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A measurement of the neutron total cross section of sodium with high resolution and high precision showed a total number of only 16 resonances from E_n = 300 - 900 keV. The seven broad resonances in this region are well established from previous work with poorer energy resolution. In addition we observed seven narrow resonances of measured widths between 0.6 and 1.7 keV and two broader resonances with low amplitudes.

The total neutron cross section of sodium has previously been investigated at several laboratories [1-6]. Nevertheless many of its features were quite uncertain. In particular it was not clear whether or not the cross section is characterized by rapid fluctuations with widths of 0.6 to 4 keV in the energy range from 300 to 800 keV. Some of the previous results [4-6] were used for systematic evaluation studies on the level structure of sodium at excitation energies above neutron binding and for information on spin distributions for light nuclei [7, 8].

Earlier investigations in our laboratory on sodium between 500-900 keV with 2-6% statistical inaccuracy performed with very high energy resolution showed that there was no indication for a large number of narrow resonances. We, therefore, have remeasured this cross section in the extended energy region between 300-900 keV with the same resolution but high statistical accuracy. The energy resolution in this measurement was determined as 0.2 keV at 300 keV and 0.9 keV at 800 keV.

The measurements were done with the neutron time-of-flight facility at the Karlsruhe isochronous cyclotron with ≈ 1 ns burst width and a 57.5 m flight path [9]. Neutron production was achieved by (d, nx) reactions with 45 MeV deuterons from the internal beam. The neutron beam was collimated at 10 m and 37 m from the source to about 2×10^{-6} sr. A sample of high-purity sodium metal with a thickness of 0.233 at/barn sealed in an aluminum can 0.6 mm thick aluminum end windows was used. For background compensation an identical empty can was put into the open beam position. Effects of impurities and non-uniformities in the sample are estimated to introduce less than 1% uncertainty in the measured cross section. The preparation and canning of the samples was done by Euratom CBNM, Geel.

The sample was moved in and out of the beam in a 200 second cycle. The cyclotron was operated at an intensity such that the 9 cm diameter, 1 cm thick proton recoil scintillator detected

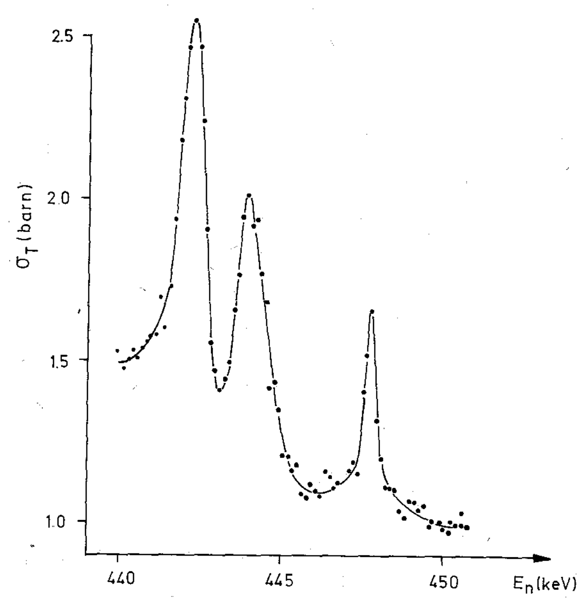

Fig. 1. Neutron total cross section of potassium demonstrating the energy resolution obtained in the present experiment.

0.8 neutrons per machine burst when no sample was in the beam. The time analyzer and the data acquisition system registered up to 4 neutrons per machine burst without dead-time losses in the time interval of 8 μs used. Precise correction for remaining dead-time effects was made with a computer program. Absolute uncertainties of the cross section are less than 2%.

The energy resolution of the spectrometer was determined both by the time distribution of γ rays within the peak of the prompt γ rays from the target and by measuring narrow resonances of ^{39}K under identical conditions in the same energy region. Near 445 keV there are three closely spaced resonances as shown in fig. 1. These resonances were well resolved in our measurements. The measured width of the 447.8 keV resonance indicates that our resolution is at least equal to or better than 0.4 keV at 450 keV. The same value within the experimental uncertainty was obtained from the width and shape of the prompt γ-ray peak which reflects the time distribution of the neutron burst at the target plus any time spread inherent in the recording equipment.

Table 1
Levels of ^{24}Na derived from the ^{23}Na total neutron cross section.

Present experiment		Stelson and Preston [1]	
E_{peak} (keV)	Γ_{obs} (keV)	E_R (keV)	Γ (keV)
299.5 ± 0.1	-	297	4 (anal.)
300.5 ± 0.1	0.5 ± 0.3	-	-
394.8 ± 0.8	23.5 ± 0.5	396	23 (obs.)
431.2 ± 0.5	6.5 ± 0.4	-	-
448.6 ± 0.2	6.8 ± 0.3	451	10 (obs.)
508.8 ± 0.2	0.6 ± 0.1	-	-
547.0 ± 2.0	-	542	39 (anal.)
564.1 ± 0.2	1.0 ± 0.2	-	-
597.5 ± 1.5	21 ± 2.0	602	8 (obs.)
599.8 ± 0.2	0.9 ± 0.2	-	-
627.0 ± 0.2	1.7 ± 0.2	-	-
683.4 ± 0.3	1.2 ± 0.2	-	-
710.0 ± 1.5	72 ± 4	710	72 (anal.)
748.3 ± 0.3	0.9 ± 0.2	-	-
766.4 ± 0.6	5 ± 0.5	-	-
778.0 ± 2.0	38 ± 2	784	38 (anal.)

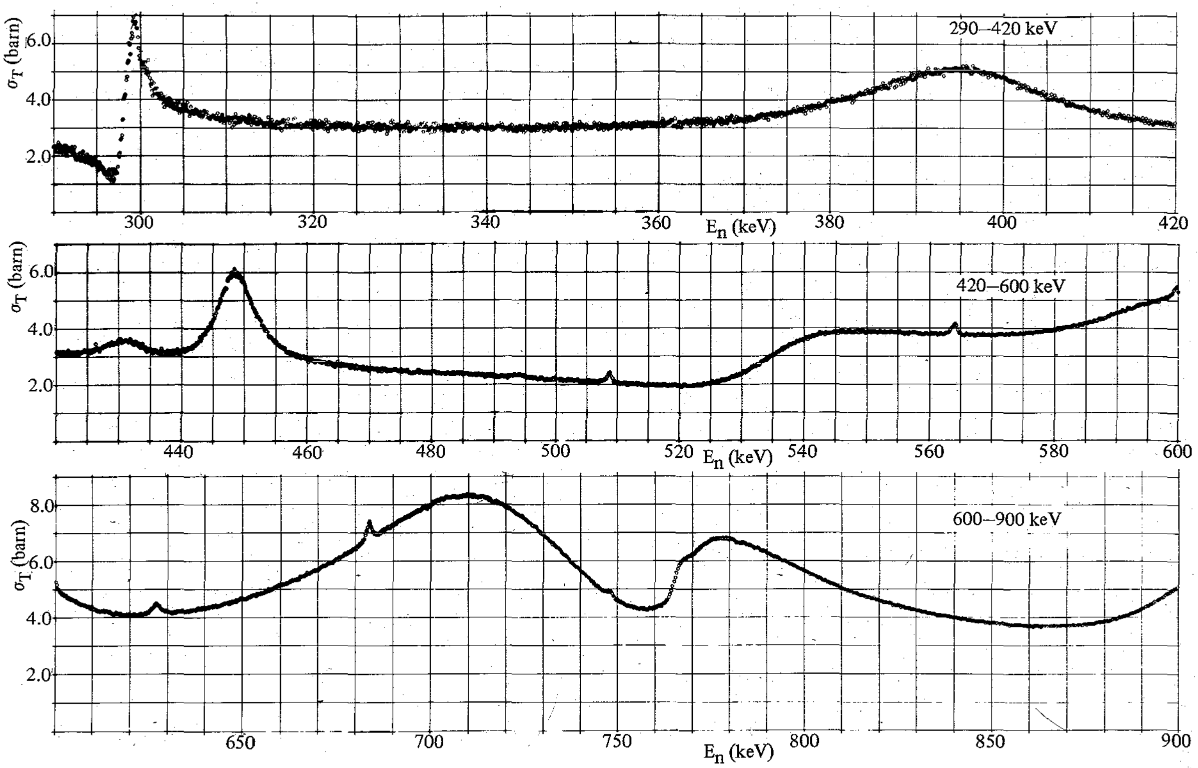

Fig. 2. Neutron total cross section of sodium from 300 to 900 keV.

Our results for sodium are shown in fig. 2. It appears from these curves that we observed only six sharp resonances at 508.8, 564.1, 599.8, 627.0, 683.4 and 748.3 keV. The narrowest of these resonances is at 508.8 keV where we measured a FWHM of 0.6 keV. In table 1 the peak energies, measured widths and energy resolutions for the 16 resonances between 300 and 900 keV are shown. Columns 4 and 5 list the resonance energies in the laboratory system and the measured or analysed widths, respectively, determined by Stelson and Preston [1]. The statistical uncertainty in the measurement is $\leq 0.3\%$ between 600 and 900 keV, and $\leq 1\%$ from 420 to 600 keV. Below 420 keV the statistical accuracy in most time channels is better than 2% with the exception of the region within the cross-section dip near 297 keV and the region between 305-350 keV where the statistical error is $\approx 3\%$.

On the basis of our measured resolution, we should have observed all resonances with widths smaller than 0.2 keV at 300 keV and 0.9 keV at 900 keV. From the present experiment we must therefore conclude to a total level density which is lower by about an order of magnitude than that reported in the literature [4-6].

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