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INDC INTERNATIONAL NUCLEAR DATA COMMITTEE

MEASUREMENT AND ANALYSIS OF DOUBLE-DIFFERENTIAL NEUTRON EMISSION SPECTRA IN (P,N) AND (α,N) REACTIONS

Summary Report
of the First Research Co-ordination Meeting
organized by the
International Atomic Energy Agency
and held in Vienna
23 - 27 June 1986

Prepared by

M.K. Mehta and K. Okamoto
Nuclear Data Section
International Atomic Energy Agency

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S u m m a r y

The First Research Co-ordination Meeting (RCM-I) of the participants in the IAEA Co-ordinated Research Programme (CRP) on Measurement and Analysis of Double-Differential Neutron Emission Spectra in (p,n) and (α,n) Reactions was convened by the IAEA Nuclear Data Section at the IAEA Headquarters in Vienna during 23-27 June 1986. The RCM was organised by the Scientific Secretary K. Okamoto and was run by the meeting Chairman M.K. Mehta.

Objectives

The main objectives of this Co-ordinated Research Programme are:

(i) to extract systematic information about nuclear level densities as function of excitation energy by analysisng the neutron emission spectra from (p,n) and (α,n) reactions on properly selected targets and bombarding energy range and

(ii) to parameterise this information into appropriate phenomenological models to enable reliable extrapolation for general use of level density information in basic and applied nuclear physics related problems.

The principal objectives of this first RCM were to report and discuss the work done at the participant laboratories related to the above objectives and to specify the detailed scope and programme of measurement and analysis to be carried out under this co-ordinated research programme.

The meeting agenda and the list of participants are shown as Appendix I and II, respectively.

The next (RCM-II) meeting is to be held after an interval of about 15 months.

1. Introduction

Information on nuclear level density - specifically nuclear level density parameter - 'a' - as a function of nuclear excitation energy (temperature) and as function of nuclear shape configuration is one of the most important inputs for the calculation of nuclear reaction cross sections. In various fields of nuclear technology, e.g. design of fission & fusion power reactors, radio-isotope production for biomedical applications etc, precise and detailed nuclear reaction data are needed which in many cases cannot be measured directly. Recourse is taken to theoretical predictions based on well established models/theories which evolved from basic nuclear physics research. Knowledge of nuclear level density for specific nuclides at specific excitations is fundamental to all such model calculations. Nuclear level densities also play a very significant role in basic nuclear structure physics. Thus a considerable effort, both theoretical and experimental, has been expanded in investigations specifically aimed at obtaining nuclear level density information.

The NDS, upon advice of the International Nuclear Data Committee (INDC), convened an Advisory Group Meeting on Basic and Applied Problems of Nuclear Level Densities at Brookhaven National Laboratory in 1983 to review the current situation and make recommendations for actions necessary to satisfy the requirements in nuclear technology applications. Two working groups discussed the theoretical and the experimental situation respectively at this meeting. It was realised that, although very good progress has been made in the fully microscopic fundamental approaches to the calculation of nuclear level densities, the results are not fully satisfactory yet. Especially from the point of view of practical applications in calculations of reaction cross sections, the microscopic theories fall short of desired accuracies in prediction and, in addition, routine cross section calculations for a large number of nuclides over a wide excitation energy range become too involved, when fully microscopic level density theory is used. On the other hand a number of simpler prescriptions to calculate nuclear level densities based on semi-microscopic phenomenological models have proven to be very promising. Such phenomenological models depend heavily on experimentally measured systematics to determine the dependence of the various semi-empirical parameters like level spins, shell corrections, pairing correction etc. on microscopic nuclear structure systematics.

Following advice of the INDC, the Co-ordinated Research Programme on Measurement and Analysis of Double-Differential Neutron Emission Spectra in (p,n) and (α,n) Reactions was started and the first Research Co-ordination Meeting was held at the IAEA Headquarters in Vienna during the week 23-27 June 1986.

Organization of the meeting

The Agenda of the meeting is listed in Appendix I. The programme consisted of (i) presentation of reports from individual participating laboratories, (ii) two status review papers and (iii) working group discussions. The two status review papers presented after the individual laboratory reports established the perspective which served as a background for the following working group discussions to specify the detailed scope of the CRP and delineate the programme for each participating laboratory.

Meeting attendance

Three research contracts and six research agreements have been awarded under this CRP, out of which seven chief scientific investigators and one alternate nominee participated at the meeting. One research agreement holder could not participate due to unavoidable local circumstances. The list of participants is given in Appendix II.

2. Meeting Programme

The programme of the meeting was arranged into five main sessions as follows:

I. Opening
Election of Chairman
Adoption of Agenda
Chairman's remarks

II. Presentation of proposed programmes by participating laboratories:

(1) S.M. Grimes -	Ohio University, Athens, USA
(2) W. Scobel -	Inst. of Experimentalphysik, Zyklotron, Hamburg, FRG
(3) Julio Cesar Suita -	IEN Rio de Janeiro, Brazil
(4) Tang Hongqing -	Institute of Atomic Energy, Beijing, P.R. China
(5) V.S. Ramamurthy -	B.A.R.C., Bombay, India
(6) D. Seeliger -	T.U.D. Dresden, GDR
(7) B.V. Zhuravlev -	Institute of Physics and Power Engineering, Obninsk, USSR
(8) H.K. Vonach -	I.R.K. Vienna, Austria

III. Status Review

1. Experimental determination of level density parameters - H.K. Vonach
2. Level Density Phenomenology - V.S. Ramamurthy

IV. Working Group Discussions

1. Specific scope of the programme
2. Distribution of work amongst the participating laboratories

V. Conclusions and recommendations

Daily Time Schedule	9-30 - 10-30 hrs
	11-00 - 12-30 "
	14-00 - 16-00 "
	16-30 - 17-30 "

3. Conclusions and Recommendations

After extensive discussions on the programmes presented by individual investigators the participants came to the following conclusions:

(1) The primary objectives of the CRP are (i) to extract systematic information about level densities as function of excitation energy by analysing the neutron emission spectra from (p,n) and (α,n) reactions on properly selected targets and bombarding energy range, (ii) parameterise this information into appropriate phenomenological models to enable reliable extrapolation for general use of level density information for basic and applied nuclear physics related problems. Validation of the phenomenological model by comparison with microscopic calculations may be undertaken in favourable cases.

(2) For the above objectives the target mass range to be covered should be around A = 60, 100, 208 respectively. The proposed programmes adequately covered these mass regions. However, the participants felt that inclusion of nuclides with large deformation in the ground state, and if possible considerable change in deformation from isotope to isotope of the same nuclide would be advisable. For this purpose targets of Samarium isotopes would be ideal, and efforts should be made to procure metallic Samarium targets for this purpose. Molybdenum could serve as an alternative in this respect. Tungsten and Holmium are other potential targets to study the effect of collective enhancement.

(3) The bombarding energy range is decided by corresponding thresholds for the first and second neutron emission as well as the bombarding energies at which a finite amount of non statistical component of the cross section is present. Determination of level densities from (n,n') experiments on a few nuclides will also be included. The participants agreed on three bombarding energy regions, namely 5-10 MeV, 11-15 MeV and 25 MeV.

(4) All data measured under this programme should be sent to Prof. H. Vonach (IRK) who would carry out the optimized analysis to extract the level density information. The data should be double-differential cross sections in mb/ster/MeV distributed in equal energy bins of 200-500 keV. Those participants who carry out their own analysis of

the data may report their results in the form of the parameters a, Δ etc. and should also provide $\rho(U)$ in the form of tables or graphs.

(5) The specific programmes for each participant laboratory would be as shown in Appendix III entitled "Summary of Programmes".

(6) The participants agreed to hold the second Research Co-ordination Meeting (RCM-II) of this CRP after an interval of about 15 months. They noted that the INDC has recommended that the RCMs for this CRP should be held adjacent to the RCMs for the CRP on Methods of Calculation of Neutron Nuclear Data for Structural Materials, as there is a large overlap of interest and expertise between the two CRPs. The second RCM of the latter CRP is planned to be held at the Institute of Atomic Energy, Beijing, in October 1987 in conjunction with the 16th INDC Meeting. It was decided that RCM-II for this CRP should be held at Beijing as suggested, subject to the convenience of and agreement by the Chinese authorities.*

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* In the meantime the meeting has been postponed to 1988.

Appendix - I

Co-ordinated Research Programme on
Measurement and Analysis of Double-Differential Neutron
Emission Spectra in (p,n) and (α,n) Reactions

First Research Co-ordination Meeting
Vienna, 23-27 June 1986

AGENDA

A. Opening, election of Chairman, adoption of Agenda

B. Presentation of proposed programmes by participating laboratories

C. Status reviews

D. Working Group discussions

E. Conclusions and Recommendations

Co-ordinated Research Programme on
Measurement and Analysis of Double-Differential Neutron
Emission Spectra in (p,n) and (α,n) Reactions

First Research Co-ordination Meeting
Vienna, 23-27 June 1986

LIST OF PARTICIPANTS

Name	Address	Remarks
(1) Steven M. Grimes	J. Edwards Accelerator Lab. Department of Physics Ohio University Athens, Ohio 45701, USA	
(2) Peter T. Guenther	Argonne National Laboratory 9700 South Cass Avenue Argonne, Illinois 60439 4822 USA	Could not attend
(3) Tang Hongqing	Neutron Physics Laboratory Institute of Atomic Energy P.O. Box 275 Beijing, P.R. China	
(4) V.S. Ramamurthy	Nuclear Physics Division Bhabha Atomic Research Centre Trombay, Bombay 400 085 India	
(5) W. Scobel	I. Inst. f. Experimentalphysik Zyklotron Universität Hamburg Luruper Chaussee 149 D-2000 Hamburg 50 Federal Rep. of Germany	
(6) D. Seeliger	Sektion Physik Technische Universität Dresden Mommsenstrasse 13 DDR-8027 Dresden German Democratic Republic	

Name	Address	Remarks
(7) Julio Cesar Suita	Physics Department Instituto de Engenharia Nuclear Commissao Nacional de Energia Nuclear - (CNEN/SP) C.P. 2186 Cidado Universitaria Ilha do Fundao 21910 Rio de Janeiro - RJ Brazil	Alternate to Da Silva
(8) H.K. Vonach	Institut für Radiumforschung und Kernphysik Boltzmanngasse 3 1090 Wien, Austria	
(9) B.V. Zhuravlev	Institute of Physics and Power Engineering 1 Bondarenko Sq. 249020 Obninsk, Kaluga Region USSR	

CRP on Measurement and Analysis of Neutron Emission Spectra from (p,n) & (a,n) Reactions

SUMMARY OF PROGRAMMES

Name	Research Agreement/Contract Number	Institution	Proposed Programme	Remarks
1. S. Grimes	4293/CF	Ohio University Athens, Ohio	(1) (p,n) on ^{51}V & ^{59}Co $5<E_p<9$ MeV (2) (α,n) on ^{48}Ti & ^{56}Fe $7<E_\alpha<13$ MeV for $0\leq\Theta\leq160°$	Intercomparison measurement with (p,n) on Mo isotopes (95,96) at 5-10 MeV to extend Hamburg work to lower energy. (α,n) on ^{92}Zr will be undertaken in the second year (1987).
2. W. Scobel	4295/CF	Univ. of Hamburg Hamburg	(p,n) on $^{92-100}Mo$ $12<E_p<15$ MeV and 2-5 MeV	Will make Mo foils available to other laboratories for intercomparison measurement. The foils are 12.5 x 12.5 mm and 4mg/cm^2 thick.
3. J.C. Suita	4351/RB	I.E.N. Rio de Janeiro	(α,n) on ^{56}Fe (p,n) on ^{59}Co at E_α = 9 and E_p = 8 MeV	Repeat and overlap with Athens work. Fe sample will be loaned by H. Vonach from Radium Inst. Vienna.
4. Tang Hongqing	4294/RB	Inst. of Atomic Energy Beijing	(1) (p,n) on Mo isotope for Mo-95 & 96 E_p = 11-15 MeV, E_p = 25 MeV (2) (p,n) on ^{59}Co $8<E_p<14$ MeV (3) (p,n) on ^{45}Sc "	Overlap & intercompare with Hamburg and Athens Overlap with Athens
5. D. Seeliger	4404/CF	TUD Dresden	Analysis of measured (p,n) data on ^{109}AG, ^{115}In, and (n,n') data. Check level density functions on ^{93}Nb for calculations of fission neutron spectra.	Intercompare In work with Obninsk. ^{93}Nb(n,n') intercompare with ANL. Will undertake Mo measurement for intercomparison and measurement of W next year.

6. B.V. Zhuravlev	4222/CF	Inst. of Physics and Power Engineering, Obninsk	Work completed (p,n) on ^{165}Ho, ^{181}Ta. ^{197}Au, ^{209}Bi at E_p = 11.2 MeV. Double diff. σ data will be sent to Vonach. New measurement to be undertaken on Pb-204,6,8...(p,n) at E_p = 11.2 MeV.	Extensive (p,n) and (α,n) work carried out on targets with 57<A<181 at E_p=5-10 MeV 11.2, 22.2 MeV and E_α = 26.8 MeV. Double differential cross section data will be made available in tabular form for systematic analysis.
7. P.T. Guenther	4412/CF	Argonne National Laboratory, Argonne	Neutron emission spectra from 5-10 MeV neutron bombardment of Co, Y and Nb have been measured. Analysis of these data will be carried out. Open for any new measurements suggested at the RCM.	Seeliger will correspond with Guenther with a view to intercompare analysis of (n,n') data and evolve prescription for calculating the non-equilibrium component of the cross section.
8. H.K. Vonach	4321/CF	Institut für Radiumforschung und Kernphysik, Vienna	Propose to analyse (p,n) and (α,n) emission spectral data under the CRP in a systematic and optimised way to extract level density parameters.	All data measured under the CRP as well as relevant data from literature to be made available in suitable form, in the form of mb/ster/MeV distributed into equal energy bins of 200-500 keV. Prof. Vonach will also make ^{56}Fe samples available for measurement.
9. V.S. Ramamurthy	4403/RB	B.A.R.C. Bombay	Share the analysis work with IRK. Will use the extracted level density information to determine systematically the relevant parameters of the phenomenological level density expressions. Will also plan appropriate experimental activity for which procurement of a Cf source for calibration purpose will be a first step. The source will be supplied under the research contract.	