agree with previous values. Most significant discrepancy may be with regard to spectrum change from one nucleus to another.

Reason for Interest: Almost every application of neutron physics is influenced by the fission neutron spectrum.

References: The literature is voluminous, mostly concerned with arguing as to whether or not a discrepancy exists. The case against the discrepancy being real (along with new measurements) is presented by:

Smith, A.B., "Some remarks on prompt-fission-neutron spectra," EANDC(US)-147/A (also INDC(USA)-16/G)

Smith, A.B., "Note on the prompt-fission-neutron spectra of ^{235}U and ^{239}Pu," EANDC(US)-153/L (also INDC(USA)-27/L). To be published as a technical note in NSE

The case for a discrepancy has been argued at length most recently (with references to earlier literature) by:

Grundl, J.A., "Fission neutron spectra, macroscopic and integral results," 70 ANL

Review papers have been presented recently by:

Wiedling, T.A., "Fission neutron spectra, microscopic results," 70 ANL

Lubitz, C., & Stewart, EANDC(US)-139/L (also INDC(USA)-17/L) 1970

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11. Quantity and Nucleus: σ_{γ}, ^{197}Au

Energy Range: 10 keV to 1 MeV

Magnitude of Discrepancy: Recent years have seen considerable resolution of discordant measurements and a "best-fit" to 15 sets of measurements has been made at Lockheed. However, the "best-fit" involves arbitrary "adjustment-factors" of up to 20-25% in relatively recent data that are supposedly several times better in accuracy.

Reason for Interest: Reference standard

References: A recent and nearly complete review is given in Carlson, A.D., "Review of capture cross sections," 70 ANL.

See also, "Summary of Session VI" in same Proceedings.

The Lockheed "best-fit" is described in EANDC(US)-150/U [INDC(USA)-25/U], p.113ff

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12. Quantity and Nucleus: $\sigma_{n,\alpha}$ for ^{10}B

Energy Range of Interest: 200 to 500 keV

Magnitude of Discrepancy: Cross sections deduced from measurements at AERE, ANL and TNC are discrepant by several times estimated error.

Reason for Interest: Flux measurement standard

References: Havens, W.W. Jr., "Summary of Session VI," 70 ANL. See in same meeting Paper 16 by Sowerby et al., and Paper 17 by Tucker et al.

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13. Quantity and Nucleus: σ_T for natural Fe

Energy Range: 20 keV to 400 keV

Magnitude of Discrepancy: Cross section values at minima measured directly at ANL and in recent unpublished Columbia experiments differ by more than factors of 2 from those deduced from resonance parameters.

Reasons for Interest: Shielding, also fast reactor core physics

References: For consequences in shielding, see Goldstein, H., Trans. ANS 13, 262 (1970)

Reactor interest is discussed in Schenter, R.E., "Fe cross sections - ENDF/B - II" in CSEWG Newsletter 26, March 1971

Brief Listing of Some Discrepancies of Lesser Significance

	Data	Comment
15.	Gd-155, 157 and Hf-179	Discrepancy between measured and calculated resonance integrals.
16.	Fission yields Xe-135, I-135, and Cs-137	Measurements discrepant to over 5%.
17.	D Total	Available measurements discrepant < 1.5 MeV - calculated and measured ages also discrepant.
18.	Cl-36, Ar-36, V-50, Pm-148_m (41d)	Thermal measurements discrepant by factors of 2 or more.
19.	Carbon (thermal, elastic scattering)	Precision thermal measurements by Houk and Wilson and Koester discrepant - measurements by Ahmed et al. discrepant with R.O. Lane's phase shift analysis .5 to 2 MeV.

Bibliographical Appendix

69 VIENNA: "Physics and Chemistry of Fission." Proceedings of the Second IAEA Symposium, Vienna 28 July - 1 August 1969, IAEA Publication STI/PUB/234, 2 volumes, Vienna 1970.

70 HELSINKI: "Nuclear Data for Reactors." Proceedings of the Second International Conference, Helsinki 15-19 June 1970, IAEA Publication STI/PUB/259, 2 volumes, Vienna 1970.

70 ANL: EANDC Symposium on Neutron Standards and Flux Normalization, Argonne National Laboratory, 21-23 October 1970 (CONF 701002). Proceedings to be published by the USAEC.

71 KNOX: Third Conference on Neutron Cross Sections and Technology, Knoxville, 15-17 March 1971. Proceedings to be published by the USAEC.