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INTERNATIONAL NUCLEAR DATA COMMITTEE

**MEASUREMENTS AND ANALYSIS OF DOUBLE DIFFERENTIAL
NEUTRON SPECTRA IN (P,N) AND (ALPHA,N) REACTIONS**

SUMMARY REPORT

Third Research Co-ordination Meeting

organized by the
International Atomic Energy Agency
Bologna, Italy, 13-15 November 1989

Prepared by

N.P. Kocherov
IAEA Nuclear Data Section

December 1989

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

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INTRODUCTION

The IAEA Co-ordinated Research Programme (CRP) on Measurement and Analysis of Neutron Emission Spectra from (p,n) and (alpha,n) Reactions was started at the beginning of 1986. The first Research Co-ordination Meeting took place on 23-27 June 1986 in Vienna. The participants have formulated the main objective of the CRP as to extract systematic information about level densities in function of excitation energies by means of analysis of neutron emission spectra from (p,n) and (alpha,n) reactions on properly selected targets and within proper bombarding energy ranges.

The participants agreed on three bombarding energy regions: 5-10 MeV, 11-15 MeV and 25 MeV. Only these laboratories which had accelerators with beams within these energy ranges and neutron spectrometer facilities could participate in the experimental part of the programme.

The measurements were done at Argonne (P.T. Guenther), Ohio University (S.M. Grimes), Hamburg University (W. Scobel), FEI Obninsk (B.V. Zhuravlev), IAE Beijing (Tang Hongqing).

The analysis of the data sets produced was done by IRK Vienna (H.K. Vonach), TU Dresden (H. Märten), BARC Bombay (S.K. Kataria, V.S. Ramamurthy), FEI Obninsk (A.V. Ignatyuk) and also by some of the data producers themselves.

Measurements of double differential neutron spectra have required a considerable experimental effort and a lot of accelerator time. Therefore it was decided during the first CRP meeting to hold the second one in 1.5 years and after the second meeting it was decided to delay the last meeting till almost 2 years to get time enough for participants to finish the measurements.

All participants have agreed that a new reliable data set with an up-to-date accuracy was produced and the volume of the data was sufficient to make an unambiguous analysis using different approaches.

As a further useful development of this programme the participants stated the need of measurements with alpha-particle beams and targets which would give the same compound nuclei as were reached in (p,n) reactions. However, there seems to be very little hope to organize this activity in the nearest future due to lack of experimental facilities capable of fulfilling this task. Therefore no recommendation was made on this point.

On the last day of the IAEA CRP meeting a joint session with the NEANDC meeting on Nuclear Level Densities was organized. The organization of these two meetings adjoint one to another was found very useful by all participants.

The papers presented by the participants during the CRP meeting will be published as an IAEA document.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions emerged as a result of extensive discussions reviewing the progress made towards achieving the objectives of the CRP in view of the results reported by each participant:

- 1) Extensive new measurements have been carried out under the CRP spanning 18 nuclides in the mass regions 45-65, 90-100, 180-210. The bombarding energies used ranged from 5 to 25 MeV for protons and 9 to 12 MeV for alpha particles and 5 to 11 MeV for neutrons. This information is summarized in the Appendix. It would be possible to extract level density information in the range of 0-10 MeV excitation energy for the corresponding residual nuclei from this data.

It is pointed out that the errors reported for all the measurements were within the required limits for the proposed LD analysis. However, it was necessary to recognize the errors in the neutron energy at the higher end of the spectrum were critical factors for matching the extracted level density information with the experimental values based on the discrete level information, especially for those odd-odd nuclides where discrete level densities were already as high as 50/MeV. It was realized that inherent errors in the timing for TOF technique were the major contribution to this error which was about 200 keV for most of the reported data. In this connection the participants recommended that work to extend the determination of level densities based on discrete level counting to higher energies should be encouraged.

- 2) Analyses of some of the data were reported which brought out the importance of contribution from non-equilibrium processes in some cases. Extraction of level densities $\rho(U)$ as a function of U was also reported in a few cases.
- 3) The participants agreed that sufficient data were reported to carry out the second stage of the CRP work namely extraction of level density information using consistent analytical procedures. It was suggested, however, that measurements on Pb isotopes at around 14 MeV and on Au-197 at 9 MeV would add useful information towards extending the range of $\rho(U)$ for those nuclides.

- 4) It was agreed that, although the experimental part of the CRP was completed, the analysis for extracting the level density information using all the data generated under the CRP was still to be done. It was decided that all the participants who measured data will carry out their own analysis, while Drs. Vonach, Märten and Kataria will analyze all the data using their own procedures to extract the level density information. It was pointed out that the authors should provide specific information on the optical parameters used by them and should check the sensitivity of L.D. parameters they obtained against the variation in the OM parameters. It was also suggested that "nuclide specific" or "regional parameters" would be preferable to "global" parameter sets. The analysis should also explicitly report on the non-compound contributions, if any, and the way in which it has been accounted for.

- 5) The participants concluded that the CRP may be terminated at this state formally, however, the analysis work mentioned above should be carried out by all the participants who should send the results to NDS by the end of 1990. It is recommended that IAEA should hold a consultants' meeting in the first half of 1991 to intercompare the results of these analyses and to prepare a final report of the outcome of work performed under the CRP for the general use in calculations related to nuclear data needed for nuclear technology applications.

Third Research Coordination Meeting of the
Coordinated Research Programme on

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

ENEA, Bologna, Italy
13-15 November 1989

AGENDA

- A. Opening
 - Election of Chairman
 - Adoption of Agenda
- B. Chairman's Remarks
- C. Reports by participants on the progress of their programmes
 - 1. S.A. Egorov, Radium Institute, Leningrad
 - 2. S.M. Grimes, Ohio University
 - 3. P.T. Guenther, Argonne National Laboratory
 - 4. A.V. Ignatyuk, FEI Obninsk
 - 5. S.K. Kataria, BARC Bombay
 - 6. H. Märtens, TU Dresden
 - 7. W. Scobel, Inst. für Exp. Physik, Hamburg
 - 8. Tang Hongqing, IAE Beijing
 - 9. H.K. Vonach, IRK Vienna
 - 10. B.V. Zhuravlev, FEI Obninsk
- D. Discussions on special problems encountered
- E. Further discussions (in detail) on future activities and actions
- F. Conclusions and Recommendations
- G. Joint session with the NEANDC Level Density Meeting

Proposed Time Schedule

9:30 - 10:30
11:00 - 12:30
14:00 - 16:00
16:30 - 18:30

IAEA Research Coordination Meeting (Third) on
MEASUREMENT AND ANALYSIS OF DOUBLE DIFFERENTIAL NEUTRON
EMISSION SPECTRA IN (P,N) and (α ,N) Reactions"

Bologna, Italy
13 - 15 November 1989

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