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NEUTRON CROSS SECTIONS: BOOK OF CURVES

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Abstract: Neutron Cross Sections: Book of Curves represents the fourth edition of what was previously known as BNL-325, Neutron Cross Sections, Volume 2, CURVES. Data is presented only for total (*i.e.*, integrated) reaction cross sections (and related fission parameters) as a function of incident-neutron energy for the energy range 0.01 eV to 200 MeV. For the first time, isomeric state production cross sections have been included.

(neutrons, cross-sections, compilation, curves, data)

Introduction

Neutron Cross Sections: Book of Curves represents the fourth edition of what was previously known as BNL-325, Neutron Cross Sections, Volume 2, CURVES. The fourth edition, Volume 1[1,2] has been published in two parts in 1981 and 1984. The first edition[3] appeared in 1955. The third edition[4] was published in 1976. Since the last edition, the data library has grown from 1,500,000 to almost 3 million data points.

As in previous editions, curves of neutron cross sections (and associated information) are displayed as a function of incident neutron energy. Tables include references to all data. Information on isomeric state production is included for the first time.

Scope

Data is presented only for total, *i.e.*, integrated, reaction cross sections (and related fission parameters) as a function of incident-neutron energy. The energy range has been limited to 0.01 eV to 200 MeV in order to exclude crystalline and magnetic effects for slow neutrons and relativistic effects for high energy neutrons. Angular distributions and partial reaction cross sections to specific excited states are not included. However, isomeric state production cross sections have been included for isomeric states with a half-life>1 sec. Data which have been measured for a broad incident-neutron spectrum, *e.g.*, Maxwellian, and sums and ratios of specific reactions (*e.g.*, $\sigma_{n,np+n,d}$ or $^{235}U\ \sigma_{n,f}/^{239}Pu\ \sigma_{n,f}$) are not included.

A table of references to data for energies greater than 200 MeV is given at the end of the volume.

Preparation of data

The data were retrieved in the table computation format from the CSISRS data library[5] using the code COFFEE[6], and checked for errors and for missing data sets. An attempt was made to include any "important" missing data sets, *e.g.*, where there were no other data for a reaction or for a given energy range.

First order plots were generated using the code BNL325[7]. The plots were checked by the authors, "eye-guides" were added (see following), and final page layouts were made.

Graphical Representation

The data have been grouped into sections corresponding to the element of the target nucleus in the neutron-induced reaction. Within a section, graphical data are presented for the natural element followed by the isotopes of that element. Bibliographic pages follow at the end of each section.

The graphical display for a reaction is subject to the following limitations:

Isolated single-point measurements (*e.g.*, thermal and 14-MeV values) are not necessarily plotted. However, the numerical data values are quoted in the bibliographic section.

In most cases, no more than fifteen data sets are presented on a given plot. Unpublished data, older data, or data sets which appeared to the authors to be in error may have been removed from the plots. However, all references have been included in the bibliographic section.

Where there were many measurements at the same energy, some single-point data sets were removed using the criteria given above.

Cross sections which are derived as sums or differences of data for reactions plotted are included only for comparison with other data. If there is no other data, they are omitted.

Where data are densely represented, the data has been thinned, *i.e.*, a maximum number of data points from each set has been plotted.

Occasionally, certain arbitrary, but reasonable, choices of data placement have been made in the interest of reducing ambiguity. For example, for elements that are approximately monoisotopic, the data for the most abundant isotope may be plotted together with the data for the natural element (*e.g.*: hydrogen, helium, oxygen).

Bibliographic Information

Bibliographic information is included following the curves for each element, and is given in the same sequence as the graphical data. For isomeric cross

sections, the half-life of the isomer, taken from ref.8, follows the reaction type.

The following bibliographic information is given for each data set:

- Publication year
- Laboratory mnemonic
- First author
- Reference
- Number of data points in set
- Energy range covered, or, for single-point measurements, energy and data value
- Standard, if given

Eye-Guides

The curves appearing on each graph are from one of the following sources; the source is identified in the legend box after the list of references. All of the "eyeguide" curves are stored in the ENDF/B[9] format at NNDC.

ENDF/B-V

The ENDF/B-V library consists of evaluations for a number of elements and isotopes. In most cases, where data exist in the ENDF/B-V library, it is used as the eye guide to the experimental data (see Figure 1). An exception to this occurs when the resonance region is not well represented in ENDF/B-V.

Pointwise data were calculated in the resonance region using the code RECENT[10] and the data were Doppler-broadened to room temperature using the code SIGMA1[10].

The ENDF/B-V library was also used to calculate cross sections for reactions which do not exist in the file but could be derived. For example, the cross section for the natural element was calculated as the abundance-weighted sum of the isotopic cross section.

In the resonance region, when only broad spectrum or averaged data are plotted, the ENDF/B-V data are sometimes averaged for comparison with the experimental data.

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Where ENDF/B-V data did not exist, or was not a good representation of the resonance region, curves were, sometimes, generated from the evaluated resonance parameter file (see Figure 2). This file consists of the recommended resonance parameters from ref.1 in ENDF-5 format.

The data were processed using the codes RECENT and SIGMA1 (see ENDF/B-V, above). As with the ENDF/B curves, cross sections were sometimes calculated from total, capture, elastic scattering or fission reaction data, or were averaged for comparison with the experimental data.

EYE GUIDE

Eye guides were produced using interactive graphics and the computer code IGUIDE[11] to fit the experimental data (see Figure 3). The data were viewed on a CRT screen and nodes were entered. Where there were sufficient data, the y-value of these nodes was adjusted by a least-squares cubic spline routine. Finally, cubic spline curves were generated using the nodes.

Eye guides have been used where data was not available in either ENDF/B-V or the evaluated resonance parameter file. The eye guides are attempts to show the main features of the data as plotted; they should not be viewed as considered evaluations. For example, cross sections have not been constrained to equal the sum of the partials, although this may have been taken into account when choosing a curve.

In a very few cases, where only discrepant data points exist, no eye guide curve is given.

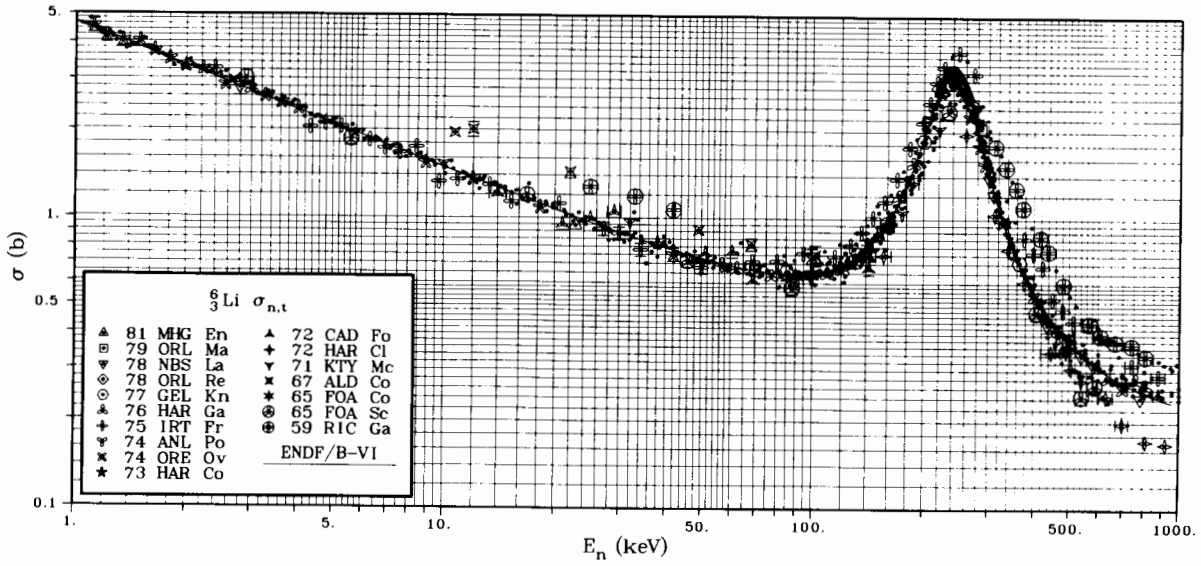

Fig.1. ^{6}Li $\sigma_{n,t}$ cross section using ENDF/B-V as an eye-guide

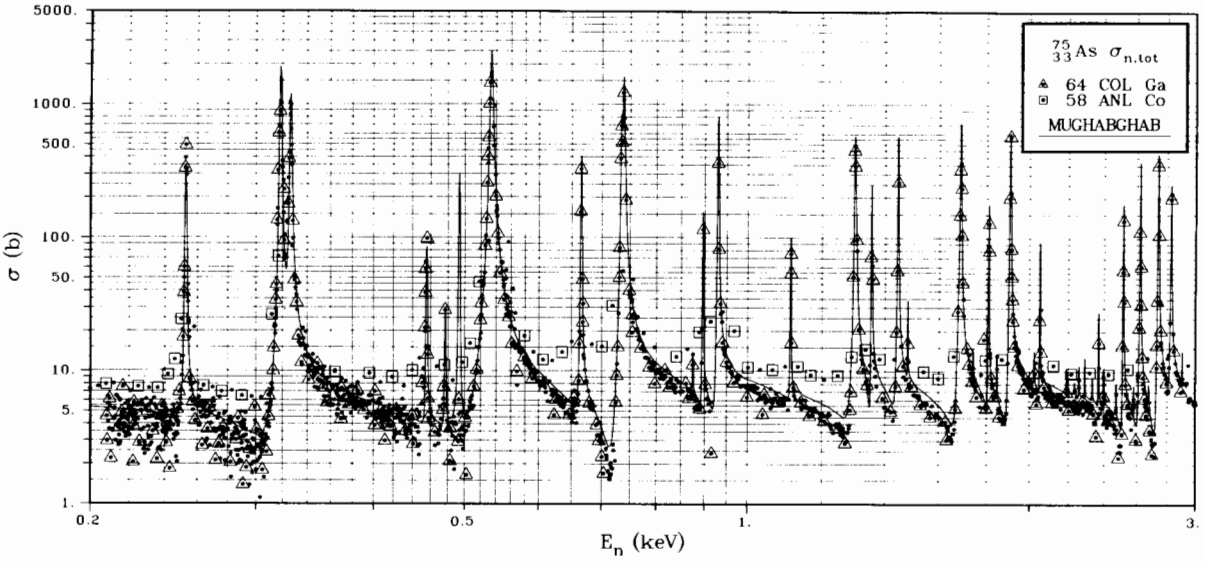

Fig.2. ^{75}As total cross section using eye-guide calculated from recommended resonance parameters

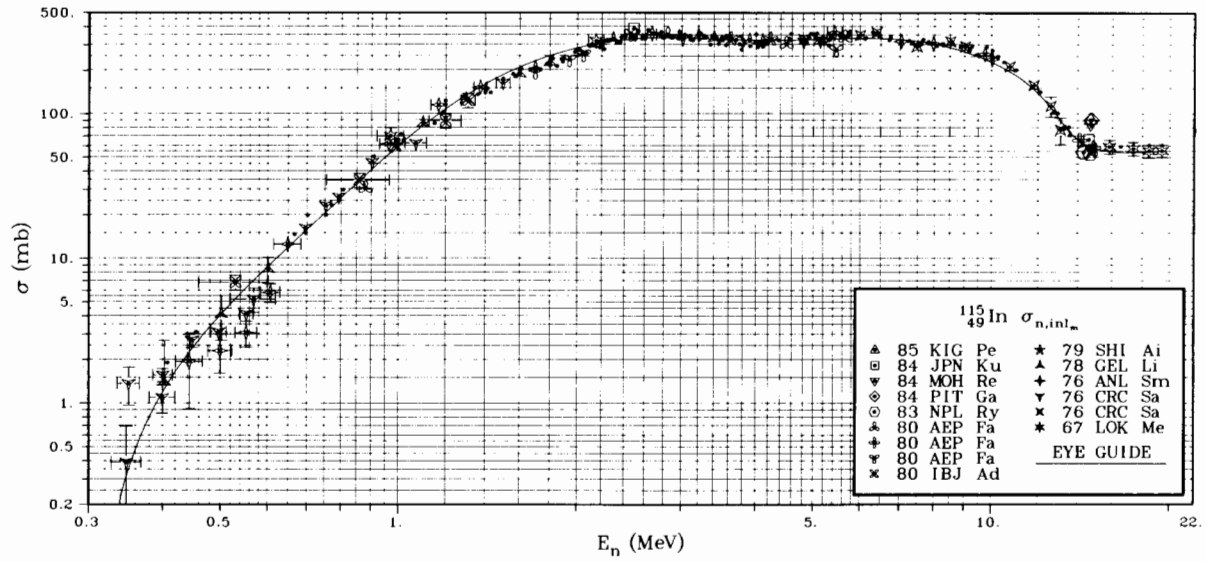

Fig.3. ^{115m}In inelastic scattering cross section using eye-guide produced using interactive graphics

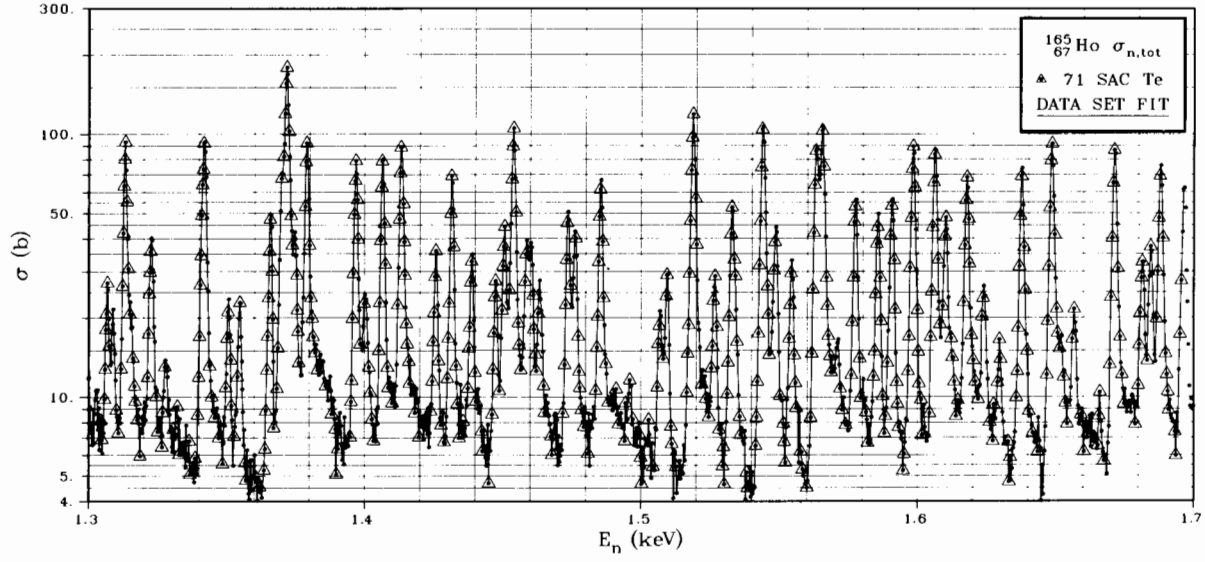

Fig.4. ^{165}Ho total cross section using fit to data set 71SAC as an eye-guide

DATA SET FIT

In the resonance region, where spline fitting is difficult, a curve was drawn using an experimental data set which was considered a good representation of the cross section in that range (see Figure 4).

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