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HIGH RESOLUTION TOTAL NEUTRON CROSS-SECTIONS BETWEEN 0.5 - 30 MeV

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Introduction

This report entitled

'High Resolution Total Neutron Cross Sections between 0.5 - 30 MeV'

is published in one and the same edition as an external report of the Kernforschungszentrum Karlsruhe, as an Euratom-report and as an EANDC-report under the reference numbers KFK 1000, EUR 3963 e and EANDC (E)-111 "U" respectively.

The book is a compilation of experimental results taken with the large neutron spectrometer of the Institut für Angewandte Kernphysik of the Kernforschungszentrum Karlsruhe. It is published to be of use to nuclear and reactor physicists interested in total neutron cross sections and in particular to those concerned with the behavior of fast neutrons in nuclear reactors and in neutron shields. The presentation of experimental information in this report is graphical only. Numerical values of the data included in this report are available on request from the ENEA Neutron Data-Compilation Centre, 91 Gif-sur-Yvette B.P. 9.

At the time of edition cross section data of the following nine elements C, O, Na, Al, S, Ca, Fe, [illegible] and Bi are available. In addition to these results the compilation will be supplemented with any further data on atomic and isotopic total neutron cross sections to be measured with the same facility. To facilitate the completion of this compilation the kind of this report is of 'ring-book' type. So any further data can be added easily.

The high resolution total neutron cross sections were measured using the fast neutron time-of-flight facility at the Karlsruhe isochronous cyclotron, described elsewhere[1]. Neutron production was achieved by (d,nx) reactions in a thick natural uranium target by bombardment of 45 ± 5 MeV deuterons from the internal beam of the cyclotron. Bursts of high energy deuterons and of 1 nsec duration yield a broad neutron spectrum capable to obtain useful neutron data in the energy region mentioned above. Time-of-flight assignments were made with a digital time sorter[2),3)]. Typically 2 x 8000 time channels of 1 nsec channel width were used.

By timing the neutrons over a 57 m flight path a total resolution of the spectrometer of about 0,03 nsec/m was obtained.
The experimental work reported here has been performed partially in the frame work of the Karlsruhe Fast Breeder Reactor Project.

Arrangement and Graphs

The arrangement of this book is as follows: Information on the various elements is placed in order of their atomic number. On the first page for each element there is a detailed description of the experimental conditions, e.g. sample thickness, purity of the material, accurate length of the flight path, time resolution, isotopic abundance etc.. The following two pages show a survey presentation on a double-logarithmic scale to give a rough information about the mean behaviour of the excitation function. The succeeding pages contain a detailed display of the data on a linear scale with the exception of some regions with a smooth energy dependence. The arrangement of the plots is in order of increasing energy.

The absolute total cross section in barn is plotted as a function of the incident neutron energy in MeV. Both the double-logarithmic and the linear representation of the data are plotted on close-meshed grids for ease of reading off the cross section as well as the energy values. In the detailed linear representation a curve is drawn through the data on each of the graphs. The curve is merely our own idea of a reasonable fit to the data; it serves as an 'eye-guide' only.

The data are presented as clear and uniform a manner as was consistent with the representation of the time-of-flight results on a linear energy scale. To accommodate on the fact of increasing resolution with decreasing energy the total energy range was divided for all elements uniformly into the following subintervals: 0.5-0.6, 0.6-0.7, 0.7-0.9, 0.9-1.2, 1.2-1.5, 1.5-2.0, 2.0-3.0, 3.0-4.5, 4.5-7.0, 7.0-12, and 12-32 MeV.

In addition to the energy scale also the ordinate scale changes from one graph to the other to account for the large differences in the fluctuation amplitudes occuring over the wide range of data.
Indication for these facts are not included in the graphs, except for the case that the ordinate scale does not start at zero. This is expressed by the notation "zero suppressed".

The statistical accuracy varying with energy is indicated by conventional error bars generally shown several times in each graph. The error bars are not shown in the figures if these are smaller than the size of the open circles representing data points. In some cases the original data were smoothed with a function given by the time distribution of the γ-peak to reduce the point scatter. Those regions are characterized by special symbols.
Neither the survey nor the detailed representation of the data contain any comparison with the results from other laboratories. Because of the large amount of the actual data this would give rise to a loss of all perspective and would considerably complicate the expeditious distribution of further data.

Notation

The notation used in this report is as follows

σ_T = total cross section in barn
E_n = energy of the incident neutron in MeV (lab. syst.)
n = sample thickness in at/barn
p = chemical purity of the sample in weight percent
l = lenght of the flight path in meter
Δt = total time uncertainty of the spectrometer in nsec (FWHM of the γ-peak)
i = isotopic abundance of the sample (e.g. natural or enriched)

Acknowledgements

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References

1. S. Cierjacks, B. Duelli, P. Forti, D. Kopsch, L. Kropp, M. Lösel, J. Nebe, H. Schweickert and H. Unseld, Rev. Sci. Instr. (to be published)

2. I. De Lotto, E. Gatti and F. Vaghi, Proceedings of a Conference on Automatic Acquisition and Reduction of Nuclear Data, organized by EANDC in collaboration with Gesellschaft für Kernforschung mbH., Karlsruhe, July 1964, ed. by K. H. Beckurts, W. Gläser and G. Krüger, published by Gesellschaft für Kernforschung mbH., p. 291 (1964)

3. C. Cottini, I. De Lotto, D. Dotti, E. Gatti and F. Vaghi, Energia Nucleare Vol. 14, No. 12, 704 (1967)

Erratum

1] Ref. 1, page 4, now published in Rev. Sci. Instr. 39, [1968] 1279

2] The third line on page 20 - nat. - S. 1 should read " l = 57.393 m "

3] The first, second and seventh line on page 26 - nat. - S. 1 should read

" n = 0.3175 at/barn [0.5 - 4.403 MeV] "

" n = 0.1587 at/barn [4.407 - 32.0 MeV] "

" The data points symbolized by + represent "

4] The following correction table for eight of our previously measured elements is the result of a careful reexamination of the dead time behaviour of the data recording system. Dead time effects arise only from the digital time-analyzer LABEN UC-KB. The dead time losses due to the detection system and the data transfer between the time analyzer and the computer are negligible.

From an extensive comparison of the above data with new measurements a slowly varying cross section shift was observed. Systematic deviations larger than the stated uncertainties were found mainly in the energy region below 1 MeV. We thus made an investigation to further improve the determination of the dead time function entering the calculations of the total cross sections. The determination of the new dead time behaviour indicated that dead time effects were overestimated for the elements C, Na, Al, S, Ca, Fe, Tl and Bi. The data for O do not undergo changes because dead time corrections were negligible due to low counting rates. The cross section data for the elements Si, Ni, Cr and Cl, K, V, Mn, and Co presented in KFK 1000 Suppl. I and Suppl. I , respectively, were calculated with the correct dead time function. Since corrections which have to be applied to the data cause a smooth cross section shift we give discrete energy points in a table which can be interpolated linearly. Table 1 contains the values $\Delta\sigma = \sigma_{KFK\ 1000} - \sigma_{corrected}$ which have to be subtracted from [no sign] or added to [negative sign] the published cross section data to obtain the corrected values. No values are given for Na below 0.9 MeV since the earlier measurements are replaced by a new set with highly increased statistical accuracy in the energy range from 0.3 to 0.9 MeV by KFK 1000 Suppl. II. For the elements S, Ca and Fe the table contains two different values at 4.4 MeV. The data for these elements are combined from two independent runs [0.5 - 4.4 MeV and 4.4 - 32 MeV] with different correction effects.

The numerical values of all data including the corrected data of the eight elements mentioned are available from CCDN, Saclay.

TABLE I

Energy	Corrections in barn for							
E_n [MeV]	C	Na	Al	S	Ca	Fe	Tl	Bi
0.42	-	-	-	-	-	-	.000	1.100
0.50	-	-	.340	.345	.330	.195	.000	1.000
0.60	-	-	.295	.295	.260	.185	.100	.900
0.70	.175	-	.250	.280	.190	.180	.160	.800
0.90	.165	.165	.200	.270	.140	.175	.180	.650
1.20	.150	.165	.165	.255	.110	.160	.220	.480
1.50	.135	.165	.155	.235	.085	.145	.215	.350
2.00	.115	.150	.150	.205	.050	.125	.210	.250
3.00	.090	.095	.150	.145	.030	.100	.170	.210
3.90	.080	.065	.140	.080	.020	.020	.175	.150
4.40	.075	.060	.105	.020	.015	-.060	.165	.030
4.40	.075	.060	.105	.145	-.040	.070	.165	.030
4.50	.075	.060	.100	.145	-.040	.070	.160	.020
6.00	.075	.020	.065	.140	-.050	.070	.065	.105
7.00	.075	.025	.050	.140	-.055	.070	.155	.170
12.00	.060	.040	.055	.115	-.060	.050	.105	.230
16.00	.040	.045	.065	.085	-.060	.030	.040	.160
20.00	.030	.050	.050	.065	-.060	.015	.085	.145
23.00	.025	.010	.075	.060	-.060	.015	.220	.325
26.00	.025	.020	.040	.060	-.060	.015	.030	.060
32.00	.025	.020	.095	.060	-.060	.015	.030	.015