STATE COMMITTEE FOR NUCLEAR ENERGY

INSTITUTE FOR ATOMIC PHYSICS

AND

INSTITUTE FOR NUCLEAR TECHNOLOGY

ANNUAL REPORT

ON NUCLEAR DATA IN ROMANIA

during the year 1971

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Compiled by

S.RAPEANU, N.MATEESCU

BUCHAREST 1972

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CONTENTS

N O T E

This annular report contains two parts :

- a general view on the future organization and activity regarding the preparation of a library of microscopic data evaluated by the Institute for Atomic Physics and group constants calculated by the Institute for Nuclear Technology;

- individual reports concerning certain results for nuclear data in the field of thermal and fast neutrons.

The individual reports are not intended to be complete or formal. Consequently, they must not be quoted, abstracted or reproduced without the permission of the authors.

PRINCIPLES CONCERNING THE ORGANIZATION OF THE NUCLEAR DATA LABORATORY

N.Mateescu, S.Râpeanu, A.Bădescu-Singureanu,
D.Gheorghe, S.Mateescu

I. INTRODUCTION

The limited preocupations of various laboratories in the field of nuclear data became unsufficient compared with the development of nuclear applications especially, in energetics on industrial scale. This represented the decisive element for the setting up of some national and then international laboratories specialized in collecting, treating and dissiminating of nuclear data.

In order to increase the capability of exchanging the huge amount of compiled and evaluated nuclear data it was necessary to create the Nuclear Data Section of the I.A.E.A. (and other international centers).

Although the N.D.S. center offers the access to many types of data, those countries which have a nuclear power programme and want to develop their own library must take into account the experience of the most developed ones as U.S.A. U.S.S.R. and England, beyound the N.D.S. recommendation.

II. THE LABORATORY OF EVALUATED NUCLEAR DATA

The purpose of this laboratory, from the general point of view, is to offer the evaluated nuclear data to the user in an appropriate form.

The role of the laboratory is of an intermediate between the producer and the user of nuclear data. By this role we understand the achievement of :

a) a concrete and coherent research programme, able to answer to the present and long-term necessities,

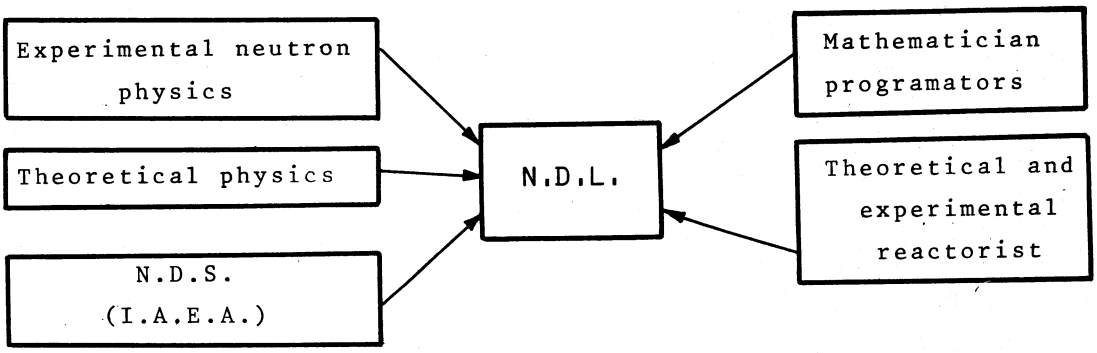
b) an effective control of the whole source of information and exchange of information concerning the nuclear data (including the exchange with the I.A.E.A. center),

c) the elimination of the discordance between the way in which the compiled data are offered and the way in which the respective data are necessary (especially the adequate data for computing the group constants),

d) as much as possible to provide the user with those data which cannot be obtained by the help of the I.A.E.A. center.

The main and immediate task of the laboratory as a result of the above mentioned consideration is to set-up a *library of microscopic evaluated nuclear data* in which these data should be accessible in the specific forms.

The connections of the nuclear data laboratory with other laboratories or centers are schematically established as it follows.



Organization

The laboratory will be divided into working team as follows :

a) The team specialized in the organization of the data format, the procedure to be used for storing, changing and retrieving of the data. First, this group must adapt one of the existing formats to our requirements and possibilities and to the international panel recommendation [1]. In addition they will adapt the associated computer programmes.

This team must include minimum three specialists among which a mathematician.

b) The evaluators team which has the tasks to establish isotopes, elements or mixture for which the data are to be evaluated and to make the proper evaluation. They will depend on the documentation offered especially by the I.A.E.A.. After the evaluation has been accomplished they introduce them into the library and check them.

This group must be composed at least of physicists specialized in thermal, resonance and fast neutron physics. The consultant physicists and the collaborators in the field of theoretical physics, nuclear reactions and nuclear reactor design are to join them.

The formats for the library will follow the main line of the most developed national library as ENDF/B (U.S.A.),U.K.N.D.L. (U.K.) and KFK (F.R.G.). The adaptation of one of these national library formats to our computer possibilities and to our necessities will maintain the flexibility, the accuracy in the cross - section description, methods of checking the evaluated data,method of interpolation as far as the possibility of a quick up-dating of the stored data.

All stored data will be accompanied by an adequate documentation and justification about the evaluation procedure. The library output must be able to provide data in various forms as required by uses.

Evaluation activities

As is well known, that the evaluation work, roughly speaking, consists in a critical comparison of the compilated data in order to select them by specific averaging procedures.The evaluator is obliged to take into account the experimental techniques and the aspects connected to the fundamental physics.

Thus we should have a detailed documentation on the way in which the data have been obtained and to have a multilateral knowledge specific to an experimental physicist and theoretician.

The evaluating *objectives,* systematically presented by Schmidt [2], are :

a) To complete the gaps in the nuclear data within the field in which measurements have not been yet accomplished. This can be made by interpolation or extrapolation using the existing experimental points. The procedure can be done graphically,by theoretical models or by nuclear systematics. The last can be applied with great care and especially for interpolation between the neighbouring nuclei.

b) To make a consistent set of data.

The achievement of this requirement can be done by :

- reducing the available data to the same physical conditions ;
- trying to obtain all the cross-sections for the same energy ;
- checking the correctness of this data (for example whether the total cross-section is identical to the sum of the partial cross-section).

c) To remark systematic experimental errors. This is the most difficult task because the evaluators have to do a very careful study about the experimental conditions. Usually, because of the limitations of time and manpower this requirement can be fulfilled only for the most important cross-sections.

The main stages which are to be carried out by the evaluator are the following :

a) The bibliographical information using as source the CINDA system and N.D.S. required information.

b) The collected data should be stored temporary using an available format so as to allow various kinds of analyses as for exemple data selection, reduction to the same condition, renormalization, average procedures, comparison with theoretical models.

Regarding the comparison of experimental results with various theoretical models it is to be emphasized that at the beginning there will be applied only a few programmes :

- a parametrized programme for scattering low generation ;
- one level Breit-Wigner for resolved resonance ;
- a simplified optical and statistical model for fast neutrons.

We hope that in the next future, the international panel should be able to recommend a more or less standard model.

c) The treatment of experimental data, as was mentioned above, to obtain the recommended value. The consistency of this value are checked taking into account, as much as possible,all information concerning the corresponding element or isotope so that finally to obtain the consistent set of evaluated data.

d) The data should be stored in the library and then printed again to avoid some possible errors.

FINAL CONSIDERATIONS

From the above related situation, it results that the problem of the group constants has not been included in the laboratory of nuclear data. In order to avoid some comentaries and to make some precissions at the same time concerning the way of using the evaluated nuclear data, the following schema gives the key to the answer.

The A laboratory - Basic nuclear data laboratory for reactors ;
The B laboratory - Group constants
The C laboratory - Reactor calculations.

In fact this schema is practical the same for all nuclear research centres. In other words the principal user of nuclear data is the B laboratory which in his turn is strongly dependent of reactorist designers.

CONCLUSIONS

1. The existence of the evaluated microscopic nuclear data library is closely connected and organically integrated in the complex activities of the energetic nuclear programme.

2. The reactorist must handle very quickly a lot of data. Because the necessary systems of codes to handling the data within the various library in the world are not accessible, is necessary a proper system of codes.

3. There are certain difficulties in obtaining evaluated data from other countries.

4. The activity of evaluating nuclear data must be specialized in a certain field. The existence of some specific sets of evaluated data allows a exchange of other sets of data from other library centres in the world.

5. A direct collaboration with I.A.E.A. or other centres in some very well delimited field of evaluation activity should be recommended.

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NUCLEAR DATA ACTIVITIES AT THE INSTITUTE FOR NUCLEAR TECHNOLOGY

S.Râpeanu, I.Iftode and H.Stefan

Our institute was founded in July 1971 and involved especially in problems of reactor engineering. The institute is supplied with the necessary microscopic nuclear data from the Institute of Atomic Physics, mainly from the laboratory of nuclear data for reactors, which is charged with the preparation of a computerized library of the ENDF/B type. However, at INT there is a team of physicists charged with the production of group constants for reactor physics and shielding calculations.

The following facilities are available :

- access at the research reactor VVR-S ;
- access at the computers IBM 370/135, ICL 1905, IBM 360/40 ;
- a PDP 15 on-line computer, ordered from the company ;
- a spectrometer with recoil protons of own design and construction, now in stage of routine operation ;
- experimental device with adjustable fast spectrum in construction ; the spectrum can be computed with high accuracy,due to the geometrical simplicity, by means of a SN code ;
- auxiliary equipment.

The nuclear data activities go towards two main directions:

A <u>Group constants</u>.

A_1 a code for generation of resonance cross-section and shielding factors in the σ_o- concept is under testing.

A_2 another code under testing is a THERMOS-like code to produce thermal group constants for reactor cells with slightly enriched uranium. The code averages the spectrum over the mains regions of the cell (fuel, cladding moderator), the running times being thus with an order of magnitude smaller than of the usual THERMOS codes ; that makes it suitable for reactor optimization studies. The number of groups is optional.

A_3 - several other codes under testing are meant to produce, among others, reactor group constants for light and heavy water power plants.

A_4 - in an early stage it is a B_1 code for calculation of within group fluxes and currents to be used as weighting functions in the cross-section collapsing calculations. This is made for several reactor block compositions and has a large variety of edits.

A_5 - it is intended to assimilate a MC^2 - like code for production of group constants directly from the nuclear data files.

B Nuclear data measurements

B_1 - experiments to measure the scattering cross-section of several reactor materials in the fast range are proceeding.

B_2 - it is performed a program of "dirty" nuclear data measurements, such as spectral indexes with activation detectors, resonance integrals, etc.

THE STRUCTURE IN THE $F^{19}(\gamma,xn)$ REACTION CROSS SECTION

D.Catană, G.Baciu, C.Iliescu, V.I.Opriş, M.Orbeşteanu

The cross section of the photoneutron and photoproton reactions as well as the photoabsorption on fluorine have been treated in many papers [1-3].

The main purpose of this work is to investigate the F^{19} (γ,xn) reaction cross section, in the energy interval 11-26 MeV, with a bin of loo keV in measuring of the yield curve. The cross section was obtained by the help of Penfold and Leiss method.

The experimental results are compared with the photo - absorption cross section computed using the single-particle wave functions of an anisotropic harmonic oscillator.

Experimental procedure

The $F^{19}(\gamma,xn)$ reaction yield was measured with the I.F.A. betatron in the energy range from 11.2 MeV up to 26 MeV the maximal betatron energy. The yield curve have been measured with a bin of loo keV, and the statistical errors on the whole were less than 1%.

The experimental procedure was extensively described in a paper [4] and here we give only those data which relevant for this reaction.

The fluorine sample was a disc from chemically pure teflon the effective thickness was o.824 g/cm^2. The contribution of the C^{12} (γ,n) reaction was substracted (the yield curve of this reaction was measured in the same conditions).

The stability of the energy control system was checked by reference to the 17.28 MeV - break in the $O^{16}(\gamma,n)$ yield curve and was constant during the experiment within + 15 keV.

The dose dependence vs. maximal energy point of bremsstrahlung has indicated an effective thickness of the Pt betatron target of o.15 mm (o.312 g/cm^2).

Results

The cross section of the reaction has been computed using Penfold and Leiss method with the B numbers for a thick Pt target (o.312/g/cm^2) in forward direction for bremsstrahlung spectrum.

In fig.1 is given the cross section of $F^{19}(\gamma,xn)$ reaction and the total photoabsorption cross section reported by Dolbikin [5].

If we suppose that the cross section of $F^{19}(\gamma,p)$ reaction has the same order of magnitude as the cross section of $F^{19}(\gamma,n)$ reaction, the using of the thick-target bremsstrahlung spectrum should be more realistic.

For the calculation of the total photoabsorption cross section we have started from the model proposed by Spicer [6]. A computation of possible E_1 transition energies in F^{19} was made, using the Nilsson level schema and treating F^{19} as a deformed nucleus in which single-particle excitation can occur alone or together with a collective rotational excitation. In the calculation of transition energies the pairing energy was included. The main assumption is that the nuclear deformation is the same both in the ground state and in excited states. The ground state deformation parameter was taken o.43.

The integrated computed cross section from 9 MeV to 3o MeV is of 381 mb.MeV, while the dipole sum rule gives for an exchange parameter K = o.5 a value of 398 mb.MeV.

The electric dipole photoabsorption cross section is shown also in fig.1

A comparison between the cross sections indicated a satisfactory agreement both in position of the peaks and in their amplitudes.

In conclusions, the use of thick target bremsstrahlung spectrum in the forward direction, when the γ beam is very well collimated should be more realistic than Schiff spectrum.

On the other hand, this measurement shown the ability to resolve resonances of the order of o.5 $\pm$ 1 MeV width in (γ,xn) cross sections in the high energy region and narrower in the low energy one, when bremsstrahlung is used as a photon source.

A computation of the E_1 photoabsorption cross section based on the single particle and rotational excitation using Nilsson levels has shown itself to be capable of explaining the kind of resonance structure which is observed in experimental photonuclear cross sections of fluorine.

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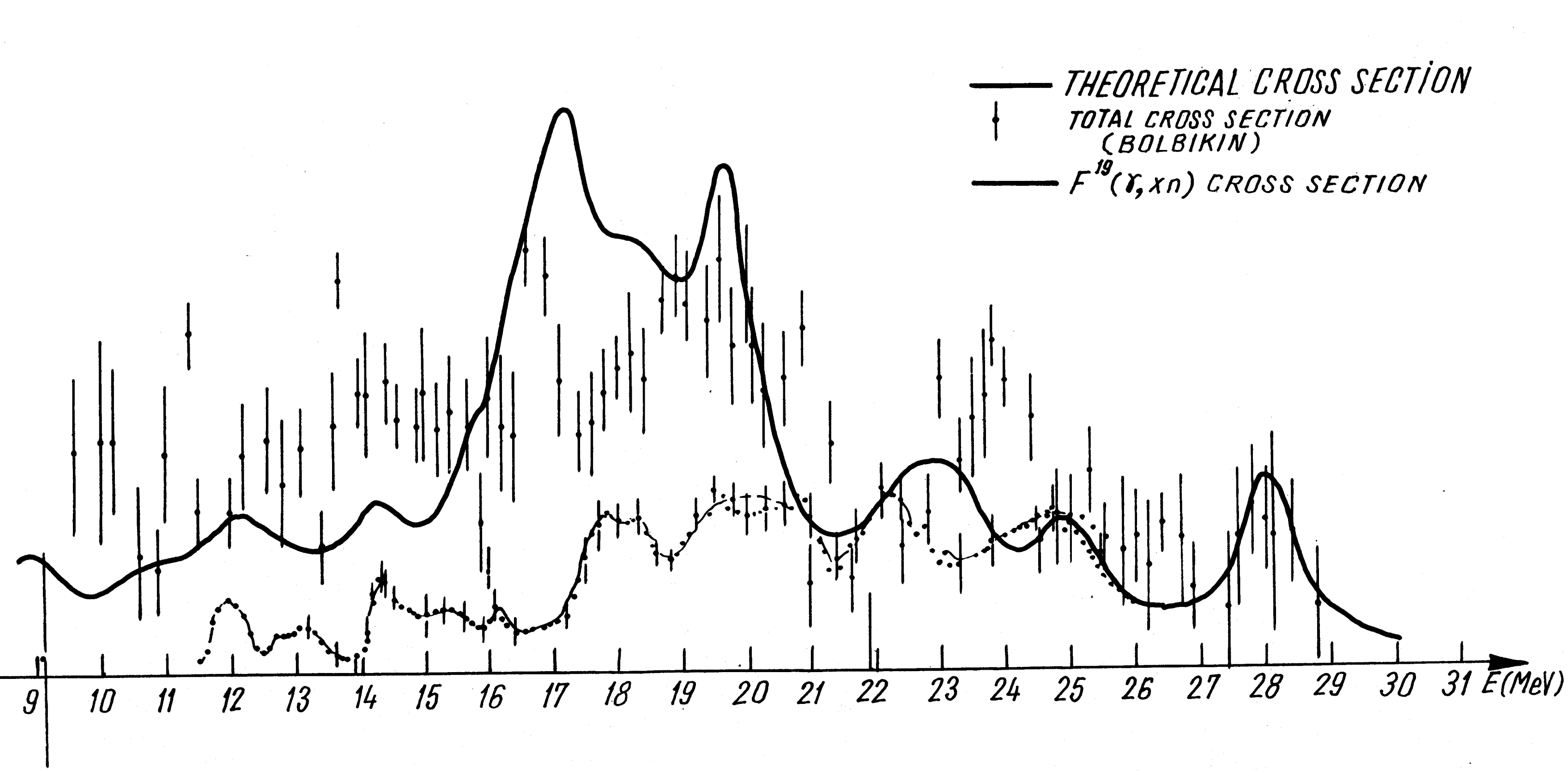
σ(mb)
45
40
35
30
25
20
15
10
5
0
9
10
11
12
13
14
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16
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18
19
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21
22
23
24
25
26
27
28
29
30
31
E(MeV)
THEORETICAL CROSS SECTION
TOTAL CROSS SECTION (BOLBIKIN)
F^19(γ,xn) CROSS SECTION

Fig.1.

MAGNETIC SCATTERING OF NEUTRONS IN $MnPt_3$

D.Bally, Z.Gheorghiu, M.Toţia

S.J.Pickart*

The temperature dependence of the small-angle magnetic scattering of neutrons in $MnPt_3$ (ordered phase) in a large domain of wave-vector values was investigated. The scattered neutrons were detected by BF_3 counters. The experimental data were corrected both for angular resolution and for inelasticity. The sample was introduced in a 4 kOe magnetic field parallel to the scattering plane. The experimental data show that for $T \leqslant T_c$ and $\varkappa \leqslant 0.08$ A^{-1} the scattering is mainly determined by the interaction of the neutrons with the collective modes. Significant scattering due to the spin waves observed up to sufficiently large $\varkappa$ values is in a good agreement with the recent results of the magnetic structure studies on $MnPt_3$ (to be published). An anomalous behaviour of the magnetic diffuse scattering was noticed near T_c. This result is strongly correlated with the temperature dependence of the individual scattering properties of the atoms in the magnetic lattice in the neighbourhood of the Curie point.

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THERMAL NEUTRON SCATTERING IN LIQUID BISMUTH

D.Bally, D.Gelberg, V.Tarină

Thermal neutron elastic scattering experiments on molten Bismuth have been carried out. The structure factor of the liquid was measured in a range of the wave-vector transfer value within 0.5 - 9.5 $Å^{-1}$. The measurements were made using neutrons of wavelength 1.15 Å and BF_3 counters. The resolution of the used dif - fractometer was about 2%. The sample was kept at a temperature of 300^{o}C. The radial distribution function was obtained and interpreted on the basis of existing theories.

ABSOLUTE DETERMINATION OF ^{235}U FISSION CROSS-SECTION FOR 2200 m/s NEUTRONS

C.Borcea, A.Borza, A.Buţă, F.Cîrstoiu, L.Marinescu, I.Mihai
I.M.Mihăilescu, M.Petraşcu, V.Savu, V.Simion, T.Năşcuţiu

An absolute ^{235}U fission cross-section measurement was performed applying a method elaborated in our institute [1,2]. In this method is avoided the knowledge of an intermediate cross - section for the neutron determination.

For the absolute cross-section measurement the determination of the following quantities is necessary : the neutron flux, the detection efficiency of fission events and the density of nuclei in the target.

The neutron flux was determined by using a thick ^{10}B target, the neutron being detected through the 477.4 keV gamma rays of ^7Li counted with a NaI spectrometer. The gamma ray detection efficiency was determined in the following way : at the same place where the boron target would be placed a gold foil of the same area and shape was irradiated with neutrons. After irradiation, the gold 412 keV line was recorded in the same geometry as the 477.4 keV line. Subsequently the activity of the irradiated gold foil was measured absolutely with a $4\pi\beta-\gamma$ counter.

The efficiency of fission fragments detection was determined using two ^{235}U targets (a thick and a thin one) in two ionization chambers, counting the number of events corresponding to the thick and thin targets, and knowing the ratio between the target densities, and the efficiency of one ionization chamber (100% for the thin target).

The density of ^{235}U nuclei in the targets was determined from alpha activity, measured in a 2π geometry, using a gas flow proportional counter. The isotopic composition was determined with a mass-spectrometer. An accuracy of 0.52% concerning ^{234}U was obtained.

The measurements were carried out at an horizontal channel of the VVR-S reactor in Bucharest, the 2200 m/sec. neutrons being selected by the time of flight technique. The determined value for fission cross-section is 581.7 $\pm$ 7.8 barns.

This work was performed under a research contract supported by CSEN - Bucharest.

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FAST NEUTRON CROSS-SECTION OF ^{24m}Na

D.Ploştinaru, E.A.Ivanov, A.Iordăchescu, S.Vajda,
Gh.Pascovici

In the literature there was given the cross-section of ^{24m}Na, excited by $^{23}Na(n,\gamma)$ reaction, only for thermal neutrons [1,2]. We have measured this isomeric cross-section at several neutron energy between 1 MeV and 4 MeV. The pulsed beam technique we have used. A ^{7}Li target has been irradiated with proton beam (width lo ms, repetition time 1 s) and so obtaining bursts of fast neutrons. In the pauses between the bursts it were recorded spectra at some different time intervals, the spectra containing the 4472 keV γ-ray from decay of ^{24m}Na.

Two methods of bombarding and recording have used :1)with an external probe and with Ge(Li) and NaI(Tl) detectors, the last shielded for the direct neutron flux, 2) internal irradiation, when the NaI(Tl) detector crystal was also as target. The final results was obtained by the second method, which has a higher efficacity than the first one. In this case an absorber was used against the 472 keV γ-ray from the decay of ^{7}Be, excited by ^{7}Li (p,n) reaction.

The experimental results obtained at three different fast neutron energies are the following : σ_m = o.1 ± o.o4 ; o.1 ± o.o4 and o.12 ± o.o4 mb. at the neutron energies of o.92; 2.28 and 3.95 MeV, respectively. The great errors are due to the correction imposed by the experiment, the principal correction being from the background which is produced by the difused neutrons, and from the imprecisely known of the detector efficacity for an internal source uniformly distributed in the crystal. The experimental errors can be decreased by rearanging the cyclotron experiments room, increasing the detector - difusing pieces, distance.

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CALCULATION OF ELASTIC AND INELASTIC CROSS SECTION ON ^{60}Ni AND ^{32}S

A.Berinde, M.Duma, R.O.Dumitru, N.Scîntei,C.M.Simionescu, G.Vlăducă*, V.Zoran

Differential cross sections for elastic and inelastic ($Q = - 1.33$ MeV) scattering on ^{60}Ni for $E_n = 2,3,4,5,6.44, 7.54$ and 8.56 MeV were calculated with optical model, Hauser-Feshbach statistical and DWBA method. Comparison are made to the experimental data of ref. [1]. Some details of calculations and model parameters were previously presented [2]. Good fits were obtained to the experimental angular distributions ($Q = 0$, and $Q = - 1.33$ MeV) at E_n = 6.44, 7.54 and 8.56 MeV.

The excitation functions for the integrated elastic and inelastic scattering cross sections are compared with the available experimental data in fig.1. The quality of the fit give some confidence for the predicted cross sections at lower energies, where the experimental data are lacking.

Similar results were obtained for ^{32}S at E_n = 2.45, 2.85 , 4.o, 4.48 and 4.9 MeV.

This work is pertinent to request 373 of RENDA [3].

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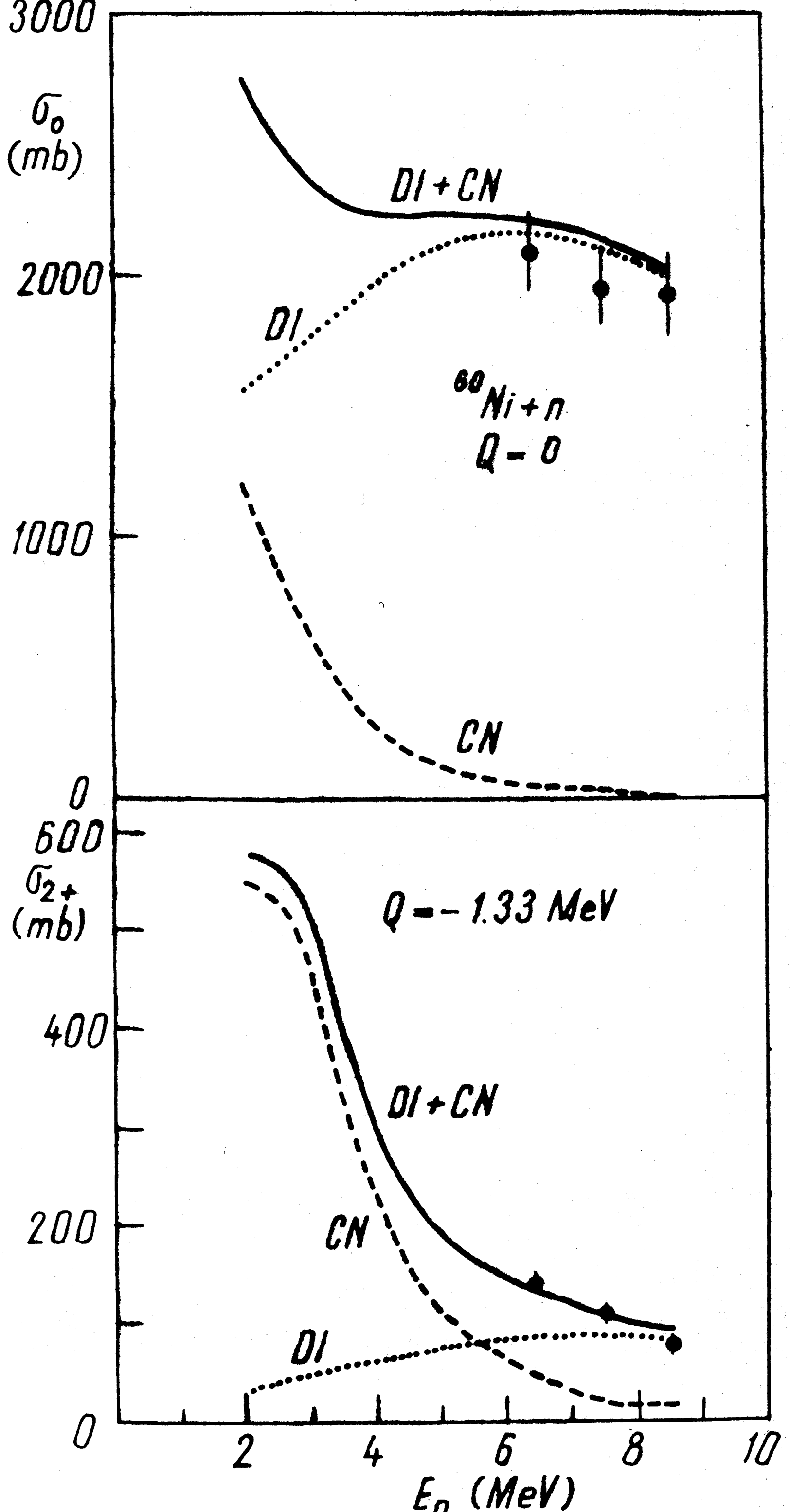

Fig.1. The theoretical integrated cross sections (full line) represent the sum of the direct interaction (dotted curves) computed by using the optical model (elastic) and DWBA (inelastic) and the compound nucleus contribution, computed with the Hauser-Feshbach theory (dashed curves).

OPTICAL MODEL CALCULATIONS FOR SCATTERING OF FAST NEUTRONS (8-15 MeV) BY Cr AND Fe

D.Bucurescu, M.Ivaşcu, D.Popescu, G.Semenescu, M.Titirici

Optical model calculations for neutrons of 8 to 15 MeV, with 1 MeV step were performed for the Cr and Fe nuclei, using both the average parameters of Wilmore and Hodgson [1], and those of Rosen et al [2]. The calculated angular distributions were compared to the existing experimental ones, at 8 MeV [3] and at 14 MeV (see [1]). Small differences between the two theoretical predictions are found at forward angles, while at backward angles the fit given by the potential of Rosen et al. (which containes also the spin -orbit interaction) is much better (fig.1). Thus, it appears that these optical model parameters should be preferred for calculations in this energy range, at least for medium weight nuclei.

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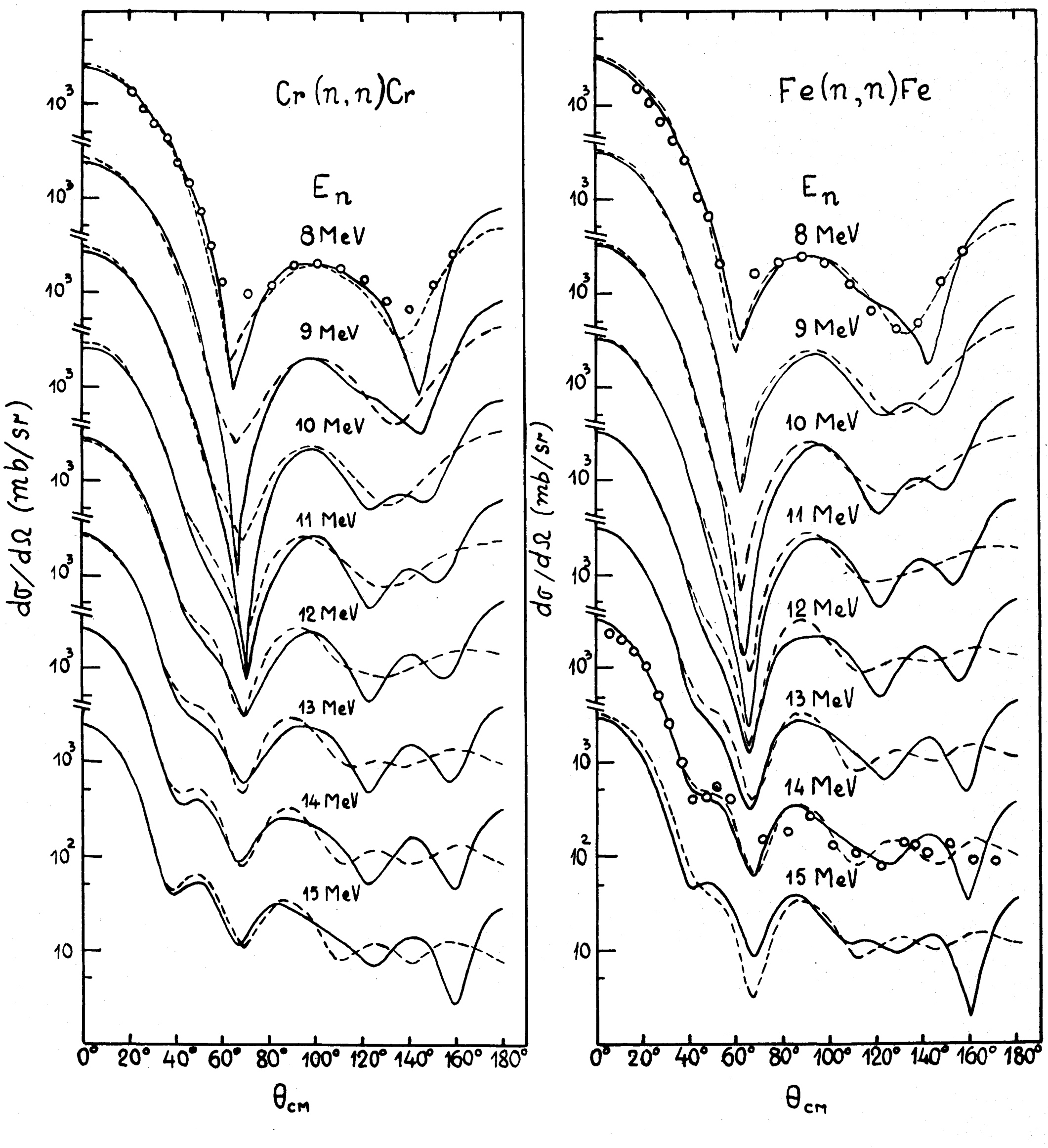

Figure 1. Optical model calculations. The full lines and the dashed lines represent the predictions of Wilmore - Hogson [1] and Rosen et al [2] potential, respectively. Experimental data are shown by circles.