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INTERNATIONAL NUCLEAR DATA COMMITTEE

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

Summary Report
of the Second Research Co-ordination Meeting
organised by the
International Atomic Energy Agency
and held in Vienna
8-10 February 1988

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

May 1988

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

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S U M M A R Y

The Second IAEA Research Co-ordination Meeting 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 8-10 February 1988. This RCM was organized by the Scientific Secretary K. Okamoto and was chaired by M.K. Mehta.

The main objectives of this CRP are:

- (i) to extract systematic information about nuclear 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, 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 First RCM had been held in June 1986, when the detailed programme was formulated and the specific tasks were distributed among the participants in order to achieve the above-mentioned objectives. This Second RCM after 21 months interval from the First one, was held to review the status of the implementation of this programme.

The Conclusions and Recommendations together with the Summary of the Programme for the period 1988/89 are attached as Appendices I and II, respectively.

The Meeting Agenda and the List of Participants are listed in Appendix III and IV, respectively.

It is proposed to hold the next RCM at Gaussig, German Democratic Republic, in conjunction with the Annual Nuclear Physics Conference organised by TUD-Dresden, in 1989.

Nikolai Kocherov, Nuclear Data Section, has taken over the responsibility as the project officer of this CRP from K. Okamoto with effect from 11 February 1988.

FULL REPORT

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.

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 with the following objectives:

- (i) to extract systematic information about nuclear 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, 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 first Research Co-ordination Meeting had been held at the IAEA Headquarters in Vienna during the week 23-27 June 1986. Unfortunately due to budgetary limitations, this Second RCM could not be held in October 1987 as originally planned. After 21 months interval from the First one, this Second RCM was held at the IAEA Headquarters.

Organization of the Meeting

The Agenda of the meeting is listed in Appendix I. The programme consisted of (i) presentation of reports by participants on the progress of their programmes, (ii) discussions on special problems encountered since the 1st RCM and (iii) further discussions on future activities in detail.

The participants agreed that M.K. Mehta should chair the meeting as he did at the first RCM to maintain continuity.

Meeting Attendance

Three research contracts and six research agreements are awarded within this CRP. Six chief scientific investigators and two alternate nominees participated in the meeting. In addition, a number of scientists working in the field who were present at headquarters were also invited to participate in the meeting. One research contract holder (A. Gerbasi da Silva) could not participate due to unavoidable engagements at home. The list of participants is given in Appendix II.

Conclusions and Recommendations

The draft of the meetings' conclusions and recommendations prepared by the chairman was discussed on the final day and adopted with minor modification. These are given in Appendix I and the workplan of each individual participant is listed in Appendix II.

Second Research Coordination Meeting of the CRP on
Measurement and Analysis of Neutron Emission Spectra for
(p,n) and (α ,n) Reactions

Feb. 8-10, 1988, Vienna

Conclusions and Recommendations

After extensive discussions on the reports presented by each individual investigator, the participants of this Second Research Co-ordination Meeting (RCM) came to the following conclusions:

1. The primary objectives of the Co-ordinated Research Programme (CRP) on Measurement and Analysis of double differential neutron emission spectra in (p,n) and (α ,n) reactions remain as stated at the first RCM, i.e. (i) to extract systematic information about nuclear level densities as a function of excitation energy by analysing the neutron emission spectra from (p,n) and (α ,n) reactions on targets and for bombarding energies mentioned in the Appendix II entitled "Summary of the programme for the period 1988-89", and (ii) to 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 models by comparison with microscopic calculations may be undertaken in favourable cases.
2. The presentation of the reports on work done by each individual participant indicated very good implementation of the programme agreed to during the first RCM.
3. The specific programme for each participant laboratory for the period 1988-89 would be as shown in the Appendix II entitled "Summary of Programme for 1988-89".
4. All participants will send their measured data to Prof. Vonach, Drs. Ramamurthy/Dr. Kataria and Dr. Märten directly for systematic analysis. The data may also be sent to the Nuclear Data Section (Dr. Kocherov) who would immediately send them to all participants. However, participants interested in each others' data should exchange them directly as circulation by NDS would be time consuming. Need for publication of reports based on data measured under the CRP would be discussed at the next RCM. The exchanged data should be double differential cross sections in mb/ster/MeV in equal energy bins of less than 500 keV. Those participants who carry out their own analysis of the data may report their results in the form of the parameters λ , Δ etc. and should also provide $\rho(U)$ in the form of tables or graphs.
5. The participants concluded that in view of the programme as defined in the Appendix, it would be advisable to hold the next RCM of the CRP after an interval not exceeding 18 months, to review the progress, intercompare the results and agree on the final steps of implementation, based on the results achieved by that time. A larger interval will result in loss of momentum of the activity and delay in progress towards achieving the objectives of the CRP, as all the measurements and analyses specified for the remaining period of the CRP would be completed during the year 1989.

CRP on Measurement and Analysis of Neutron Emission Spectra for (p,n) and (α ,n) Reactions

SUMMARY OF ACTIVITIES 1986-87 AND PROGRAMMES FOR 1988-89

Name	Research Agreement/Contract Number	Institution	Work completed to date	Proposed Programme for 1988-1989
1. H.K. Vonach	4321/CF	Institut für Radium- forschung & Kernphysik Vienna	Analysis of $^{181}\text{Ta}(p,n)$ received from Zhuravlev	1) Analysis of all data received from participants of the CRP in terms of extraction of level densities 2) Measurement of the total $^{181}\text{Ta}(p,n)$ and $^{51}\text{V}(p,n)$ reaction cross sections by activation in co-operation with S. Grimes at mutually agreed neutron energies.
2. Zhou Zuying (Tang Hongqing)	4294/RB	Inst. of Atomic Energy Beijing	Completed measurements on $^{59}\text{Co}(p,n)$ at 11 and 15 MeV	Measurements at 9 MeV for ^{59}Co , $^{95,96,97,100}\text{Mo}$, and for ^{95}Mo at 13 MeV to overlap with Scobel's work. Will send all data to Vonach, Ramamurthy, Märten, Scobel and NDS.
3. W. Scobel	4295/CF	Univ. of Hamburg Hamburg	Completed analysis of (p,n) data measured on all Mo isotopes at $E_p=255$ MeV. Measured data at $E_p=13.1$ MeV	Completion of measurement and analysis of data on $^{95,100}\text{Mo}(p,n)$ at $E_p=13.1$ MeV. If possible, measurement of (p,n) at $E_p=15$ MeV on all Pb isotopes. Will send data to Vonach, Ramamurthy, Märten and NDS and exchange with Zuying/ Hongqing

Name	Research Agreement/Contract Number	Institution	Work completed to date	Proposed Programme for 1988-1989
4. H. Märten	4404/CF	TUD Dresden	Analysis of $^{109}\text{Ag}(p,n)$ and $^{93}\text{Nb}(n,n')$ data using SMD/SMC theory. Analysis of ^{252}Cf neutron emission spectrum with complex cascade evaporation model for integral test of level density descriptions	Continue integral test of level density description with fission neutron theory. Analysis of $^{93}\text{Nb}(n,n')$ data (overlap with Guenther's work). Theoretical analysis of all (p,n) data available within the CRP to deduce "contamination" contributions to equilibrium neutron spectra (SMD/SMC theory). Final analysis of $^{109}\text{Ag}(p,n)$ and $^{115}\text{In}(p,n)$ reactions.
5. S.K. Kataria	4403/RB	B.A.R.C. Bombay	Developed a phenomenological prescription for level density calculation including pairing correlations, deformation dependence of shell effects and spin dependence.	Analysis of all (p,n), (α,n) data measured under the CRP to determine nuclear level density parameters for various phenomenological level density expressions. Investigation of spin dependence effects on angular distributions.
6. B.V. Zhuravlev	4222/CF	Inst. of Physics and Power Engineering Obninsk	Measurement and analysis of (p,n) reactions for $^{204}, ^{206}, ^{207}, ^{208}\text{Pb}$ at $E_p=11.2$ MeV. Data sent to Vonach. Data available at NDS.	Measurements on ^{165}Ho , ^{209}Bi and analysis of all data within the framework of the consistent unified superfluid model for the level density. Will send measured data to Vonach, Ramamurthy, Märten and NDS.

Name	Research Agreement/Contract Number	Institution	Work completed to date	Proposed Programme for 1988-1989
7. S. Grimes	4293/CF	Ohio University Athens, Ohio	Measurements on $^{59}\text{Co}(p,n)$ at $E_p=5,6,7,8$ & 9 MeV and $^{56}\text{Fe}(\alpha,n)$ at $E_\alpha=9,11,13$ MeV and preliminary analysis of the data.	Repeat measurements of $^{59}\text{Co}(p,n)$ and $^{56}\text{Fe}(n)$, measurements of $^{51}\text{V}(p,n)$ ($5 \leq E_p \leq 9$ MeV) and $^{48}\text{Ti}(\alpha,n)$ ($9 \leq E_\alpha \leq 13$ MeV) measurements of $^{57}\text{Fe}(^3\text{He},n)$ at $E_{^3\text{He}}=8$ & 10 MeV, fine resolution measurements ($\Delta E \sim 5$ keV) of $^{59}\text{Co}(p,n)$, and measurements of $^{92}\text{Zr}(\alpha,n)$ and $^{95}\text{Mo}(p,n)$. Will send measured data to Vonach, Ramamurthy, Märten and NDS.
8. P.T. Guenther	4412/CF	Argonne National Laboratory, Argonne	Measurements of neutron emission spectra for Nb, In, Ho, Ta and Bi carried out at neutron bombarding energies 5,5.5,6,6.5,7,7.5 and 8 MeV.	Analysis of measured neutron emission spectra from Nb, In, Ho, Ta, and Bi. Will send measured data to Vonach, Ramamurthy, Märten, Zhuravlev and NDS.

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NEUTRON EMISSION SPECTRA IN (P,N) and (α ,N) REACTIONS

IAEA Headquarters in Vienna, 8-10 February 1988
Building C, Meeting Room VI

AGENDA

- A. Opening
 - Election of Chairman
 - Adoption of Agenda
- B. Chairman's Remarks
- C. Reports by participants on the progress of their programmes

H.K. Vonach	IRK Vienna
Zhou Zuying	IAE Beijing
H. Märten	TUD Dresden
W. Scobel	Inst. f. Exp. Physik Hamburg
S.K. Kataria	BARC Bombay
B.V. Zhuravlev	FEI Obninsk
S.M. Grimes	Ohio University
P.T. Guenther	ANL
V.S. Ramamurthy	BARC Bombay

Others

- D. Discussions on special problems encountered
- E. Further discussions (in detail) on future activities
- F. Conclusions and Recommendations
- G. Miscellaneous

- contract renewal
- next meeting
- issue of final CRP report
- others

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IAEA Headquarters in Vienna, 8-10 February 1988
Building C, Meeting Room VI

ADDRESSES

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A. Gerbasi da Silva Commissiao National de Energia could not attend
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IAEA Staff Members

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V.A. Konshin
M.K. Mehta (Chairman)
K. Okamoto (Scientific Secretary)
J.J. Schmidt

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