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Progress Report to International Nuclear Data Committee
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CONTENTS

Progress Report to INDC

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The nuclear data activities in some Chinese institutions during 1984 - 1985 are introduced in this report. This paper is consisted of three parts: I. Nuclear Data Measurement: In this part the measurements performed and the facilities concerned at some institutions in China are listed respectively; II. Nuclear Data Evaluation: Evaluation activities in the network coordinated by CNDC are reviewed; III. Analysis of Nuclear Data and Related Underlying Research: Systematics studies and theorectical calculations on nuclear data, and related underlying researches are presented. Besides the References for part I - III, the other works which have not been mentioned in part I - III are also listed for reference.

Almost all listed publications in References are presented in Chinese nuclear science journals with English abstracts or to be published soon.

I. Nuclear Data Measurement

Institute of Atomic Energy

During recent two years, the majority of the manpower those engaged in data measurement in IAE have been making preparation for experiments at tandem HI-13 which will soon be put into operation. The beam time had been allocated are including following neutron nuclear data measurements:

. Secondary neutron spectrum and angular distribution measurement at ~10 MeV on U-238 etc.;

. Fission spectrum for U-238 at ~10 MeV;

. γ -production cross section on Fe, Li etc. at MeV energy region;

. Excitation function of some activation reactions;

. Neutron spectrum of (x,n) reaction; etc.

For financial problem, the 100 MeV LINAC project at IAE has been cut-off. Measurements performed on other accelerators at IAE are listed as follows:

. Fast Neutron Elastic Scattering Differential Cross Sections from U-238[1]

14.2 MeV, ~3 M flight path, resolution time ~1 ns, 44 angles from 10°-160° with 2.5° or 5° step were measured. The results are in agreement with other results within experimental errors. The results have been compar-ed with spherical optical model and coupled channel theory analysis.

The secondary neutron spectra on U-238 have also been measured and submitted for publication.

. Mass Distribution in Fast Monoenergetic Neutron Induced Fission of U-238[2,3]

Incident neutron energy E_n = 8.3 and 14.2 MeV. Ge(Li) γ-ray spectrum method. The absolute measurement of fission rate is carried out by a double ionization chamber.

. Cf-252 Spontaneous Fission Characteristics Research[4-8]

The three-parameter measurements (recording a fragment kinetic energy, prompt neutron average number and KX-ray[5] or recording average neutron number, fragment mass and total kinetic energy[6]) are made for 252-Cf spontaneous fission. No even-odd effect in $\bar{\nu}(Z)$ or $\bar{\nu}(A,E_K)$ is obtained. With three-parameter correlation measurements, the structure[7] and correlation properties[8] in long range α particle are investigated.

. Fast Neutron Induced Reaction Cross Sections

Measurements reported recently are listed in the following table. All these measurements were performed by activation method[9-16].

Reactions	Energy Region MeV	Neutron Source	Standard
180-Hf, 152-Sm(n, γ)	0.1 - 1.5	7-Li(p,n),T(p,n)	197-Au (n, γ)
169-Tm (n, γ)	thermal	pile	197-Au (n, γ)
90-Zr (n,2n)	12 - 18	T (d,n)	α-associated
93-Nb(n,2n)Nb-92m	14.58	T (d,n)	α-associated
197-Au (n, γ)	0.030	7-Li(p,n)	7-Be radioactivity
24-Mg,46,48-Ti, 54-Fe, 58-Ni, 93-Nb,113,115-In } (n,p) (n,α) (n,2n)(n,n')	8.62	D(d,n)	27-Al (n, γ)
Pt(n,x) Pt-195m	0.144,5.19,14.64	D(d,n),T(d,n)	197-Au(n,γ),27-Al(n,α)
193-Ir (n, γ)	0.565	7-Li(p,n)	191-Ir (n, γ)

As examples, some results for comparision between this work and others are given in fig. 1 to fig. 4.

. Gamma Ray Source Facility

A gamma ray source facility with high intensity and high monochromaticity is built at the swimming pool reactor of IAE. The photons are produced by thermal neutron capture reactions. The energy range of γ-rays from 4 MeV to 11 MeV with typical intensity 5 x 10^{13}/s. Some measurements have been done with this facility[17,18].

. Nuclear Structure and Decay Data

A few studies on energy level with thermal neutron capture gamma-ray or in

beam gamma-ray spectroscopy have been carried out.[19-22] Two groups (at reactor and accelerators respectively) have been working in this field.

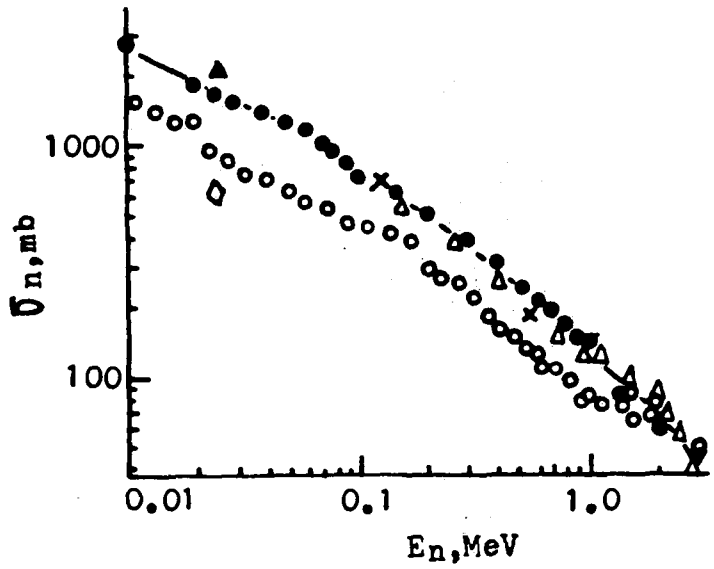

Fig. 1 Neutron Capture Cross Sections for 193-Ir
× this work [16]

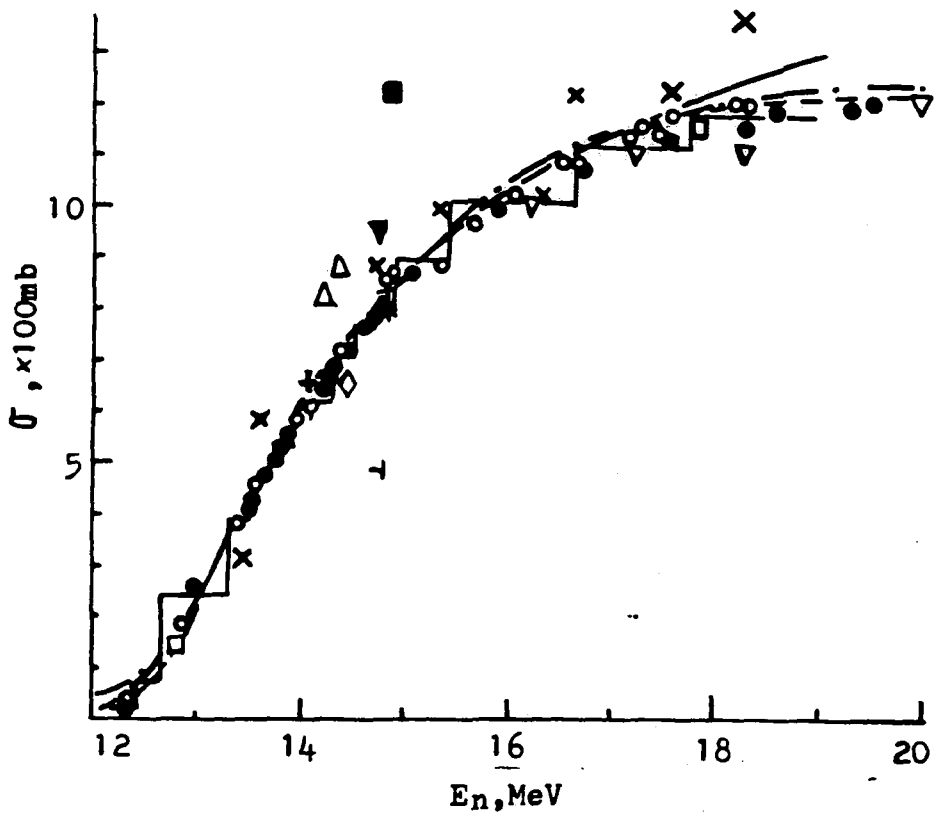

Fig. 2 Cross Sections for 90-Zr (n,2n) Zr-89 Reaction
• this work [11]

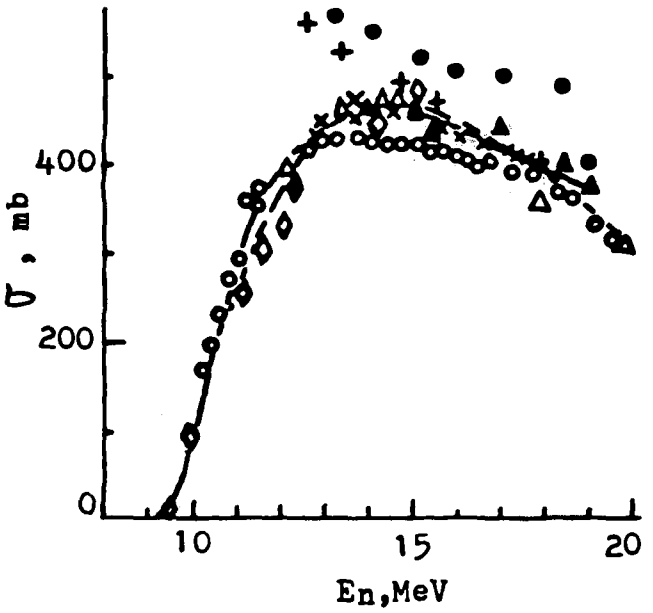

Fig. 3 Cross Sections for 93-Nb (n,2n) Nb-92m Reaction
× this work [10]

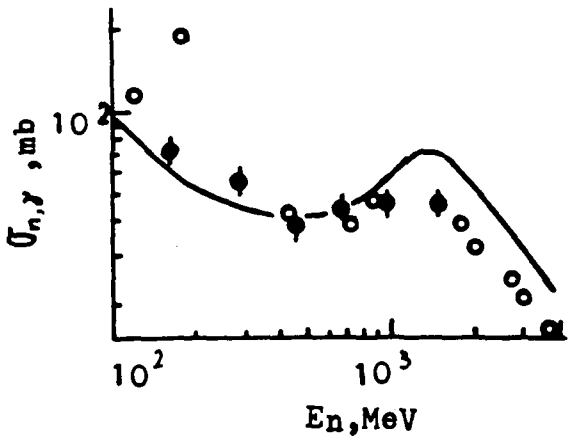

Fig. 4 Neatron Capture Cross Sections for 180-Hf
. this work [13]

For example, in the γ-ray spectrum of the S-32 (n,γ) reaction at thermal energy measurement, the excitation energies of 25 levels and the decay branching ratios have been deduced. Three possible levels of 7505.0, 4473.1 and 2884.6 keV were not reported previously. The neutron separation energy of S-32 is determined to be 8641.7$\pm$0.6 keV. The thermal neutron capture cross section of S-32 is determined to be 529$\pm$26 mb .[19]

In a similar measurement for Na-23 the level scheme of 35 levels has been established. The neutron separation energy obtained is B_n = 6959.51(21) keV. With back-shifted Fermi model, the level density parameter a = 3.43 (19) MeV^{-1} for Na-24 was derived. It is concluded that the statistical process is dominated in neutron capture reaction at thermal energy for Na-23.[20]

Institute of Nuclear Science and Technology, Sichun University, Chengdu

. Fast neutron spectroscopy have been established at VDG (2.5 MV,pulsed) and HT (400 kV, associated purticle) for years. Angular distribution of neutron elastic scattering at E_n = 1 MeV and 14 MeV on Ni and Nb have been carried out respectively[23,24].

. Facilities for small angle ($\lesssim 10^o$) elastic scattering differential cross section measurement have been established at Cockcroft-Walton. A position sensitive neutron detector consisting of a 80 cm long liquid scintillator is used to detect the positions of the scattered neutron and at the same time to determine the scattering angles. With a two dimension multichannel analyzer scattering signal from different angles (3.9^o - 14.6^o) can be detected simultaneously. The time resolution of 1.1 ns (for 5 MeV neutron) and 0.7 ns (for 14.7 MeV neutron) have been obtained. The differential elastic scattering cross sections on Pb, U-238 etc. have been measured[25,26].

. A ϕ1 M scintillation tank[27] and a Moxon-Rae detector have been constructed and are being used for the (n,γ) cross section measurements in $\lesssim$1.5 MeV neutron energy region[27].

. In this Institute, a measurement of excitation functions of charged particle induced reactions have been carried out on Au with 13.5 MeV deuteron from 1.2 M cyclotron [28]. In this measurement, a stacking gold foil sample was used for irradiation and the relative yields of different layers (corresponding to different energies) were measured and excitation functions of 197-Au (d,p) Au-198, 197-Au (d,2n) Hg-197m, 197-Au (d,2n) Hg-197 and 197-Au (d,p2n) Au-196 have been obtained. A Ge(Li) spectrometer was used for γ-ray measurement.

Low Energy Nuclear Physics Institute, Beijing Normal University

A time of flight spectroscopy has been established on a pulsed Cockcroft-Walton accelerator for measuring γ-ray spectrum and γproduction cross section.

The pulse width (FWHM) of the primary neutron is ~1 ns. A Ge (Li) detector of Type ORTEC-8000 (sensitive volume 111 cm^3) is used for γ-ray spectrum measurement. γ-production cross sections at 90° on Fe, V-51, Nb, Al and C have been measured recently. Reports on the facility and the results of the measurements will be published in near future.

Department of Physics, Tsinghua University

The measurement of neutron scattering cross section at small angle on Pb has been done [29]. A position sensitive neutron detector has been developed for this measurement with which the differential cross section may be measured simultaneously at $\lesssim 10^o$. The detector consists of a long cylindric liquid scintillation tube and two photomultiplies at both ends of the tube. The position information of the scattered neutron was extracted by two methods: 1, the time difference between the signals from the two PMS; 2, the amplitude ratio between the pulses from the two PMS[29].

Neutron Physics Laboratory, Department of Technical Physics, Beijing University

A 4.5 MV VDG is being installed, and a 2 x 6 tandem will be installed in this laboratory. Preparations for neutron nuclear data measurement at those accelerators are under way. Measurement of nonelastic cross section on Si and Cu at 14 MeV neutron at HT[30] and neutron spectrum of a Am-Be source (by time of flight method) [31] have been carried out.

Nuclear Science Department, Fudan University, Shanghai

The inelastic scattering cross sections for the reaction $^{87}Sr(n,n')\,^{87m}Sr$ at the neutron energy range 0.9 - 1.8 MeV and 3.2 - 5.7 MeV are measured by the activation method using enriched targets on a VDG accelerator[32].

II Nuclear Data Evaluation

. Neutron Nuclear Data Evaluations

Evaluations for Co, Mn, Ag, In, Ca, Al etc are in progress.

. Nuclear Structure and Decay Data

Ten mass chains of A = 51 - 56, 195 - 198 have been permanently assigned to China. Evaluations for A = 51, 54, 55, 56, 170 and 172 have been finished and for A = 52. 195 and 196 are in progress.

. Fission Product Yields

Since the early 1985, a group has been devoting efforts to the project of seting up to the FPY library. In the first phase of the project, a top priority was given to the following 10 fission systems:

U235T, U235F, U235HE, U238F, U238HE, Pu239T, Pu239F, Pu241T, U233T, Th232F. (U235T stands for 235U fission induced by thermal neutrons, the others are on the analogy of this. T - thermal neutron, F - fission spectrum neutron, HE - 14 MeV neutron.)

The working contents may be divided into the following parts:

(1) Collecting and evaluating experimental data;

(2) Calculating fission yields through Gaussian-Charge-distribution-dispersion model;

(3) Producing recommended values;

(4) Transforming into the ENDF/B format.

The items (1) and (2) have been finished. At present, the item (3) is being carried out.

Besides the 10 fission systems mentioned above, this fission yield library will include some 30 more ones, they are:

U233F, U233HE, U236F, Pu239HE, Pu240F, Pu241F, Pu242F, Th232HE, Np237F, Cf252F;

U234F, U237F, Pu240HE, U234HE, U236HE, Pu238F, Am241F, Am243F, Np238F, Cm242F;

Th227T, Th229T, Pa231F, Am241T, Am241HE, Am242mT, Cm245T, Cf249T, Cf251T, Es254T.

More evaluation efforts will be paid to what they are frequently taken as "reference nuclide" in fission yield measurements, such as Mo-99, Ba-140, Nd-148, Xe-138, Kr-88 etc.

. Transplutonium Nuclear Data

Work on testing and improving the evaluated data for Am-241 and evaluating Bk-249 and Cf-249 is under way. Some problems exist in the capture cross section evaluation for Am-241. The point is that the integral Am-241 capture data measured in different fast neutron fields indicate that the evaluated capture cross sections are too low, but an increase of the capture cross section would create problems elsewhere.

. Charged Particle Data

Measured data for ~15 reactions performed in China have been collected and made them in EXFOR format.

. Data Treatment

The possibility of application of Bayesian approach of data adjustment to microscopic nuclear data evaluation has been discussed. The examples for single parameter, multiparameter and self-consistant multiparameter evaluation have been given[33].

A unified scheme for data (with covariance) treatment has been adopted and some simplified methods to get inversion of high order matrix for saving CPU time have been developed to meet the needs of nuclear data evaluation work [34].

Efforts have also paid to the improvement of curve fitting with B-Spline[35,36].

A spline fit method and program for multi-set data have been developed. The main improvements are as follows: any order spline as base, knot optimization and accurate calculation for error of fit value. The program has been used for practical evaluation of nuclear data.

III Analysis of Nuclear Data and Related Underlying Research

. MUP-2, a computer code for neutron nuclear data calculation for medium mass nuclei

This is a combined code including calculations based on optical model, Hauser-Feshbach statistical theory with width fluctuation correction and evaporation model including preequilihrium statisticul theory based on exciton model. Some study results of the microscopic theory of optical potential have also been used in this code (it has been submitted to NEADB).

. Systematics study on Excitation Function of Neutron Induced Reactions[37,38]

Systematics studies on (n,2n), (n,3n) as well as (n,x) (x = p, α, d, t and ^{3}He) reaction excitation functions have been performed. In the present work, the parameterized formulas have been obtained on the basis of evaporation model taking the preequilibrium process into account. The measured data in the regions of E_n = thr. - 25 MeV and A = 25 - 200 have been collected up to the year of 1985 and fitting them with the parameterized formulas to obtain the local parameters. The systematic behavior of these parameters have been studied and the systematics parameters have been obtained. With these parameters, the excitation function could be predicated for unmeasured energy region or nuclide more reliably than before.

. Calculation of n + D Reaction Cross Section with Faddeev Equation

In this calculation, a separable potential including only central force has been used.

. Phase Shift Analysis of n - d Scattering [39].

A new parameter set based on measured data has been extracted. With these parameters the total Cross Sections at $E_n < 1$ MeV could be reproduced much better than before.

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