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compiled by K. Nishimura

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Low Energy Neutron Scattering Cross-section of ^{6}Li

A. Asami and M. C. Moxon*

A full paper on this work, which was outlined in the previous report (EANDC (J) 13L P.10), is to be presented at the IAEA Conference on Nuclear Data for Reactors to be held at Helsinki in June 1970. (paper number CN-26/25)

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Neutron Resonance of ^{59}Co at 132 eV

Y. Nakajima, M. Ohkubo, A. Asami, and T. Fuketa

A full paper on this subject was published in the Journal of Nuclear Science and Technology 7 (1970) 7 - 12 with an abstract as follows:

Neutron transmission measurements on ^{59}Co have been made for neutron energies from 0.8 eV to 3 keV using the time-of-flight spectrometer of a linear accelerator at the Japan Atomic Energy Research Institute. The maximum time resolution was 10 nsec/m. Resonance parameters of the 132-eV resonance of ^{59}Co were determined from the neutron transmissions of several samples of different thicknesses by the thick-thin method, using an area analysis method based on the Breit-Wigner single-level formula.

The following results were obtained, $E_0 = 132.0 \pm 0.5$ eV, $\Gamma = 6.0 \pm 0.2$ eV, $\Gamma_n = 5.15 \pm 0.06$ eV and $J = 4$. The value of the potential scattering radius, obtained from the transmission of the thickest sample, was $R' = 5.3 \pm 0.5$ fm.

$^{208}Pb(\gamma,n)$ Reaction near Threshold

Y. Nakajima, R. Bergère*, M. Mizumoto, and T. Fuketa

The following is an epitome of the paper presented at 1970 Spring Sectional Meeting of the Physical Society of Japan.

Photoneutron spectra of the $^{208}Pb(\gamma,n)$ reaction have been measured with the time-of-flight spectrometer[1] at the JAERI accelerator. The experimental conditions are the following:

Electron energy: 10.5 MeV, Electron pulse width: 150 ns,

Channel width: 62.5 ns, Flight path length: 50 m,

Detector: ^{6}Li glass scientillator.

The spectra were measured at 85° and 130° to the direction of photon.

First, the photoneutron spectra of $^{208}Pb(\gamma,n)$ reaction had been measured by Bertozzi et al.[2] up to 2 MeV neutron energy. Then, they have been recently greatly improved up to 350 keV neutron energy by Bowman et al.[3]. As is seen in the Table, our data are in good agreement with

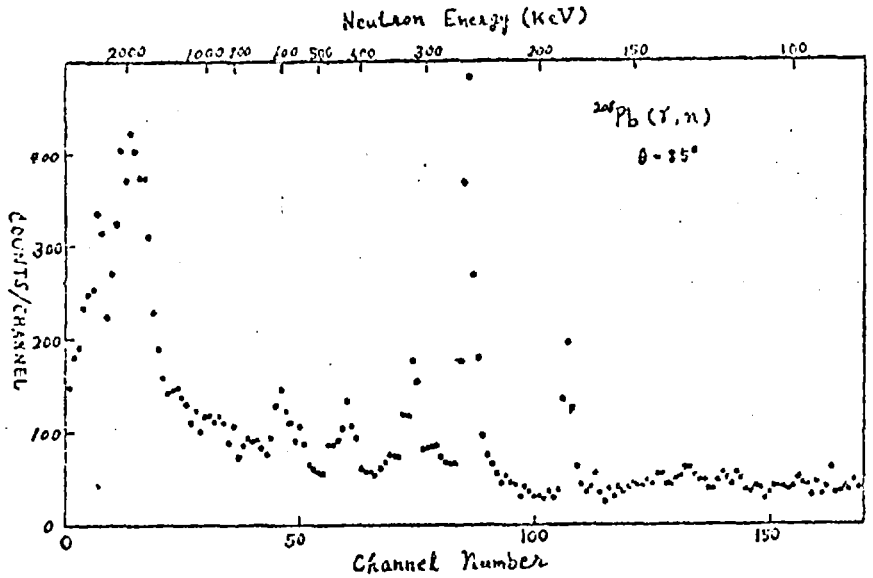

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Table Resonance Energy

915 MeV		877 MeV
		93.3
		114.7
130		123.7
		139.5
		158.0
168		166.8
182		181.3
257	268 MeV	256.7
301		279
317	324	312.7
333		335
430	437	
460		
486	557	
615	624	

these data. Multipole assignments of the absorbed photon will be made in the favourable resonances.

Recent measurements in Saclay of ^{208}Pb (γ,n) cross section seem to show some intermediate structure near the threshold[4]. Our high resolution data are compared with the data of Saclay and preliminary results and discussion are presented.

References:

1) A. Asami et al: JAERI 1138 (1967)

2) W. Bertozzi et al.: Phys. Letters, 6, 308 (1963)

3) C. D. Bowman et al.: Phys. Rev. Letters, 23 796 (1969)

4) R. Bergere: Private communication.

An Area-Analysis Program for Neutron Resonances based on the Atta-Harvey Code

A. Tachibana*, T. Iwaki**, E. Kimura, A. Asami, Y. Nakajima, and T. Fuketa

A report on this subject was published in JAERI-memo 3728 (1969) with an abstract as follows:

Modification of the Atta-Harvey Area-Analysis Code was made with regard to the calculation of the neutron width consistent with the total width and to the evaluation of the error of computed value of neutron width in addition to the minor change of the program. Instruction for the use of the program and the program list are given.

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Fast Neutron Scattering from Al, Si, S and Zn

S. Tanaka, K. Tsukada, M. Maruyama and Y. Tomita

Differential cross sections for elastic and inelastic neutron scattering have been measured for natural samples of Al, Si, S and Zn at incident energies from 4.5 to 8 MeV in about 1-MeV steps. Scattered neutrons were observed at angles from 30° to 150° in 10° steps with a Mobley bunching system of the JAERI 5.5 MV Van de Graaff accelerator and a time-of-flight spectrometer. The absolute differential cross-section scale was fixed with reference to the n-p scattering cross section. The data were corrected for flux attenuation, multiple scattering in the samples and source-to-sample angular distributions for the first 2^+ states of ^{32}S and Zn even-even isotopes show forward peaks.

The differential cross sections were analysed by using the optical model, the Hauser-Feshbach theory and the DWBA method. The optical-potential parameters were chosen by fitting the sum of the shape-elastic and compound-elastic scattering cross sections to the observed data. Actually, two kinds of parameters were searched; (1) a best-fit parameter set at each incident energy for every sample and (2) an "overall-fit" parameter set with smooth energy dependence of V and W. In general the Hauser-Feshbach calculation using the former parameter sets gives a good agreement with the observed inelastic data for several low-lying levels of ^{27}Al and ^{28}Si but agreement with the inelastic data for ^{32}S is rather poor. The DWBA calculation using standard deformation parameters reproduces fairly good angular-distribution patterns for the first 2^+ and the sixth 3^- levels in ^{32}S, and for the first 2^+ levels in even-even isotopes of Zn, but results in values larger than the observed cross sections. Using the "overall-fit" set, calculations based on the Moldauer theory and the coupled-channel

theory are under progress for ^{27}Al, ^{28}Si and ^{32}S.

A full paper will be published in the proceedings of the IAEA International Conference on Nuclear Data for Reactors (Helsinki, 1970). The number assigned to this paper is CN-26/31.

Width Fluctuation and Resonance Interference Effects in Neutron Scattering Cross Sections of Aluminum, Copper and Zinc

K. Tsukada, Y. Tomita, S. Tanaka and M. Maruyama

Neutron scattering cross sections of aluminum, copper and zinc have been analyzed in the energy region of 1 to 8 MeV by means of the optical and statistical models, the width fluctuation effect and the resonance interference effect being taken into account. Data of the cross sections used in the analysis include those at 4,81, 5.96, 7.03 and 8.03 MeV for aluminum, at 1.71 and 2.24 MeV for copper and at 1.71, 2.24, 4,48, 5.92, 6.97 and 7.99 MeV for zinc which were measured in our laboratory, and data available in BNL-400 and CCDN. Best fit sets of optical-model parameters are searched for the angular distributions of elastic scattering, the inelastic scattering cross sections and the total cross sections at each energy. By using a compute code "STAX2", calculations on the basis of Hauser-Feshbach's formulation and Moldauer's formulation are performed. In the latter formulation, the calculations are carried out with the maximum and zero values of Moldauer's parameter Q. Difference in fitting among the three calculations appears in backward angles in a limited energy region. Systematic energy variations of the optical-model parameters are seen more or less in the region lower than 4 MeV for all cases. In the region higher than 4 MeV, where the Moldauer effect is to be ineffective, the energy variations are not so pronounced. Judging from these two, the calculation with the maximum value of Q is considered to be best among the three calculations to reproduce the measured data, though fluctuations in the cross sections and simple forms of the angular distributions in the lower energy region make the choice ambiguous.

A full paper will be published in the proceedings of the IAEA International Conference on Nuclear Data for Reactors (Helsinki, 1970). The number assigned to this paper is CN-26/30.

Neutron Scattering Cross Sections of Iron

Y. Tomita, K. Tsukada, M. Maruyama and S. Tanaka

The differential cross sections of elastic and inelastic scatterings by iron have been measured at incident neutron energies from 1.43 to 2.15 MeV in steps of 40 keV with an energy resolution of 50 keV. Scattered neutrons and gamma rays produced in the inelastic process were observed at the same time with a Mobley bunching system of the JAERI 5.5 MV Van de Graaff accelerator and a time-of-flight spectrometer. The neutron scattering cross sections were measured relative to the p-n cross sections, and the neutron energy standard was the 2.08-MeV resonance of carbon. The cross sections of gamma ray production were measured with the same liquid scintillation detector as the neutron detector, and normalized to the neutron scattering cross sections. Both neutron and gamma ray cross sections were corrected for multiple scattering and attenuation of neutrons in the scattering sample, and source-to-sample angular spread. The angular distributions of the neutron and gamma ray cross sections thus obtained were fitted with Legendre expansions of a form of $\frac{1}{4\pi}\sum_{l=0}^{4} B_l P_l(\cos\theta)$ (l_{max} =6 for elastic scattering). Intermediate structures, which are similar to those observed by Elwyn and Monahan, and Barnard et al. in the energy region of 0.3 to 1.5 MeV, appear in the excitation functions of some of the expansion coefficients of the cross sections, i.e. the coefficients of l=0 to 4 for the elastic scattering, l=0 for the inelastic scattering and l=0 and 2 for the gamma ray production. Energies of humps in the excitation functions are about 1.6 and 2.05 MeV.

A full paper will be published in the proceedings of the IAEA International Conference on Nuclear Data for Reactors (Helsinki, 1970). The number assigned to this paper is CN-26/29.

Excited Levels of ^{133}Cs by Neutron Inelastic Scattering

S. Kikuchi

The levels of ^{133}Cs were investigated by means of the $(n,n'\gamma)$ reaction. Five gamma rays were observed and the energies of levels associated with the individual gamma rays have been determined[1] from the informations of the threshold energies of excitation functions.

The angular distributions of these gamma rays were also measured and have been compared with theoretical prediction based on the Satchler formalism[2] in order to deduce spins and parities of the levels.

Further examination of spin and parity assignments is now under progress, by comparing the observed excitation functions with those calculated on the basis of the Moldauer theory[3].

References:

1) S. Kikuchi, Y. Yamanouti, and K. Nishimura, J. Phys. Soc. Japan 28 (1970) 1089

2) G. R. Satchler, Phys. Rev. 94 (1954) 1304; ibid. 104 (1956) 1198

3) P. A. Moldauer, Phys. Rev. 123 (1961) 968; ibid. 129 (1963) 754; Rev. Mod. Phys. 36 (1964) 1079

Elastic and Inelastic Scattering of Neutrons in 20 MeV Region

Y. Yamanouti, S. Tanaka, S. Kikuchi and K. Tsukada

Preliminary experiments to get information on neutron background and shielding in 20 MeV region by using $T(d,n)^4He$ reaction have been completed. The design of a multi-angle detector system which has the maximum flight path of 8 m is now in progress.

Direct Measurement of Nuclear Reaction Times by the Use of the Blocking Effect in Single Crystals

M. Maruyama, K. Tsukada, K. Ozawa, F. Fujimoto*, K. Komaki*, M. Mannami**, and T. Sakurai**

A full paper reporting the results on the $^{28}Si(p,p')$, $^{70}Ge(p,p')$ and $^{72}Ge(p,p')$ reactions, which were outlined in the previous report (INDC(JAP) 4E p.10), is in press in Nuclear Physics.

The measurement of reaction times of the $^{63,65}Cu(p.p')$-$^{63,65}Cu^*$ (1st and 2nd excited states) reactions has been performed using the same method and the analysis of the observed data is now in progress.

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Evaluation of the Total Neutron Cross Section of Carbon up to 2 MeV

K. Nishimura, S. Igarasi, T. Fuketa and S. Tanaka

A treatment of least-squares method has been applied to the evaluation of carbon total neutron cross section in the energy region 1 eV to 2 MeV. The number of total cross-section data, which were available from CCDN and collected from other published reports, amount to almost 2,200 points. A fourth order polynomial is adopted as an empirical formula for these cross-section data. Two different methods for the assignment of weight have been tried in the least-squares fit, i.e., equal weight and weight of inverse square of error. The results indicate that the difference in the cross-section values obtained with the two different weight assignments does not exceed 1% in the entire energy region. The numerical data are classified into two groups of experimental data sets, one obtained by the time-of-flight (TOF) and the other by the direct-current-beam (DCB) method. In order to find out systematic trend depending on the different methods of measurements, the least-squares fits with the equal weight and the weight of inverse square of error are applied to TOF and DCB data, separately. Systematic deviations of about 3.5% for the equal weight and about 2.5% for the weight of inverse square of error, are found in the cross section at 350 keV between TOF and DCB data. The cross-section curve obtained by the weight of inverse square of error is compared with those of ENDF/B, KFK 750 and UK data file.

Fast Neutron Capture Cross Sections of Cr, Fe, Ni and Mo

K. Nishimura, T. Asami, S. Igarasi, M. Hatchya* and H. Nakamura**

In the keV-energy region, neutron radiative capture cross sections for such reactor materials as Cr, Fe, Ni and Mo have been measured by a number of authors. A variety of standard cross sections used in different groups of measurements makes a systematic comparison among their results difficult. In the present work, the Au(n,γ) cross section measured by Poenitz et al. is adopted as a common standard cross section. By multiplying the normalization factors to the each (n,γ) cross section in different groups of measurements, the renormalized (n,γ) cross sections for Cr, Fe, Ni and Mo have been obtained. By the use of the results of the systematic study of level density parameter a and strength function $1/\xi^0$, statistical model calculations have been performed up to about 10 MeV. The competition with neutron inelastic scattering is taken into account in the statistical model calculations. Collective and direct model calculations have been performed above several MeV region. Calculations are made by the use of a computer code RACY. The results of calculations from 10 keV to 20 MeV are adjusted to the renormalized (n,γ) cross sections for Cr, Fe, Ni and Mo, and are compared with the curves of ENDF/B, KFK 750 and UK data.

A full paper will be published in the proceedings of the IAEA International Conference on Nuclear Data for Reactors (Helsinki, 1970). The number assigned to this paper is CN-26/28.

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Analysis of Neutron Inelastic Scattering by ^{238}U

S. Igarasi, H. Nakamura*, T. Murata**, and K. Nishimura

Total and partial inelastic scattering cross sections of ^{238}U are investigated in the range of neutron energy from 50 keV to 15 MeV. Optical model and Hauser-Feshbach's formula are mainly used in the energy range from 50 keV to 1.5 MeV and evaporation model is used above 1.5 MeV. Values and trends of optical potential parameters and level density parameters are searched for by fitting the calculated values of the inelastic scattering cross sections and the emitted neutron spectra to the experimental data. Spin and parity for each discrete level of ^{238}U are tentatively determined, after surveying experimental and theoretical information, and comparing results of calculations with experimental data for excitation functions. Effects of competitive processes, such as (n,γ), (n,f), etc. are taken into account in the calculations. Above 1.5 MeV, the inelastic scattering cross sections are obtained by using Hauser-Feshbach's model which includes contribution from continuous state of the target nucleus, and by using calculated cross section for compound formation and experimental data for (n,f), (n,2n), (n,3n) and (n,γ) cross sections. The inelastic scattering cross section obtained in this work is comparable to that presented in KFK-120.

A full paper will be published in the proceedings of the IAEA International Conference on Nuclear Data for Reactors (Helsinki, 1970). The number assigned to this paper is CN-26/27.

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Half-lives of Some Fission Product Nuclides

S. Baba, H. Baba and H. Natsume

The half-lives of nuclides supplied in the proton-induced fission of ^{238}U were investigated. The β-countings of chemically separated fission products were performed with end-window gas-flow proportional counters. Obtained decay curves were analyzed with a non-linear least squares fitting programme for the IBM-7044 electronic computer. Resulting half-life-values of several nuclides are summarized in the table. A full paper with this title will be published in Journal of Inorganic and Nuclear Chemistry.

Table

Nuclide	Half-life	Nuclide	Half-life
^{72}Zn	46.6 ± 0.2 h	^{136}Cs	13.00 ± 0.02 d
^{86}Rb	18.61 ± 0.04 d	^{140}Ba	12.789± 0.006 d
^{89}Sr	50.55 ± 0.09 d	^{141}Ce	32.6 ± 0.2 d
^{91}Y	58.51 ± 0.06 d	^{143}Pr	13.57 ± 0.02 d
^{99}Mo	66.5 ± 0.2 h	^{147}Nd	10.98 ± 0.01 d
^{112}Pd	20.12 ± 0.06 h	^{149}Pm	53.08 ± 0.11 h
^{115}Cd	53.38 ± 0.04 h	^{153}Sm	46.44 ± 0.08 h
^{115m}Cd	44.8 ± 0.3 d	^{156}Eu	15.17 ± 0.03 d
^{129m}Te	33.52 ± 0.12 d	^{161}Tb	6.90 ± 0.02 d

Average Level Spacings and the Nuclear Level Density Parameter

H. Baba and S. Baba

A full paper on this subject was published in the Japan Atomic Energy Research Institute report, JAERI 1183, August, 1969, with an abstract as follows :

The average level spacing D_0 was computed with neutron resonance capture data summarized in BNL-325, and compared with those given by several authors. The values thus fixed with reliability were plotted versus the neutron number to see the systematic behavior of the D_0. The less reliable or ambiguous group of the D_0's was then fixed by taking the systematics into consideration. It was also decided from the systematics that the error involved in the D_0's would be at most of the order of a factor of two.

The level density parameter a was calculated with the fixed value of the level spacing D_0. The effect of an alternative choice of the level density formula or the moment of inertia on a was discussed and its dependence on the nuclear radius parameter was studied as well.