International Atomic Energy Agency

INDC(NDS)-215/LJ

INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

# NUCLEAR DATA FOR STRUCTURAL MATERIALS OF FISSION AND FUSION REACTORS

Summary of the Second Research Coordination Meeting on Methods for the Calculation of Fast Neutron Data for Structural Materials held in Vienna, 15-17 February 1988

Edited by V. Goulo
Nuclear Data Section
International Atomic Energy Agency

June 1989

IAEA NUCLEAR DATA SECTION, WAGRAMERSTRASSE 5, A-1400 VIENNA

INDC(NDS)-215/LJ

# NUCLEAR DATA FOR STRUCTURAL MATERIALS OF FISSION AND FUSION REACTORS

Summary of the Second Research Coordination Meeting on Methods for the Calculation of Fast Neutron Data for Structural Materials held in Vienna, 15-17 February 1988

Edited by V. Goulo
Nuclear Data Section
International Atomic Energy Agency

June 1989

Reproduced by the IAEA in Austria
June 1989

89-02561

## Contents

Programme of the Research Coordination Meeting (RCM)
on Methods for the Calculation of Fast Neutron Nuclear Data
for Structural Materials

## Organization

The second RCM of the IAEA Coordination Research Programme on Methods for the Calculation of Fast Neutron Data for Structural Materials of Fission and Fusion Reactors was convened by the IAEA Nuclear Data Section at the IAEA Headquarters in Vienna 15 - 17 February 1988. It was attended by 24 participants (15 members of the CRP).

## Objectives

The main objectives of the meeting were to review the status of nuclear reaction theory, to assess the reliability of calculational methods, recommend those suited for use in calculation of neutron nuclear data for structural materials of fission and fusion reactors, to discuss the status of activities of CRP participants and plans for future year.

## Next Meeting

The next RCM in the frame of the CRP was planned to be convened in the beginning of 1990.

## Publication

Papers presented at the meeting have been published as INDC - report series:

INDC(NDS)-214, INDC(ROM)-20, INDC(IND)-41,
INDC(CPR)-14, INDC(CSR)-15, INDC(BZL)-030.

## Working Group I

## OPTICAL MODEL DEVELOPMENT

Chairman, H. Hodgson
Secretary, H. Gruppelaar

### I. General Comments

During the last year it has become increasingly clear that the dispersion relations connecting the real and imaginary parts of the optical potential remove many of the anomalies that arise when the spherical optical model is used to analyse accurate neutron data (Hodgson, 1987). In several cases it is found that the experimental data can be described more accurately and with fewer parameters by using the dispersion relations. This is a strong indication that it is a more physical description, and this, in turn, implies that they provide a more reliable basis for extrapolation to other nuclei and energies. Some more examples are discussed in detail below.

During the discussion several questions were raised, and these are summarised below.

#### 1. The overall consistency of the optical model description

It has been found possible to fit neutron scattering data by global potentials adjusted to fit the data in particular energy regions, but they cannot be extrapolated to other energies. Two examples of this were discussed:

a) The global neutron potentials all over-estimate the neutron total cross-section in the region of the minimum around 1 MeV (Konshin, 1987). It has now been shown that a consistent dispersion-relation analysis gives lower values of the total cross section in agreement with the experimental data (Smith, 1988; Su Zongdi and Hodgson, 1988).

b) Several analyses by Smith have shown that the values of the depth of the real potential, when extrapolated to negative energies, do not agree well with the experimental bound-state energies. The reason for this is that the scattering data do not contain sufficient information to allow such an extrapolation. It is more satisfactory to make a global analysis, including from the beginning both the bound-state and the scattering data, and then it is possible to obtain overall consistency.

c) Smith pointed to the discontinuity of the real part of the optical potential around 16-18 MeV above the Fermi energy. This refers to potentials with energy-independent radii. However, now from the standpoint of the dispersion relations, we now can see that they give a surface-peaked contribution to the real potential at the lower energies. This has the effect of increasing the radius of the real potential; nevertheless, if we analyse the data with an energy-independent radius, the effect of the surface-peaked addition is to increase the strength of the potential at lower energies, giving the observed discontinuity. Thus, it is possible to analyse the data in a consistent way using dispersion relations, and when this is done, the discontinuity disappears.

## 2. The effect of deformation on the spherical optical-model parameters

If the differential cross sections corresponding to scattering from deformed nuclei are analysed by the spherical optical model, it is found that the parameters sometimes show an apparently unphysical behaviour. For example, a negative value of $dJ_w/dE$ has been found in some analysis. Such behaviour is due to the parameters of the spherical optical model adjusting themselves to mock up the effects of deformation. It is more physical to make the analysis with the coupled-channels theory that includes the effects of deformation in a physical way, and then the parameters do not have an unphysical behaviour. This has been verified by Lawson (1987) by a model calculation in which he generated cross sections by a coupled-channel calculation, and then used them as "data" to be fitted by a spherical optical model. This gave the anomalous behaviour for the parameters that has been found by analyses of elastic scattering from deformed nuclei.

## 3. Effects of fluctuations in the cross sections

The data at low energies show strong fluctuations with incident energy due to the individual states in the compound nucleus. These can be smoothed by averaging over a range of energies, but when this is done over an energy region large enough to reduce the fluctuations to a level sufficient to allow comparisons with optical-model calculations, it is found that the physics of the interaction changes over the energy range, for example, by the opening of additional reaction channels. There is, unfortunately, not much that can be done about this situation. Physical systems involving either rather few or very many particles can be treated by microscopic or statistical methods, respectively, but the intermediate systems are rather intractable.

## 4. Anomalous elastic scattering of 8 MeV neutrons from $^{59}Co$ and $^{58}Ni$

Smith has found that the ratio of the elastic-scattering differential cross section for 8 MeV neutrons on $^{59}Co$ and $^{58}Ni$ has a broad peak of magnitude around two, in contrast to the values near unity that are given by both the optical and the coupled-channels calculations. It has been suggested by Hodgson (1988) that this effect is due to multistep compound-elastic emission. If the effect is attributable to differences in nuclear structure between the two nuclei, it may be connected with the Rosenzweig effect, as suggest by Dr. Blann.

## 5. The form factor of the imaginary potential at low energy

It has been noticed that many analyses with parameter optimization give very small values of the diffuseness parameter of the surface-peaked imaginary potential at low energies. It is indeed rather similar to a delta function. It is difficult to understand the reason for this, particularly because at these low energies the neutron wave length is much larger than the width of the potential. Possibly the effect is due to a physical property that is not properly included in the model. A potential of this form is needed to account for the low values of the total cross-section (see remarks in Section 1, above).

## 6. The desirability of complete analyses

It was pointed out once again that it was highly desirable that theoretical analyses be made of the cross sections in all channels

contributing to a particular reaction and over a fairly wide energy range. This imposes important consistency conditions and provides a much more stringent test of nuclear models. All too frequently, analyses are made of the cross section in just one channel, and this is much less informative than a comprehensive analysis.

## 7. The usefulness of proton analyses

There are many similarities between the interaction of neutrons and protons with nuclei, and, in addition, the proton data are often available with higher accuracy. It is therefore helpful to bear in mind the usefulness of analysing proton data as well as neutron data, if possible, in a consistent way. There is a difference between proton and neutron optical potentials proportional to the asymmetry parameter (N-Z)/A, and for each particular nucleus, this is the isospin potential. A systematic analysis of data for one nucleus over a range of energy therefore requires a knowledge of the energy dependence of the isospin potential. It should be noted that potentials fitted at one energy for a range of nuclei also show a dependence on the asymmetry parameter, but this has a geometric component that depends on the parameterization of the form factor, and so cannot be identified with the isospin potential.

## 8. Anomaly in the imaginary potential

Smith presented the results of analyses that gave large imaginary potentials with a broad maximum as a function of A, centered around A~105. This was parameterized by a cosine function. It was suggested that these high values of the imaginary potential are unphysical artifacts that arise when the radius of the real potential is too small. The maximum is then a size effect that occurs in nuclei that have a node in the nuclear wave function at or near the nuclear surface.

## 9. Anomaly in the total cross section for bismuth

Smith reported a small but significant dip in the total cross section for $^{209}$Bi around 3-4 MeV. A similar effect is found in $^{207}$Pb. No explanation of these observations is yet available.

## 10. Use of alternative nuclei

There are some cases where measurements are needed on nuclei that are extremely expensive to prepare in the form of isotopic targets, such as isotopes of Ru and Pd. Ignatyuk suggested that, in such cases, it might be possible to find nuclei of very similar structure that are much easier to obtain. Experiments could then be made on such nuclei, the results analysed, and then similar calculations made with same confidence for the expensive nuclei.

## 11. Multi-channel coupling method

Ignatyuk (this conference) has applied the multi-channel coupling method, using a very high number of couplings, to explain s- and p-wave strength functions. Failure of the model for p-wave strength functions is ascribed to difficulties in the analyses of the experimental resonance data (mixing of d-wave resonances). The remaining imaginary strength is very small (W ~ 0.2 to 0.4 MeV).

12. Experimental total neutron cross sections

It was pointed out that $\sigma_t$ measurements at low energies for isotopic samples are sometimes difficult because of self-shielding effects or because of the difficulty to prepare (metallic) homogenous samples.

13. Inelastic scattering to low-lying vibrational states in Ru and Pd isotopes

Gruppelaar (this conference) has shown that quite high inelastic scattering cross sections are possible for the excitation of the low-lying states of the even mass isotopes of Ru and Pd. This is partly due to relatively high direct components at quite low energies. Further experimental verification is necessary. The theoretical interpretation is of considerable interest because it includes the calculation of the width-fluctuation correction factor in the presence of direct reactions. This could be performed with ANL-ECIS code.

14. Dependence of the transmission coefficients for α-particle emission on nuclear temperature

Pashchenko (this conference) presented evidence showing that the calculated α-particle emission probability is lower than the data, particularly at smaller outgoing energies. He found that the data can be fitted by altering the α-particle emission probabilities by increasing the diffuseness of the real potential by 20-25%. This indicates that the α-particle optical potential may depend on the nuclear temperature, and Blann mentioned some calculations of this effect. Another possibility is that the effect is due to the modification of the α-particle potential in the region of the coulomb barrier that has already been found. This modification is automatically given by the dispersion relations, and it is suggested that it would be interesting to investigate the possibility in detail.

## II. Recommendations

### A. Experimental Measurements

1. Neutron elastic scattering at 14 MeV for A = 50-60, 90-100 and ~ 208 from ~ 10-20 MeV for selected nuclei.

2. Neutron total cross sections from 20 to 200 MeV for the same nuclei. This could be conveniently done with a white-source facility such as that at Los Alamos.

3. Double differential cross sections for inelastic scattering at 18, 22, 26, and 30 MeV on selected targets such as $^{27}Al$, $^{59}Co$, $^{93}Nb$, $^{124}Sn$, Ho, Au and Bi.

4. Further measurements are needed to check the neutron inelastic- scattering cross sections of Ru and Pd at low energies.

### B. Analyses

1. Global analyses of neutron data to test the usefulness of the dispersion relations.

2. Reinterpretation of data combining coupled-channels analyses for the more strongly coupled states with dispersion relations for the remaining states.

3. Further investigation of inelastic scattering to low-lying states in the presence of direct reactions.

C. Codes

1. Include the dispersion relation in spherical optical-model codes.

2. Develop coupled-channels code with complete H-F contributions (including continuum emission) and with calculation of width- fluctuation factors in the presence of direct reactions (using Moldauer's method or the HTWR method for fluctuation corrections).

3. Use fast coupled-channels codes for optical-model parameter searches. A new development is HETEROCLITE (Lagrange), a CRAY version of JUPITOR.

## References

P.E. HODGSON. Oxford Report 78/87. Paper presented at the IAEA Advisory Group Meeting on Nuclear Theory for Fast Neutron Nuclear Data Evaluation, Beijing (1987).

V.A. KONSHIN. Paper presented at the IAEA Advisory Group Meeting on Nuclear Theory for Fast Neutron Nuclear Data Evaluation, Beijing (1987).

A.B. SMITH. This conference and private communication (1988).

SU ZONGDI and P.E. HODGSON. Unpublished work 1988.

R.D. LAWSON, et al. Argonne National Laboratory Reports, ANL/NDM-100 and -102 (1987).

P.E. HODGSON. This conference (1988).

## Working Group II

## LEVEL DENSITY MODELS AND PARAMETERIZATION

Chairman, G. Reffo

Large attention was paid to the problems of level density in all sessions of the present meeting and it was stressed on the impact of the adopted level density on cross section determination whatever the reaction model adopted.

Both total level density and quasi-particle level density are involved in typical calculations for fast neutron induced reactions.

### 1. Total level density

The model most widely used is the Fermi-gas approach to which different corrections are added to account for the residual pairing interaction.

For the version Gilbert-Cameron (which is the most widely used) parameters systematics are available through the whole periodical table. Ignatyuk pointed out that the latter approach may become a poor one above the neutron resonance region. This is mainly because it does not account for shell model irregularities, for the pair correlation effects and for coherent effects typical of the collective nature of certain nuclides. In particular, commonly used level density parameters do not include any excitation energy dependence. The deficiencies mentioned prevent the safe use of commonly adopted parameterizations of the stability valley (as it is needed in nuclear astrophysics) or at higher excitation energies (as is needed in a number of applied and basic science problems like space science or calorimetry).

In the context of his presentation Ignatyuk presented overall systematics for the asymptotic value $\tilde{a}$ of the level density parameter expressed in terms of an expansion in mass number A including surface effects. In his approach Ignatyuk allows for an energy dependence of $\tilde{a}$. Ramamurthy pointed out that not only surface effects but also size effects are lumped into the mass dependence of $\tilde{a}$, consequently he suggested more detailed microscopic shell model calculations to investigate this point.

A most interesting feature of Ignatuk's treatment is given by the possibility of including enhancement factors for the treatment of collective rotational and vibrational effects.

It was also suggested that the overall pairing correction $\Delta_o=12/\sqrt{A}$ proposed by Ignatyuk may be to a simple and therefore responsible for part of the large fluctuations of $\tilde{a}$ value systematics. A recommendation was made that Ignatyuk's approach should be used by all laboratories involved in the present CRP, eventually with accomplishment of the recommendations from the experts participating in this meeting.

The point of including isospin dependence in level density was also discussed. The conclusion was that this has to be considered a lower priority refinement which should be dropped for the purpose of our CRP because of theoretical complexities as well as lack of reference experimental information.

The discussion then was focused on the choice of what type of experimental information is best suited for the purpose of level density parameterization.

At lower excitation energies use of discrete level and neutron resonance schemes are most appropriate.

At higher excitation energies doubts were expressed on the use of whatever reaction data. In fact the relation between level density and cross sections is complicated by concomitance of different reaction mechanisms, with the respective inherent approximations, which may result in significant amplification of the uncertainty to be given to the parameters so deduced. Thanks to a very good assessment of compound nucleus reaction mechanism, most favourable cases would be those where this mechanism dominates. This happens, however, in an excitation energy range not much higher than neutron resonances, which does not enlarge too much the basis of our input experimental information.

## 2. Particle-Hole and Quasi-Particle Level Density

Different approaches are used to describe the density of exciton states involved both in emission channels from pre-equilibrium configurations and in the calculations of the density of accessible states in the intra nuclear transition rates.

Namely, either Ericson-type approaches are used or shell model calculations. The latter consist namely of two different treatments. Either combinatorial calculations are used to generate all possible configurations compatible with a given excitation energy (Reffo method which also includes BCS treatment of pairing correlations) on the partition function method (Carlson method, or Williams recursion relation method).

From detailed comparison of microscopic calculations by Reffo with Ericson-type calculations, one can realize the difficulty of reconciling Ericson-type p-h calculations with more realistic quasi-particle state densities.

This namely comes both from the impossibility of including shell structure fluctuations (in what is a typical smooth statistical treatment based on equipacing assumption) and from the difficulty of introducing appropriate effective excitation energies by use of exciton dependent pairing corrections from BCS theory.

It was clearly shown that there is no hope for a systematic treatment of shell and pairing gaps.

The inconsistencies between realistic and Ericson-type calculations tend to disappear either for higher exciton configurations, or for higher deformations, or at higher excitation energies.

The treatment suggested by Reffo allows for an easy distinction between conditional and unconditional quasi-particle state density as needed in MSC and in MSD reaction mechanisms respectively.

We may state on a complete assessment of the treatment of spin distribution to be used.

Also parity distribution is an easy result of combinatorial calculations, but does not pretend for any systematic treatment.

According to the presentation of Reffo, two component treatment of pre-equilibrium reactions should be investigated in order to account for the different neutron and proton configurations involved as well as for the

different nuclear structure properties of n and p gases. In this context it was also pointed out the necessity of distinguishing between single particle state for particles and for holes.

A new theoretical approach has been presented by Carlson with a consistent quantum mechanical treatment of the transition rates under the constraint of angular momentum conservation only in the determination of the transition matrix elements.

A unanimous consensus was reached about the necessity of using more realistic microscopic quasi-particle level densities.

There is now a relatively good understanding of the physics to be implemented in order to account for the relevant nuclear structure properties in level density. But still some theoretical doubts and controversies remains which suggested the idea of proposing a 3 week workshop limited to a few experts (3-4) with a task very clearly addressed to the end of this CRP. That is to assess both total and quasi-particle level density treatments from the application view point in the context of the present CRP needs. This would consist in particular of arriving at indicating a methodology, including parameter systematics, and to make available computer routines.

Merging the experience gained both at Obninsk and at Bologna this is envisaged as possible within the indicated length of time and could be organized prior to the next CRP meeting, so to make the results available sufficiently in advance.

## Working Group III

## PRE-EQUILIBRIUM AND DIRECT PROCESSES

Chairman, E. Arthur
Secretary, M. Blann

### I. General Comments

The formal presentations and the associated discussion lead to the following general conclusions.

#### 1. Regions of suitability

We have satisafactory models and codes for calculating (n;x,n) and (n;p,x,n) spectra, pre-compound plus compound, for nuclei away from shell closures. These now include closed form exciton/hybrid + Weisskopf models and "unified" spin-dependent exciton/hybrid + Hauser-Feshbach approaches. The methods give similar results and satisfactory agreement with evaluated data sets where tested in the structural-materials area.

#### 2. Problem ares, particularly shell closures

We have seen that these models are deficient in the area around closed-shell nuclei and at the highest-energy end of the pre-emission spectra where coherent collective excitations are involved. Seeliger has suggested a quite tractable model for treating these low-lying collective excitations. He will compare his model predictions with data from many nuclei, and he will also make comparisons with predictions of more sophisticated model approaches, principally coupled-channels results such as those obtained by Ignatyuk. Specific test comparisons will be made for collective states in $^{93}$Nb and $^{208}$Pb. For these two nuclei, theoretical treatments will be compared with one another and with available experimental data. Around closed-shell nuclei the problems are of a different nature, as shown by the experimental results on the zirconium isotopes due to Scobel and Blann. Blann and Reffo will continue attempts to interpret these data using pre-equilibrium models with state densities calculated with realistic single-particle models. In particular, Blann will next try using the single-particle levels of Möller and Nix, and will try several changes in the single-particle densities in the emission channel. Regarding future state-density calculations involving realistic single-particle levels, it is specifically recommended that the Möller-Nix formulation be used since it is presumably the most realistic single-particle set that now exists. Such pre-equilibrium calculations will be made for nuclei showing collective effects so as to better separate single-particle and collective contributions in such cases.

A second area of discussion concerning more realistic calculations of state densities occurred during the presentation of Reffo. His emphasis was on the microscopic calculation of such state densities in the context of a two-component exciton model where neutron and proton p-h configurations are treated explicitly. Examples were presented where strong deviations occurred with respect to the Williams state density, principally because of energy-gap effects. Similar phenomena also occur in microscopic calculations of the total state densities for nuclei such as $^{27}$Al. In effect, pre-equilibrium contributions for higher emission energies are eliminated in such cases because of the energy gap.

## 3. Angular Distributions

We did not reach a complete consesus on this topic, but we are in agreement on how to proceed. We agree that the systematics of Kalbach are at a useful stage and may be used satisfactorily for evaluation purposes. We should determine the applicability of the new Kalbach systematics at neutron energies $\leq$ 20-25 MeV.

We feel that extrapolation is safer when using a model based on physics rather than systematics; however, this is only true if the model or theory has the correct physics. First, there is the question of the applicability of the Goldberg/Hayakawa-Kikuchi approach with changes for finite size effects. To help test the extrapolability of this apporach, Gruppelaar will calculate angular distributions for $^{90}Zr$ and $^{208}Pb(p,n)$ reactions at incident energies of 25, 35, 45, 80, and 160 MeV. He will send the results to Blann who will compare them with new experimental data obtained at Indiana University and with the Kalbach systematics. This comparison may help answer the question of the extrapolability of this approach.

We are in agreement that the best future hope of a physical solution to this modeling problem lies in quantum-mechanical approaches, such as those of Tamura or of Geshbach-Kerman-Koonin. The latter seems to receive the greater attention. We encourage the further development of these approaches; perhaps several meetings between the active parties would be fruitful. There are questions to be answered on the calculation of overlap integrals, form factors for the residual interaction ($V_0$), values of the parameter, and its relationship to the two quasi-particle state density used in the application. In particular, the presentation of Marcinkowski, describing more realistic calculations of bound-particle state densities in the MSC theory, illustrated several problems. There the improved treatment of state densities worsened the agreement with experimental data, particularly for $^{92}Mo$ neutron emission. Also there were uncertainties pertaining to the overall normalization of such calculations. Thus, this approach is surely not predictive at the present stage, but we should encourage further work to see if we can make it predictive and tractable for use by evaluators.

In the interim, the "unified" reaction-model approach appears to offer a practical method for implementation of more quantum-mechanical models into codes used for data evaluation. In particular, recent developments reported by Fu, Ackermans, and Zhang (see INDC(NDS)-193/L and upcoming proceedings of the Specialists' Meeting on Pre-equilibrium Reactions, Semmering) indicate impressive accomplishments both in model development and in agreement with experimental data using few adjustable parameters. Because of their success thus far, and because of their apparent practicality for use in nuclear-data evaluation, more effort should be applied to enhance the quantum-mechanical underpinnings of these approaches.

## 4. Cluster emission

This remains one of the open and difficult questions for nuclear modeling. There exists no tractable approach which is predictive in nature and proven against a broad data base. We can predict the evaporation component adequately, and, fortunately, this is the dominant mode for $\alpha$ production in lighter structural materials. More work needs to be done on pre-equilibrium cluster emission. Dr. Shibata has discussed one promising approach and Dr. Zhang another. We would like to see these methods applied, for example, to $(n,\alpha)$ and $(p,\alpha)$ reactions on heavier materials where the pre-equilibrium component is more clearly isolated from the evaporation component. Also in regions where there are significant compound-nucleus

contributions to (n;x,α) spectra, special care must be taken in the determination of α-particle transmission coefficients. In such instances $\sigma_r$ data available for α-particles (such as the new Vonach data) should be used in the independent verification of the optical-model parameters.

5. Requisite data base

The recent "blind" code comparison for $^{184}W$(n;x,n) at 26 MeV incident energy has revealed deficiencies in our codes. To gain a higher degree of confidence for both single and double differential cross sections, we need data sets for selected targets (e.g., $^{27}Al$, $^{59}Co$, $^{93}Nb$, $^{124}Sn$, Ho, Au, and $^{208}Pb$) at incident energies of 14, 18, 22, 26, and 30 MeV. Charged-particle data, including that due to cluster emission, would also be valuable. Other experimental measurements recommended include $^{93}Nb$(n,n') measurements possibly to be performed at Ohio University ($E_n \simeq$ 11, 14, 26 MeV) and detailed examination of the upper few MeV of the emission spectrum via experiments under way at Argonne.

## II. Recommendations

1. Capability for calculating low-lying collective excitations will be tested, particularly using $^{93}Nb$ and $^{208}Pb$.

2. Pre-equilibrium models with state densities calculated with realistic single-particle models will be explored in the context of the zirconium isotopes.

3. Future state-density calculations should employ realistic single- particle levels, particularly those of Möller-Nix.

4. The systematics of Kalbach are useful for evaluation of angular distributions.

5. Calculated angular distributions resulting from (p,n) reactions on $^{90}Zr$ and $^{208}Pb$ ($E_p \simeq$ 25, 35, 45, 80, and 160 MeV) will be compared with experiment and the systematics of Kalbach.

6. Further development of quantum-mechanical mthods for calculating angular distributions are encouraged. However, problems associated with overlap integrals, form factors, etc., must be solved before practical application to evaluation can occur. A selected group of researchers should address these problems.

7. In the interim, "unified" approaches, such as those of Fu, Gruppelaar, Zhang, etc., appear to offer a practical method for implementation of quantum-mechanical techniques in data evaluation.

8. More work needs to be done on pre-equilibrium cluster emission, particularly addressing (n,α) and (p,α) processes in heavy nuclei.

9. Quality single- and double-differential neutron-emission data are needed for selected targets over the incident energy range ~ 14-30 MeV in order to give confidence to the calculations.

10. Neutron emission involving direct excitation of levels to a few MeV in excitation energy should be carefully measured to provide a test of the associated calculations.

IAEA Second Research Coordination Meeting on
METHODS FOR THE CACLULATION OF FAST NEUTRON NUCLEAR DATA
FOR STRUCTURAL MATERIALS

IAEA Headquarters, Vienna, 15-17 February 1988

AGENDA

15 February

9:30 Opening session

- Opening Speech (V.A. Konshin, IAEA)
- Chairman election

10:00 SESSION 1. OPTICAL MODEL DEVELOPMENT

(Chairman: P. Hodgson; Secretary H. Gruppelaar)

1. H. Gruppelaar (ECN, Petten): An attempt to construct a regional potential for coupled-channel calculations of neutron scattering cross-sections of light fission products

2. S. Gmuca (INP, Bratislava): Microscopic neutron optical potential for several structural materials. Progress Report 1987.

11:00-11:20 Coffee break

3. A.B. Smith (ANL, Argonne): Optical-model calculations for experimental interpretation and evaluation: Practical considerations and fundamental implications

4. A.B. Smith (ANL, Argonne): Some fundamental aspects of the optical potential for the interaction of fast neutrons with cobalt

5. A.V. Ignatyuk (FEI, Obninsk): Use of the multi-channel coupling method for the neutron strength function description (presented orally, copy not available)

13:00-14:30 Lunch

14:30-15:45 Discussions: Working Group I

16:00 SESSION 2. LEVEL DENSITY MODELS AND PARAMETERIZATION
(Chairman, G. Reffo)

6. A.V. Ignatyuk (FEI, Obninsk): Consistent systematics of nuclear level densities for mean and heavy nuclei

7. B.V. Carlson (CTA, Sao José dos Campos): State, level, and transition strength densities

16:30-18:00 Discussions: Working Group II

19:00 Dinner at Restaurant La Creperie, Jasomirgottstr. 5

16 February

9:00 SESSION 3. PRE-EQUILIBRIUM AND DIRECT PROCESSES

(Chairman, E. Arthur; Secretary, M. Blann)

8. M. Blann (LLNL, Livermore): Effects of realistic partial state densities on pre-equilibrium decay

9. A. Marcinkowski (IPJ, Warsaw): The MSC calculations with use of empire

10. K. Shibata (JAERI, Tokyo): Analysis of (n,α) reaction by use of modified TNG code

10:30-11:00 Coffee break

11. D. Seeliger (TUD, Dresden): SMD- plus SMC-calculations below 30 MeV neutron incidence energy

12. D. Seeliger (TUD, Dresden): Measurement and analysis of continuous spectra from inelastic neutron scattering on 93-Niobium in the energy range from 7 to 14 MeV

13. M. Blann (LLNL, Livermore): Precompound gamma-ray emission

12:00-14:00 Lunch

14. G. Reffo (ENEA, Bologna): On the two gas approach for exciton model master equations

15. Zhang Jingshang (IAE, Beijing): The formulation of UNIFY code for the calculation of fast neutron data for structural materials

16:30-16:45 Coffee break

16:45-18:00 Discussions: Working Group III

17 February

9:00 SESSION 4. CALCULATIONS OF STRUCTURAL MATERIALS AND THEIR INTERCOMPARISON (FE, CR, NI, AL, PB, NB)

(Chairman, D. Seeliger; Secretary, S. Gmuca)

16. A. Pashchenko (FEI, Obninsk): Analysis of threshold reaction cross-sections and spectra of particles emitted in them on iron-group nuclei

17. E. Arthur (LANL, Los Alamos): Cross section calculations of neutron reactions on zinc isotopes for fusion applications

10:00-10:15 Coffee break

18. H. Jahn (KFZ, Karlsruhe): Angular distribution of secondary energy dependent inelastic neutron cross sections in structural materials investigated using Blann's geometry dependent hybrid model

19. S. Garg (BARC, Bombay): Binary and tertiary neutron induced reaction cross sections of chromium and iron

12:00-14:00 Lunch

14:00 Discussions: Working Group IV

15:30 Discussions for future programme, time and place of the final CRP; preparations for summary documents

WORKING GROUPS Proposals after corresponding sessions

Working Group I: Optical model development

Working Group II: Level density parameterization

Working Group III: Pre equilibrium and direct processes

IAEA Second Research Coordination Meeting on
METHODS FOR THE CACLULATION OF FAST NEUTRON NUCLEAR DATA
FOR STRUCTURAL MATERIALS

IAEA Headquarters, Vienna, 15-17 February 1988

LIST OF PARTICIPANTS


| | |
|---|---|
| E. Arthur | Los Alamos National Laboratory<br>P.O. Box 1663<br>Los Alamos, New Mexico 87545<br>U.S.A. |
| M. Blann | Lawrence Livermore National Laboratory<br>L-280<br>P.O. Box 808<br>Livermore, California 94550<br>U.S.A. |
| B.V. Carlson | Instituto de Estudos Avançados<br>Centro Técnico Aeroespacial<br>Rodovia dos Tamoios, Km. 5,5<br>Sao José dos Campos - SP<br>Brazil |
| P. Fu | Oak Ridge National Laboratory<br>P.O. Box X<br>Oak Ridge, Tennessee 37830<br>U.S.A. |
| S. Garg | Bhabha Atomic Research Centre<br>Experimental Reactor Physics Section<br>Trombay, Bombay 400 085<br>India |
| S. Gmuca | Electro-Physical Research Centre (EPRC)<br>Institute of Physics of the Slovak Academy of Sciences<br>Dubravska cesta 9<br>CS-842 28 Bratislava, Czechoslovakia |
| V. Goulo<br>(Scientific Secretary) | IAEA Nuclear Data Section<br>P.O. Box 100, Wagramertr. 5<br>A-1400 Vienna, Austria |
| H. Gruppelaar | Netherlands Energy Research Foundation (ECN)<br>Department of Physics<br>P.O.B. 1, 3 Westerduinweg<br>NL-1755 ZG Petten<br>The Netherlands |
| P. Hodgson | Nuclear Physics Laboratory<br>Nuclear Physics Department<br>University of Oxford<br>Keble Road<br>Oxford OX1 3RH, United Kingdom |

| | |
|---|---|
| A.V. Ignatyuk | Fiziko-Energeticheskij Institut<br>Ploschad Bondarenko<br>249 020 Obninsk, Kaluga Region<br>U.S.S.R. |
| H. Jahn | Institut für Neutronenphysik und Reaktortechnik<br>Kernforschungszentrum Karlsruhe<br>Postfach 3640<br>D-7500 Karlsruhe<br>Federal Republic of Germany |
| N.P. Kocherov | IAEA Nuclear Data Section<br>P.O. Box 100, Wagramerstr. 5<br>A-1400 Vienna, Austria |
| V.A. Konshin | Division of Physical and Chemical Sciences<br>International Atomic Energy Agency<br>P.O. Box 100, Wagramerstr. 5<br>A-1400 Vienna, Austria |
| H.D. Lemmel | IAEA Nuclear Data Section<br>P.O. Box 100, Wagramerstr. 5<br>A-1400 Vienna, Austria |
| A. Marcinkowski | Institute for Nuclear Studies (IPJ)<br>Department P-I<br>Ul. Hoza 69<br>PL-00681 Warsaw, Poland |
| K. Okamoto | IAEA Nuclear Data Section<br>P.O. Box 100, Wagramerstr. 5<br>A-1400 Vienna, Austria |
| V. Pashchenko | Fiziko-Energeticheskij Institut<br>Ploschad Bondarenko<br>249 020 Obninsk, Kaluga Region<br>U.S.S.R. |
| V.S. Ramamurthy | Bhabha Atomic Research Centre<br>Nuclear Physics Division<br>Trombay, Bombay 400 085, India |
| G. Reffo | E.N.E.A. - Centro Ricerche Energie "E. Clementel"<br>Div. Fis. e Calcolo Scientifico<br>Via Mazzini 2<br>I-40138 Bologna, Italy |
| D. Seeliger | Technische Universität Dresden<br>Sektion Physik<br>Mommsenstr. 13<br>DDR-8027 Dresden<br>German Democratic Republic |
| J.J. Schmidt | IAEA Nuclear Data Section<br>P.O. Box 100, Wagramerstr. 5<br>A-1400 Vienna, Austria |

K. Shibata — Japan Atomic Energy Research Institute (JAERI)
Tokai-mura, Naka-gun
Ibaraki-ken 319-11, Japan

A.B. Smith — Applied Physics Division-316
Bldg. 314
Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439
U.S.A.

Zhang Jingshang — Nuclear Data Center
Institute of Atomic Energy
P.O. Box 275 (41)
Beijing, China