

International Atomic Energy Agency

INDC

INTERNATIONAL NUCLEAR DATA COMMITTEE

TECHNICAL MINUTES
OF THE EIGHTH INDC MEETING

Vienna, 6-10 October 1975



Compiled by

V. Benzi (CNEN Bologna, Italy)
(Executive Secretary)

Aided by

W. Gemmell (AAEC Lucas Heights, Australia)
(Chairman)

J.J. Schmidt (IAEA)
(Scientific Secretary)

January 1977

IAEA NUCLEAR DATA SECTION, KÄRNTNER RING 11, A-1010 VIENNA

Reproduced by the IAEA in Austria
January 1977
77-0073

T E C H N I C A L M I N U T E S
O F T H E E I G H T H I N D C M E E T I N G

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INTRODUCTION

The International Nuclear Data Committee (INDC) at its Sixth Meeting in Vienna in October 1973 decided to issue "Technical Minutes" of each of its meetings for distribution to scientists interested in the production, evaluation and use of nuclear data. These minutes contain information of a technical nature which was presented and discussed at the INDC meeting. The numbering of items in the table of contents is not in accord with the item numbers on the INDC agenda.

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8th INDC MEETING

Vienna, 6-10 October 1975

LIST OF PARTICIPANTS

I. Members and advisers (indicated by asterisks)

<u>Australia</u>	W. Gemmell	(Chairman)
<u>Canada</u>	W.G. Cross	
<u>France</u>	A. Michaudon	
	* R. Joly	
	* J. Legrand	
	* A.P. Schmitt	
	S. Cierjacks	
<u>Hungary</u>	D. Berenyi	
<u>India</u>	M.K. Mehta	
<u>Italy</u>	V. Benzi	(Executive Secretary)
<u>Japan</u>	T. Fuketa	
<u>Netherlands</u>	A.H. Wapstra	
<u>Sweden</u>	H. Condè	
	T. Wiedling	
<u>USA</u>	A.B. Smith	
	* H.T. Motz	
	* J. Decker	
<u>USSR</u>	L.N. Usachev	
	* G.B. Yankov	
<u>UK</u>	B. Rose	
	* J.L. Rowlands	
<u>IAEA</u>	J.J. Schmidt	(Scientific Secretary)
	* A. Lorenz	(Local Secretary)

II. Observers

<u>Austria</u>	O.J. Eder
<u>German Democratic Republic</u>	K. Seidel
<u>Israel</u>	S. Amiel
<u>Rumania</u>	S.N. Rapeanu , G. Vasiliu
<u>CEC-Geel</u>	H. Liskien
<u>OECD-NEA</u>	H. Derrien
<u>IAEA</u> (Part time)	P. Attree G. Lammer J. Lemley H. Lemmel J. Phillips M. Vlasov

I. INTRODUCTORY ITEMS

Professor Glubrecht, Deputy Director General of the Research and Isotopes Department of the IAEA welcomed the participants to the 8th INDC meeting on behalf of the Director General. In his address, Glubrecht placed importance on the role of NDS in the IAEA work and its future role in the new areas of data for non-energy applications (e.g. material analysis, environment etc.) and for fusion (atomic and molecular interactions), as recommended by the IFRC. He hoped they would be as successful as the work for WREND and neutron data for energy production. NDS has played an important role in involving the less developed countries in nuclear data measurements and by encouraging the International Centre for Theoretical Physics, Trieste, to take an interest in theoretical techniques for nuclear data computation. Glubrecht hoped NDS would continue to be useful in encouraging and cross-fertilising such cooperation. The Tentative Agenda is given in Appendix I.

II. NEUTRON NUCLEAR DATA

II.A. Report on 11th Four Centre Meeting

Lemmel provided the background to the discussion by summarising the "Report on the Eleventh Four-Centre-Meeting", INDC(NDS)-68. Smith pointed out that the exchange situation is not good yet. Even if EXFOR is routinely working as a tool, the system is not fully working as far as the compilation and exchange of data is concerned. Derrien, speaking for CCDN, said that this was true for old data, mainly due to EXFOR-NEUDADA interface problems, shortage of manpower and computer change. A short discussion followed the Usachev suggestion that the effectiveness of the 4-Centres in this field by monitoring the turn-around time for response be evaluated. For this purpose, the Committee recommended that :

- the 4-centres indicate on tape the dates on which data (a) were received and (b) became available for exchange
- all members advise the 4-centres on gaps in the Data Centre files available (Action n.8)
- all members continue to urge physicists in their respective Countries to send the data to the Centres (Standing Action n.9)
- the 4-centres give maximum priority to the compilation and exchange of important discrepant data and standards, as decided during the Sydney meeting.
- the chairmen of the standing Sub-Committees on Standards and Discrepancies submit to the appropriate Data Centres the names of the reviewers and topics covered by their Sub-Committees (Action n. 10)
- The above mentioned reviewers ask the appropriate Data Centres to send them all available information on their own reviewed topic (Action n.11)

During the discussion of the above mentioned points, Actions n.12, 13 and 14 were decided.

II.B. Additional Information from Neutron Data Centres other than NDS

Smith informed that Brookhaven Laboratory was extending the scope to include the compilation of non-neutron nuclear data at modest level of manpower effort.

A large effort continued on data evaluation for fission reactors, and a new BNL-325 curve-book for the actinides had gone to press.

Usachev said that at Obninsk work has begun on those important data assigned high priority by the Sub-Committees on Standards and Discrepancies. Usachev also pointed out that at Obninsk there was some work on data adjustment, an activity that is not typical of other Data Centres.

II.C. Two Years Publication Cycle of CINDA

Working papers by Lemmel and Rose provided the basis for the discussion. Lemmel summarised the proposals for changing the present way of publishing CINDA in order to reduce the cost of production.

The pros and cons of two possible solutions, i.e. a two-year publication cycle and a splitting of the book in 'old' and 'new' volumes, were examined by Lemmel, taking into account Rose's proposal.

The present way of blocking entries with all references and EXFOR indexes was highly appreciated by the users, so that maximum priority has to be given to a systematic tie up of this type for all references before 1970. For this reason, argued Lemmel, any change in the CINDA publication cycle seemed to be premature at the moment.

Rose replied that the reasons advocated by Lemmel were rather weak when compared with the problem of reducing costs. Motz expressed the view that maximum effort should be put in updating references through supplements and that periodic publications of a cumulative volume containing 'old' references was of little use for the evaluators. Smith pointed out that CINDA was an outstanding success and a very useful tool for the nuclear data community. His personal view on the matter was that the primary concern of INDC should be on the policies for improving CINDA rather than on the way of reducing costs. Derrien and Joly supported Smith's views. In summarising the discussion the Chairman proposed the following recommendation: "The INDC support the Data Centres in their effort to improve the quality of CINDA, but urge that

the 4-centres bear in mind the financial cost of the project and take all the necessary actions to reduce this cost, e.g. by making an 'archive volume'. This was accepted by the meeting.

II.D. International Exchange and Assessment of Use of Evaluated Data

Smith pointed out that those parts of ENDF/B-IV concerning dosimetry and fission product nuclear data had been released on a world-wide basis. A full description is given in INDC(US)-70/L and INDC(US)-71/L. The dosimetry file is also described in Nuclear Technology, 25, 376, 1975 by Magurno and Ozer.

A comprehensive revision of the files, (ENDF/B-V), will be completed in approximately 18 months. Smith stressed that US was very interested in receiving feedback from the users.

Usachev reported that since the last INDC meeting, tapes containing an evaluation of Pu-239 (Minsk) had been distributed in addition to magnetic tapes containing evaluations of U-235 (Minsk) and of Fe (Obninsk) distributed at the last meeting.

Several other evaluations were available, unfortunately only in internal USSR format at present. As soon as the format translation is complete, they will be distributed. Possibly, evaluation of H, He-3, He-4, D, Pu-238 and Cm-240 will be distributed at the next 4-Centres meeting. Evaluations on Pu-240, Pu-241 and U-233 are going on in Minsk, whereas evaluations of Ni and Cr were completed at Obninsk.

Usachev pointed out that analyses performed at Obninsk and Minsk of ENDF/B data on Gold, He-3 and C-12 were included in ENDF/B-IV. This feedback indicated that the international cooperation in the field of evaluated data was beginning.

Smith noted that an American private industrial foundation, namely the Electrical Power Research Institute, provided additional significant funding to the US program on nuclear data evaluation, thereby demonstrating that the economic importance of the evaluation is largely recognised. Rowlands and Cierjacks indicated that use of ENDF/B data was an important aspect of data work in their respective countries.

III. NON-NEUTRON NUCLEAR DATA

III.A. Progress Reports on Activities, Services and Coordination of 'Non-Neutron' Nuclear Data Centres and Groups (+)

Motz informed the Committee on the development of the Nuclear Data Project in Oak Ridge. The next issue of Nuclear Data Sheets covering the A=75 mass chain, now in print, is completely computerised, like BNL-325. A short 'Report to the INDC on U.S. Data Study' was presented by Smith (see Appendix II). He informed that about 80% of the requests on non-neutron nuclear data were from basic side.

Wapstra announced that a new issue of the 'Tables of Nuclear Masses' would be ready in one year.

A memorandum by Legrand on the activity of the International Committee on Radiation Metrology was submitted to the Committee. At an ICRM meeting in Saclay, a Working Group was established to determine the real needs and to improve the existing situation in the field of decay data and radioactive nuclei. Fuketa indicated that some work on nuclear structure data was being undertaken in Japan in connection with the problem of fission product-decay heat. Seidel said that in the German Democratic Republic there was some work going on in the compilation of decay schemes and charged particle cross-sections for industrial purposes.

Condé explained that in Sweden activities were mainly at individual level. He mentioned the work at Studsvik on charged particle cross-sections for activation analysis and on decay schemes (measurements and compilation) for fission products. Data on photo-reactions are being measured and compiled at Lund University. Cross reported that in Canada Walker was developing his 'FISPRO' Program, to include all the relevant data of 800 fission product nuclei. This work is partly based on ENDF/B data. In addition two volumes were published (by Plenum Press), giving calculated values of ranges and energy loss of many ions in various materials which are of interest for ion implantation and damage problems.

(+) Partly discussed on Wednesday morning

The summary of non-neutron nuclear data work in the Federal Republic of Germany by Cierjacks highlighted the activities on charged particle (p,d, α) excitation functions by Münzel in Karlsruhe (see INDC(NDS)-69). Mehta mentioned that an effort on mass-chain compilations was planned in India (Tata Institute). Work on charged particle reactions (d,p reaction and angular distribution compilations) is underway in the Universities. BARC would try to coordinate the activities, with the help of NDS.

A compilation of (α ,n) excitation functions up to 5-6 MeV was planned at Trombay.

Rose said that in the UK discussions were underway to contribute to the Oak Ridge program in A-chains. Other activities underway included : preparation of a file on decay schemes of fission products and actinides and compilation of cross-sections for ion beam analysis of materials (see Appendix III). Yankov mentioned activities in the USSR on compilation of data concerning charged particle interaction with heavy nuclei. Additional information is contained in the NDS Memo 294 by J.Schmidt (available on request); see also Appendix XV.

A number of actions were decided during the discussion of the above mentioned points (Actions 15, 16, 17, 18 and 19).

III.B. Report on Meeting on Charged Particle Nuclear Data (CPND) for Applications ⁽⁺⁾

The Consultant's Meeting on CPND Compilation held in Vienna, 8-12 September 1975, (see INDC(NDS)-69) was briefly reviewed by Lemmel.

III.C. Discussion on Recommendations from 'Non-Neutron' Nuclear Data Meetings April/May 1974, including plans for 1976 meetings.

This item (Appendix IV) was discussed at the meeting of the Energy Applications Sub-Committee.

(+) Discussed on Wednesday morning

IV. COORDINATION OF NUCLEAR DATA ACTIVITIES (MEASUREMENTS & EVALUATION)

IV.A. Status of Development of Regional Nuclear Data Centres and National Data Committees

Fuketa indicated that a Nuclear Data Centre was not yet established in Japan. He required support from INDC in this matter in the form of a letter from the INDC Chairman to the Japanese AEC. At present, about 90 people are part-time engaged in nuclear data work at JAERI. Two senior scientists, one junior and an engineer are working full time.

Gemmell had nothing to add to what was said during the Sydney meeting.

Mehta informed that it was difficult to start a formal Nuclear Data Centre in India. An analysis of the material provided by NDS to Indian Laboratories will be sent by NDS to Mehta (Action n. 24) in order to provide elements for judgements on the need for a Nuclear Data Centre.

IV.B. Neutron Data for Reactor Dosimetry

Discussed by the Energy Applications Sub-Committee.

IV.C. FPND Newsletter

As IV.B above.

IV.D. WRENDA for Fission, Fusion and Safeguards

The Chairman recalled that during the Sydney meeting it was decided to have at least one working paper 'for' WRENDA, and one 'against' for discussion at the 8th INDC Meeting.

Rose outlined the arguments against WRENDA and was followed by views in favour of WRENDA by Usachev. In particular, Usachev said that national lists, as proposed by Rose, were a kind of administrative action, whereas WRENDA was much more comprehensive in scope. In fact, it provided: (a) general comments by requestors (see, e.g. WRENDA 75, INDC(SEC)-46/U, page II, ii); (b) a comparison on international basis among various requests, as far as wanted accuracies and areas (fusion, biology, etc.) are concerned; (c) a concise description of achievements and status. NDS experience with the operation of WRENDA was presented by Lemley. Then participants indicated their views about usefulness of WRENDA. Some members (Smith, Michaudon, Joly, Cierjacks, Rose, Gemmell, Cross) felt that WRENDA had little influence on measurements in their countries because programs in the various laboratories were mainly determined on the basis of the facilities available.

Some of the above mentioned members, however, felt WRENDA to be useful as a tool for discussion about accuracies (Joly) or in order to justify sample requests to the US (Cierjacks). Other participants (Mehta, Fuketa, Liskien, Seidel, Rapenau, Berenyi) felt that WRENDA was of great value to their respective organisations in establishing research programs. WRENDA was also useful for those countries, like the USSR or the Federal Republic of Germany without national request lists. On this basis, it was unanimously agreed that WRENDA should continue.

The committee then considered how WRENDA could be improved by discussing Schmidt's paper 'Proposal on WRENDA'.

Specific points discussed and conclusions reached, were as follows :

1. Request list should continue as 4-Centres responsibility.
2. WRENDA publication should contain separate request lists for Fission Reactors, Fusion and Safeguards, and should include requests for measurements, evaluations and information.
3. As far as request file and status file were concerned, the present format of publication was felt acceptable.
4. The word 'measurements' should be dropped from the WRENDA document title.
5. No particular action was requested about Satisfied/Withdrawn requests.
6. About assignment of request numbers, it was recommended to the 4-Centres to move the file number to the right side and to add a sequential number on the left side of the request (Action n. 25).
7. Requests unreviewed for 2 years should be automatically dropped.
8. Delete status comments. The NDS would provide comments on WRENDA 76 using the reports by technical Sub-Committees as guideline. (Action n.26).
9. Uncertainty information from evaluated data files should not be extracted and summarised for WRENDA status comments.

The problem of WRENDA distribution was also discussed. Smith proposed that a fiscal charge for WRENDA (like CINDA) would indicate the real interest.

It was decided that all members would revise the WRENDA distribution list before 31 December 1975 (Actions n.27, 28 and 29).

Two working papers concerning the Japanese Request lists on Fusion and Safeguards were submitted by Fuketa (Appendix V and VI).

IV.E. Nuclear Data Measurements in Developing Countries

Working papers were submitted by Fuketa, Schmidt, Ferguson (presented by Rose), and Condè (Appendix VII, VIII and IX).

Mehta informed that cooperation between India and Bangladesh was summarised in the Progress Report from India. Schmidt said that IAEA was prepared to help the cooperation between JAERI/KAERI and BARC/Bangladesh by providing targets, fellowships, and research contracts for priority I measurements. See also Action n. 30.

IV.F. Status and NDS Targets and Samples Program

Lemley referred to the NDS Progress Report, where an account of the program was given. There was some difficulty with the supply of targets by BCMN which, Liskien thought, arose because of some arrangement of personnel at BCMN in connection with a program of Safeguards.

Because of the interest at the last INDC meeting in Lithium-fluoride foils made at Argonne, said Smith, fifty of these foils had been prepared and were available on request. There were inquiries in the U.S. as to long-term sample needs with the result of no demand grossly exceeding supply. Smith said that Oak Ridge has considerably reduced its activity in this field. People should bear in mind that the 'form-of-the-sample' cost could be many times the cost of the sample, and loans were easier if materials were to be borrowed in existing form and shape.

V. PROGRESS REPORTS ON NUCLEAR DATA MEASUREMENTS, FACILITIES AND EVALUATIONS.

V.A. Additions to submitted progress reports

AUSTRALIA

Gemmell mentioned the following activities.

A) Measurements

The energy dependence of σ was studied on Th-230 and Th-232. Some structure was found in Th-232. The analysis of capture cross-sections of Cr-50, Cr-52 and Cr-54, in cooperation with Macklin, is going on.

The analysis of resonances of the above mentioned nuclei was completed.

B) The evaluation on FP performed at AAEC will be distributed in ENDF/B format.

AUSTRIA

In the absence of Eder, Condè drew attention to the "Progress Report to NEANDC and INDC from Austria" distributed as INDC(SEC)-51/L.

CANADA

Cross referred to INDC(Can)-15/G underscoring the measurements by Santry on the excitation curves for $^{113}\text{In}(n,n')^{113\text{m}}\text{In}$ and $^{115}\text{In}(n,2n)^{114\text{m}}\text{In}$. A search for two photon decay in thermal (n,p) capture, by Earl et al. was noted.

FRANCE

In addition to the progress Report NEANDC(E)162"U", vol.IV (France), the following information was given by the French delegation (Michaudon, Schmitt, Legrand).

A) Measurements

a) Work in progress at Cadarache.

i) Self-shielding factor measurements on natural Ni and Ni isotopes.

This work was carried out in cooperation with F. Perey's group at

ORNL in order to improve the evaluation of resonance parameters for these isotopes.

- ii) Extension of U-235 fission cross section measurements up to neutron energy 3.6 MeV.
- b) Work in progress at Bruyères - Le-Châtel
 - i) Elastic and inelastic cross section measurements at 4.1 and 7 MeV incident neutron energies on even Nd isotopes and at 4.1 MeV for even Sm isotopes. These measurements were made in order to study the effect of deformation on the cross sections. This effect is a minimum at 4.1 MeV and maximum at 7 MeV on the total cross section of these nuclei.
 - ii) Measurements of (n,2n) cross sections on a series of nuclei, using big scintillator technique, from near threshold to 15 MeV. Since January 1975, measurements were made on Sm and Nd separated isotopes and on V, Ti, Cr, Cu, Zr, Mo, Pb natural elements.
 - iii) Fission cross section measurements of the following nuclei: Am-241 (in the energy range 1.1-1.7 and at 1.9 MeV), U-235, U-238 (from 0.5 to 3.2 MeV and at 14.6 MeV).
 - iv) Measurements of the fission neutron energy spectrum for fission induced by 7 MeV neutrons in U-238 and by 0.6 and 7 MeV neutrons in U-235.
 - v) Detailed study of the $^{233}\text{U}(\text{d},\text{pf})$ reaction, by measuring the kinetic energy and mass distribution of the fission fragments.

The purpose of this study is to see whether the fission process for U-234 varies as a function of the excitation energy as it does for Pu-240.

Additional information of the activities at Bruyères-Le-Châtel is given in the report CEA-N-1978/INDC(FR)-6/L.

- c) Work in progress at L.M.R.I. - Saclay

An internal progress report of L.M.R.I. is available upon request. The following activities were mentioned.

- i) Accurate measurements of the half-life of Cf-252

- ii) Development of a method to measure the activity of sulfur detectors by liquid scintillation
- iii) Decay schemes of ^{64}Cu , $^{93\text{m}}\text{Nb}$, and $^{103\text{m}}\text{Rh}$ (measurements and evaluation)
- iv) Neutron Spectrometry with proportional counters and liquid scintillators using ^{252}Cf sources
- v) ^{252}Cf fast neutron standard (energy spectrum and fluence)
- vi) Dosimetry by calorimetric methods for high energy photons and electrons (observed dose)
- vii) Multi- γ -ray-standard (^{152}Eu) and high-energy γ -ray standard (6.1 MeV) studies.

B) Facilities

Construction of the accelerator GANIL (Grand Accélérateur National à Ions Lourds) has been definitely approved by the French Government, and would be built at CAEN (Calvados) in Normandy, about 200 Km north-west from Paris. GANIL comprises a two sector-focused cyclotron (CSS), having a K-value of 400, with one compact cyclotron as injector. Provision was made also to install a Tandem VdG accelerator. With the CSS, it is expected that light ions can be accelerated up to 100 MeV/nucleon and heavy ions, up to Uranium, to about 10 MeV/nucleon. Particle current should reach 10^{14} particles/second for light and 10^{13} particles/second for heavy ions.

The total cost of the facility (without Tandem VdG) was estimated to be about 175 millions of FF. Construction would take 5 years.

GANIL represents the second big investment in the France 5-year plan (1975/1979) for nuclear physics. The first one was the modernisation of Saturne, an old elementary particle physics machine which will then become a medium-energy nuclear physics facility.

C) Evaluation

- i) At Cadarache, Au-197 capture cross-section between 20 and 550 KeV was evaluated using the experimental results obtained by Le rigo-leur with the Maier-Leibniz technique and those by Fort by activa-tion.

- ii) At Bruyères-Le-Châtel, a complete evaluation of C-12 was performed and sent to CCDN in ENDF/B format. Evaluations of the energy-dependence of $\bar{\nu}_p$ for isotopes of Th, U and Pu, was also carried out.
- iii) At L.M.R.I., Saclay, evaluated tables of radionuclides decay-schemes were produced.

GERMAN DEMOCRATIC REPUBLIC

Seidel said that a progress report will be distributed at L-level by NDS. The following activities were underscored.

A) Measurements

- i) Measurements of cross-sections for double differential neutron emission at 14 MeV for 34 elements in the mass range $9 \leq A \leq 209$. Results, which meet about 40 WRENDIA requests, are available from NDS in EXFOR format. A report will be distributed at L-level.
- ii) Measurements of differential elastic and inelastic scattering cross sections at 3.4 MeV incident neutron energy for a number of elements with $24 \leq A \leq 209$.

B) Evaluation

- i) The influence of the pre-compound process on (n,np), (n,pn), (n,2n),, cross sections was studied for many nuclei.
- ii) A cooperation was established with Obninsk to perform the evaluation of fast neutron data in SOKRATOR format.

FEDERAL REPUBLIC OF GERMANY

A) Measurements

1. At Karlsruhe. At the 3 MeV VdG
 - $\bar{\nu}_p$ measurements for ^{239}Pu were in progress
 - Capture cross-section measurements on noble gases in the 10-20 KeV neutron energy range had been performed.
 - Cross sections for γ -ray productions for natural iron and Ni-isotopes were evaluated.

- Capture cross sections of ^{240}Pu and ^{242}Pu were investigated in the 10-200 KeV energy range. A sample of ^{241}Am was prepared for σ_c measurements.

At the Cyclotron :

- Elastic scattering cross sections at 10 angles in the energy range 0.5-10 MeV for Fe, O, S were evaluated.
- The analysis of γ -ray production cross sections of Ni and Cr isotopes in the energy range 0.5-20 MeV was completed.

2. At the European Institute for Transuranium Elements.

Irradiation in RAPSODIE of samples of Np-237, U-233, Pu-239 and Pu-241 for determination of fast fission yields were continued. Besides the yield for Sb-125, Cs and Xe isotopes, bulk fission yields for Nd-isotopes were examined.

3. At Hamburg University

Studies on systematic of (n,x) reactions were continued. Experimental results measured by the University were compared with predictions of pre-compound model.

4. At the Institut für Nuklearchemie, Jülich.

- Measurements of (n,p), (n, α), (n,2n), (n,n'p), (n,n' α) cross sections on several nuclei were continued. Results at 14 MeV were reported during the Washington Conference.
- Further work was devoted to measurement and interpretation of tritium production rate in a Li-model blanket.

5. At Technische Universität, München

- Nuclear structure studies by thermal neutron capture were continued
- Some coherent neutron scattering amplitudes were measured
- Slow neutron transmission and scattering measurements at 1.26, 1.46 and 5.2 MeV were continued.

B) Evaluation

At Karlsruhe, the work on KEDAK 3 was nearly completed. Evaluated files were available; details were given in various progress reports.

New calculations and systematics were performed in order to compare predictions of the pre-compound models with the results of high energy neutron scattering.

HUNGARY

Berenyi indicated that in addition to the four Institutions mentioned in the Report to INDC, the Isotopes Institut was also dealing with applied research.

At the Institut for Nuclear Research (Debrecen) a superconducting magnet for a two Si(Li) electron spectrometer was under construction.

The goal of the programme would be to measure conversion electrons from transition of final nuclei.

INDIA

In addition to the report on the activities of the Indian laboratories included in the general document INDC(SEC)50, the following points were added by Mehta.

A) Measurements

- i) $^{232}\text{Th}(n,\gamma)$ cross section; in order to study the feasibility of accurate measurement for (n,γ) cross section on ^{232}Th up to 3 MeV, an experimental programme has been started utilising a 30 cc Ge-Li detector at Trombay.

The secondary gamma spectrum from the decay of ^{233}Th , after thermal capture, has been measured with respect to gold. The aim is to determine the accuracy which Ge-Li measurements could yield. The next step would be to extend the measurements to higher energies utilising the Van der Graaf accelerator. A programme of developing a "surface barrier detector - Li sandwich" neutron counter for flux measurements has also been taken up.

ii) 25 KeV capture cross section: A 25 KeV filter has been installed on the 40 MW CIRUS reactor which yields a flux of about 10^5 n/cm²/sec. 25 KeV capture cross sections with respect to thermal capture cross sections have been measured for 19 isotopes ranging from ⁵¹V to ¹⁸¹Re.

iii) Charged Particles: The (p,n) and (α,n) cross section measurements have been continued with the 5.5 MeV Van de Graaf at BARC. The measurements of (p,n) reaction cross sections on ⁵⁵Mn up to 5 MeV have been completed.

Hauser-Feshbach and optical model analysis of the excitation functions and the shape analysis of the observed isobaric analog resonances have been carried out. The work on the study of ¹⁹F (α,n) reaction is also completed. Multilevel-multichannel analysis of the alpha particle elastic scattering cross section for ²⁴Mg measured at four angles is underway. The work on ²⁶Mg(α,α) ²⁶Mg reaction is completed.

iv) Fission: Main thrust of the work done in the Fission Physics Section of the Nuclear Physics Division at Trombay has been towards theoretical investigation of ternary and quaternary fission of ²⁵²Cf.

B) Facilities

The Variable Energy Cyclotron installation at Calcutta has proceeded to a stage such that beam trials are expected to begin within a few weeks.

A series of seminars oriented towards the utilisation of the Cyclotron are planned during the forthcoming Annual Nuclear Physics and Solid State Physics Symposium which will meet in Calcutta this year in the last week of December. The design of the 100 MW thermal research reactor at Trombay has been frozen and the civil works have started.

The reactor at Trombay is expected to be operative in 1979.

Two 14 MeV neutron generators (H.V.E.C. made PN-400 machines) have been installed one each at the Banaras Hindu University and at the Punjab University respectively. It is expected that some 14 MeV neutron data work will be started at both the places.

C) Evaluation and Compilation

In addition to the work reported in the progress report (item A-22), the Theoretical Reactor Physics Section at Trombay has carried out the following programmes :

1. Evaluation of neutron cross-sections in the resolved and unresolved resonance regions.

- i) A computer code RESEND to evaluate the neutron cross-section in the resolved and unresolved resonance regions was modified and commissioned on CDC-3600 computer. The code consists of two overlays and is based on single and multilevel Breit Wigner theory, Adler and Adler formalism in the resolved resonance region, and Lane and Lynn theory in the unresolved resonance region.
- ii) Cross-sections for Na, Fe, Cr; Ni, Th-232, Pa-233, U-233, U-234, U-235, U-236, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Am-243 and Cm-244 were evaluated in resonance regions with the resonance parameters taken from ENDF - data files and the point cross-sections thus generated were combined with the background corrections listed in ENDF-files. These cross-sections can now directly be used in generating the unbroadened dilute-multigroup cross-sections for reactor physics studies.

2. Generation of Legendre Coefficients and Transformation Matrices.

Using the updated scattering cross-section data from ENDF-files Legendre coefficients have been generated at 1021 energy points in the energy range 0.4 eV to 10 MeV with a constant lethargy width of 1/60 for nuclides B,C,Be,O,Na,Cr,Fe and Ni.

3. Generation of Multigroup Cross-sections.

To carry out the reactor physics studies multigroup cross-sections for fissile, fertile and structural materials have been generated in the energy range 0.2 eV to 15 MeV using the point cross-section data from ENDF-files. The discrete level, inelastic and (n,2n) scattering matrices have also been evaluated.

4. Compilation

A compilation programme for charged particle reaction data has been started at the Banaras Hindu University, where a group has started compilation on (d,d) and (d,p) reaction data for all targets at all energies. The interest there is the development of a proper coupled channel reaction theory and computer codes to account for angular distributions and absolute cross-section in a global way.

ISRAEL

In addition to the Progress Report to INDC, the following items were mentioned by Amiel.

- Independent, partial and cumulative fission yields from ^{232}Th and ^{235}U fission produced by fission neutrons, and from ^{252}Cf spontaneous fission
- Thermal neutron fission yields of ^{233}U and ^{235}U (published in the 1975 March issue of Phys. Rev. C.)
- Re-evaluation of delayed neutron data previously reported by Amiel et al. in Nucl. Sci. Eng.
- New data on nuclear properties of very short-lived nuclei produced from fission and separated by an on-line isotope separator (SOLIS).

ITALY

Benzi informed that a detailed progress report would be published as NEANDC (E) 162 vol. 7. The following points were underscored :

A) Measurements

i) Level schemes

At Florence University, experimental work carried out on ^{49}V , ^{46}Ca , ^{54}Mn , ^{45}Sc , ^{96}Tc .

ii) Charged particle reactions.

The $\text{T}(^3\text{He}, \text{n})^5\text{Li}$ reaction was studied by the Trieste University group at incident ^3He energies from 2 to 5.5 MeV using the pulsed-beam time-of-flight method.

The experimental differential cross sections for neutron arising from the ground and first excited state of ^5Li were compared with theoretical curves, which are in reasonable agreement with the experimental data.

The Catania group extended the study of the $^7\text{Li}+d \rightarrow 2\alpha + n$ to $E_d = 7$ MeV. Preliminary results show a cross-section at least one order of magnitude lower than at $E_d = 1$ MeV.

A similar study was carried out for the reaction $^9\text{Be}+d \rightarrow t+2$ at $E_d = 1.7$ MeV. The analysis of the results is underway.

- iii) Average cross section measurements of structural materials in fast neutron spectra.

These measurements, based on the null-reactivity method, are carried out at Bologna (by CNEN, AGIP-N, and CCR-Ispra) by using the RB-2 fast-thermal reactor.

Very preliminary results obtained for Iron seem to indicate a $\frac{\sigma_c}{\sigma_f} \sim 10^{-5}$ experimental ratio about 30% lower than the one predicted by using ENDF/B-I for Iron capture.

Measurements on Ni, Cr and SS are underway or scheduled for the end of this year.

B) Evaluation

The evaluation of 22 fission products underway at the CNEN (Bologna) in the framework of French-Italian cooperation for fast reactors has been completed.

JAPAN

In addition to the Progress Report (INDC(JAP)-28"L"), Fuketa informed that a 20 MV tandem machine would be ordered by JAERI from the National Electrostatics Corporation of the United States.

This is a vertical folded type machine, whose guaranteed performance are as follows :

- 5.0 μ A at 20.0 MV terminal voltage for proton DC beam,
- 0.5 μ A at 20.0 MV terminal voltage for iodine DC beam,
- 0.8 mA at 20.0 MV for \leq 1.0 nanosecond FWHM, 1 MHz pulsed proton beam.

NETHERLANDS

The only remark by Waspra was that the organization for Atomic Energy in Netherlands, formerly RCN-Petten, changed its name to Netherlands Energy Development Agency.

ROMANIA

In addition to a short description of several codes for the production and handling of nuclear data libraries, the following activities carried out at the Institute for Atomic Physics (IAP), Bucharest, were mentioned by Rapeanu.

A) Measurements

- Measurements of neutron interaction with Boron isotopes in the MeV neutron energy range
- Production and study of new fissionable isomers in the U, Pu and Am region
- Measurements of angular distribution of neutrons produced in (p,n) and (α ,n) reaction on medium nuclei
- Simulation of irradiation with fast neutrons by irradiation with alpha-particles
- Measurements of excitation functions of some reactions in order to determine the optimum conditions for producing new radioisotopes
- Measurements of cross-sections for X-ray fluorescence by charged particles and neutron activation
- Measurements of the lifetime of excited nuclear states via Doppler and Planger shift.
- Production of new isomers and g-factor determination for medium nuclei.

The above mentioned measurements were carried out by means of the U-120 cyclotron. Measurements performed by using the IAP tandem and betatron in the field of fundamental nuclear physics were also mentioned.

A high accuracy absolute determination of neutron fission cross section of ^{235}U was carried out by using the IAP reactor, under IAEA contract.

B) Facilities

A facility for generating a neutron standard spectrum was built at the Institute for Nuclear Technology, Bucharest, in order to improve multi-group nuclear data by means of integral experiments.

SWEDEN

A) Measurements

Condé reported that at the Neutron Physics Laboratory at Studsvik earlier measurements on elastic neutron scattering performed on a large number of elements at several energies in the energy region from 1.5 to 8 MeV, have been somewhat extended recently. New experiments are in progress at about 10 MeV neutron energy for the same elements as in the previous study.

Furthermore, to test the optical model calculations in more details, experiments have been made in an angular region extending up to 174° . It was concluded that the previous calculations give a satisfactory description even in the increased angular interval.

From a systematic study of neutron inelastic scattering in the energy range 2.0 to 4.5 MeV it has been found that the H-F-Moldauer formalism well describes the experimental data in most cases. However a discrepancy of a factor 2 has been observed for some levels in odd-mass nuclei. The discrepancy might be due to collective states in the odd-mass nuclei which are not taken into account in the formalism.

Studies are underway at the Neutron Physics Laboratory on decay heat problems by measuring the delayed gamma-rays from thermal fission of ^{235}U . The gamma-ray emission is studied from a few seconds up to about 30 minutes after fission.

The measurements of the $^{59}\text{Ni}(n,\alpha)$ cross section at the Department of Reactor Physics at Chalmers University of Technology was reported to the Washington Conference. The result for the $^{59}\text{Ni}(n,\alpha)$ thermal cross section

was 22.2 ± 1.7 barns, which is higher than the value by Eiland and Kirouac (13.7 ± 1.2 b) but also slightly higher than the value by Werner and Santry (18.0 ± 1.6 b).

At the Department of Nuclear Physics of Lund University measurements of fast neutron capture cross sections using activation techniques have continued. The activation capture cross section of $^{115}\text{In} (n, \gamma) ^{116}\text{In}$ at 15 MeV is about 0.9 mb which is an order of magnitude lower than the results from previous measurements using activation techniques. The discrepancy might be due to low energy secondary neutrons which were not properly taken into account in those latter measurements.

At the Swedish Research Council's Laboratory at Studsvik studies on decay data (γ - rays, conversion electron, half lives, delayed neutrons) of short lived fission products have continued by use of the isotope separator on-line with the R20 reactor.

Fast neutron capture reaction studies have continued at the Tandem Accelerator Laboratory at Uppsala. A better theoretical description of the mechanism has been developed by introducing collective effects in the direct-semi-direct capture model.

The studies of the gamma-ray production cross section in light nuclei, and of fission cross section and fragment angular distribution have also continued in the neutron energy range 5-11 MeV, but no final data yet exist.

B) Facilities

The 6 MeV tandem-pelletron has been delivered to the Nuclear Physics Laboratory at Lund University. The machine is equipped with a duoplasmatron ion-source for the acceleration of p, d and He-ions. The research program will include neutron physics.

U K

Rose reported the following additional items to the UK Annual Progress Report.

A) Measurements

In high energy neutron capture work on the Harwell linac, it has been found possible to improve the signal/background ratio, by about a factor of

10 at 150 keV, by the use of a 30 cm liquid He filter to remove the high energy neutrons which otherwise arrive early and, after moderation, are detected at the same time as the lower energy neutrons of interest.

A depletion of the Li content of two samples of Li-glass, around the cylindrical surface, was discovered recently. (Nothing is known about the flat surfaces, or the effects on scintillation properties).

This depletion, which extends up to 1 mm from the surface, was measured by a neutron transmission method, which also revealed some different materials replacing the lithium. A tempting theory to explain the effect is that such glasses are ground under water and that as lithium is a very mobile element, it has moved and been replaced at least partly by hydrogen. This effect is unimportant in many experiments, where a neutron beam is collimated through the centre of the glass, but it may be important in others where the whole glass is irradiated.

B) Facilities

At Harwell approval was received to build a 136 MeV (unloaded energy) electron linear accelerator to inject into the existing neutron booster and flight paths, though one or more additional target cells will also be built. Its overall parameters will be similar to ORELA. The new machine should be operational in the middle of 1978 and the existing machine should operate at least until the end of 1976.

A new 30 MeV linac, primarily for neutron studies and photoneutron reactions, is being built at the Kelvin laboratory of the U. of Glasgow.

The beam from this machine will also be directed into either an existing target cell for neutron work or into a new cell. This machine should be operational some time in 1976.

C) Evaluation

A new programme has been started up on the study of nuclear incineration, to examine whether it is technically feasible to destroy radio nuclides (primarily the actinides) by transmutation in a reactor. The first objective is to investigate whether the nuclear physics "is on our side" in this matter. Calculations have been carried of the quantities of high actinide remaining after continuous irradiation for up to 32 years in hard and soft spectrum fast reactors and of the potential hazard remaining at any time, and the initial results are encouraging.

It is already clear that hard spectrum reactors are better than those with softer spectrum and that, for example, if a fuel could be left to 100% burn-up, with fission products extracted, there would be a slight improvement to the neutron economy in a CFR and a marked benefit in a DFR spectrum.

Sensitivity studies have begun to show how sensitive the calculations are to the assumed cross sections, which were themselves a mixture of the rather scanty experimental data with theoretical values derived in recent work by J.E. Lynn. As expected, the preliminary indications are that the most important cross sections will be those of Am-241, Am-243 and Cm-244.

U.S.A.

Motz and Smith confined their remarks mainly to highlights of INDC (USA)-72/U.

A) Measurements

- a) At Brookhaven National Laboratory, a number of activation cross sections at 24 KeV were measured making use of the HFBR tailored-beam facility.
- b) At Lawrence Livermore Laboratory. The Linac was used to perform prompt measurements for ^{235}U in the 0.5-20 MeV neutron energy range. Preliminary results were shown in INDC(USA)-72/U. Fission cross section ratios $^{233,4,6,8}\text{U}/^{235}\text{U}$ (see UCRL-76219) and $^{241}\text{Pu}/^{235}\text{U}$ (see UCID-16878) were measured in the energy range 1 KeV-30 MeV and 100 KeV-20 MeV, respectively.
- c) At Los Alamos Scientific Laboratory thermal neutron capture were measured for Th, U, Nb and ^{59}Ni with very low background. The experimental set-up allows measurements of pbarn cross-sections. Motz called attention upon the measurements on ^{59}Ni , reported at pg.28 and 89 of INDC(USA)-72/U. The results had to be renormalized, due to a misinterpretation of sample composition. Neutron spectrum sources through $\text{T}(p,n)^3\text{He}$ and $\text{H}(t,n)^3\text{He}$ were studied at ~ 10 MeV. Measurements on neutron production from Be at 10 MeV were also carried out at LASL. Experimental results show large

discrepancies when compared with theoretical estimates. Motz mentioned that commercially available ^3He neutron counters could be unsatisfactory for long irradiation periods. Technical development for this kind of counters which are important for safeguards were studied. Bayhurst et al, measured threshold neutron cross section for a large number of nuclei in the 7.5-28 MeV energy range (see Phys.Rev.C,12, 451,1975). The results of radio chemical analysis of fission products yields in twelve fast assemblies were tabulated and would be published at the end of 1975.

d) At Oak Ridge National Laboratory, Physics Division. Motz called attention to the following experimental work (see ORNL-5025 Progress Report).

- neutron capture and absorption measurements of ^{59}Ni for thermal and resonance energy neutrons (Raman et al)
- absolute neutron detector calibration in the 10-30 MeV energy range (Fowler)
- measurements on neutron spectra from Ta, H_2O and Be target used at ORELA (Harvey)

In addition Motz informed that the two photons decay in $\text{H}(\text{n},\gamma)\text{D}$, as indicated by the "Grenoble experiment", was not, very likely, a real effect.

e) At Argonne National Laboratory. Studies on the delayed neutron yields as a function of the incident neutron energy were mentioned by Smith, who mentioned also the programme on ^{238}U , Pu and Am fission cross ratios to ^{235}U and the Interlab Committee Programme on Half-Lives. In particular, he pointed out that recent measurements support the ^{239}Pu half-life obtained via calorimetric determination.

f) The extensive study of neutron elastic and inelastic scattering in the mass region A ~ 90-100 underway at the University of Kentucky was mentioned by Motz.

B) Facilities

The following information was provided by the US delegation.

- A pulsed neutron facility (WNR) was developed at LAMPF. Pulse width can vary from few nanoseconds to several microseconds. The source, comparable with or better than ORELA, should be ready to operate in 1976. Total expenditure: about 5.5 million dollars.

- A 400.000 US \$ budget was available in 1975 in order to improve the ORELA injection system by a factor 6-10, with a pulse of 3ns at the target. The system should be completed in 1977.
- A new 14 MeV Intense Neutron Source (INS) for CTR studies was developed at LASL. The "marriage" between beam and target was scheduled for Spring 1976.
- Columbia University Synchro-Cyclotron will operate at full energy at the end of 1975.

C) Evaluation

Several reports were distributed by Smith (available through NDS), who drew attention on Moldauer's paper "Why the Hauser - Feshbach formula work", published in Phys.Rev. C,11,426 (1975). Motz mentioned error function studies performed at Idaho for after heat by fission products.

Old D(d,n) and T(d,n) cross section measurements by Arnold et al (see Phys.Rev.,93,483,1954), were analysed in the framework of R-matrix theory at LASL (see USNDC - CTR-2). In the original work experimental data below 16 KeV were neglected because they were appreciably below the Gamow theoretical curve. New fits have indicated about 8% increase of the cross sections below 10 KeV.

USSR

Yankov highlighted the Proceedings of the 3rd All-Union Conference on Neutron Physics, (Kiev, June 1975)

A) Measurements⁽⁺⁾

The radiative capture cross section of ^{197}Au for a neutron energy in the neighbourhood of 600 KeV was measured by the activation method⁽¹⁾. The source of neutrons was the T(p,n) reaction. The induced activity was measured by means of a γ spectrometer having a Ge(Li) detector with known efficiency; the neutron flux was measured by gaseous hydrogen counters of different constructions.

The radiative capture cross section of gold, tantalum and indium was measured in the neutron energy interval 4 - 380 KeV (2). The relative cross section was determined by means of the known dependence on energy of the ^{10}B (n, $\alpha\gamma$) reaction cross section. In order to obtain the absolute

(+) References are given in Appendix X

value, the gold relative capture cross section at 30 KeV energy was used. The error in the cross section was established to be 5-7.5% for gold and 7.5-9% for tantalum and indium.

Absolute measurements of the fission cross section of ^{235}U at 14.8 MeV neutron energy were carried out by the associated particle method (3) with a 1.7% accuracy. The value obtained is 2.35 ± 0.04 barns.

Absolute measurements of the ^{235}U and ^{238}U cross sections for fission by ^{252}Cf fission spectrum neutrons were performed (4). Recorded were coincidences of fragments from the Californium fission with fragments from the fission of the studied targets. The following cross section values were obtained: 1265 ± 19 mb for ^{235}U and 347 ± 6 mb for ^{238}U .

Comparisons of the obtained data with the results of Grundl et al. (1972) (1207 ± 52 mb and 324 ± 14 mb, respectively) and also with the calculated values of 1281 and 352 mb, respectively, were performed.

The measurement of the energy spectrum of prompt neutrons from spontaneous fission of ^{252}Cf was performed by the time-of-flight method (5).

The spectrometer resolution was 4 ns and the flight distance 140 cm.

The fragments were detected by a silicon surface barrier detector and the neutrons by a scintillation detector with known (within 3.5% accuracy) relative efficiency. For the energy interval 0.5-7.0 MeV, $T = 1.46 \pm 0.02$ MeV.

The investigation of the neutron spectrum from ^{252}Cf fission in the neutron energy region 0.02-2 MeV was continued (6). The time-of-flight method based on 12.5, 25, and 37.5 cm was employed. A $^6\text{LiI}(\text{Eu})$ crystal of 1.9 mm thickness was the neutron detector. The full width at the half-maximum of the line was around 1 ns. The energy relation between the cross section for the $^6\text{Li}(n, \alpha)$ reaction and the calculated cross section values obtained in the recent years was used in refining the dependence of the detector efficiency on neutron energy.

For neutron energies below 200 KeV, the new data agree with the results published by the same authors at the 2nd Neutron Physics Conference (Kiev, 1973). In the neutron energy interval 0.8-2 MeV, the results obtained agree satisfactorily with the Maxwell distribution with $T = 1.40$ MeV; at lower energies, an excess (of 10-15%) over the Maxwell distribution was observed. The data are preliminary.

The experimental determination of the neutron emission probability for ^{252}Cf fission for the times exceeding 10^{-14} sec was carried out (7). For this purpose, a comparative study on neutron spectra from Californium fission fragments moving in vacuum in a dense medium was performed.

Within the limits of experimental error, the spectra have coincided in the interval where the comparison was made, namely 0.05-7 MeV. The emission time for neutrons with energies above 500 KeV (laboratory coordinate system) was less than 2×10^{-14} sec and the fraction of neutrons with emission time $t > 10^{-12}$ sec does not exceed 1 - 1.5%. The upper limit of emission time for neutrons with energies below 500 KeV is 10^{-13} sec and the fraction of neutrons with emission time $t > 10^{-12}$ sec is less than 5%.

The energy dependence of the cross section for the radioactive isotope ^{152}Eu ($T=12.4$ yr) in the energy interval 0.02 - 02 eV was obtained by the transmission method (8). The cross section value at $E_n = 0.0253$ was 12.800 ± 600 barn.

The transmission of an ^{243}Am sample was measured for neutrons of 0.4 eV energy and higher by the time-of flight method (9). Parameters for 48 levels and the total resonance integral were computed.

The obtained mean separation between levels is $\bar{D} = 0.71$ eV and the strength function is $S_0 = 0.89 \times 10^{-4}$.

Also measured were total neutron cross sections for ^{226}Ra , ^{181}Ta , ^{182}Ta and ^{147}Pm and the resonance parameters determined (10). The total cross section σ_{tot} for ^{226}Ra for the neutron energy range below 2000 eV, resonance parameters for ^{226}Ra to 880 eV and for ^{181}Ta , ^{182}Ta , and ^{147}Pm in the energy range to 1000 eV were determined. Values of the neutron strength functions and resonance integrals for ^{182}Ta and ^{147}Pm were also presented for the thermal region.

Resonance parameters for the $^{244,245,246,248}\text{Cm}$ isotopes for neutron energies between 1.5 eV and 200 eV were investigated (11). The transmission through samples with 70 and 140 ns/m was measured by the time-of-flight method. Resonance parameters and total resonance integrals were determined. Statistical analysis for the ^{244}Cm resonances was carried out. The ^{245}Cm data are preliminary.

Thermal cross sections and capture and fission resonance integrals for the $^{241,243}\text{Am}$, ^{249}Bk , ^{249}Cf isotopes were obtained (12). The measurements were made by the relative method using as reference the capture cross sections of ^{197}Au and ^{59}Co .

The ^{238}U radiative capture cross section for neutrons in the energy interval 0.6 - 1 MeV was measured by the activation method (13).

The cross section value at 1026 KeV energy agrees with earlier results of the same authors published at the First All-Union Congress on Neutron Physics (Kiev, 1971), for which the ^{235}U fission cross section was used as reference. The data for the neutron energies of 590 and 790 KeV are in agreement with the latest data of Pönitz (1974).

More accurate data on $\alpha = \sigma_{ny}/\sigma_{nf}$ for ^{239}Pu in the neutron energy region 0.2 - 30 KeV as well as a comparison with works performed after 1972 are given in Ref.(14).

The fission cross section for ^{235}U was measured with a neutron spectrometer for neutrons from the 60 MeV linear accelerator IAZ with a nominal resolution $\Delta t/2L \approx 3\text{ns/m}$. Resonance integrals and fission integrals were computed for the energy region 0.01 - 10 KeV; these values were compared with published data (15).

The energy dependence of the average emission of prompt fission neutrons, $\bar{\nu}$, from ^{233}U , ^{238}U and ^{239}Pu in the primary neutron energy range 0.8-5.0 MeV was investigated (16). Recommended curves $\bar{\nu} = f(E)$ were obtained by means of polynomial representation and the character of the deviation from a linear dependence was studied.

The fission cross section ratio $\sigma_{nf}(^{239}\text{Pu})/\sigma_{nf}(^{235}\text{U})$ in the neutron energy interval 0.024 - 7.4 MeV was measured (17). Monoenergetic neutron sources were used for the $\text{Li}(p,n)$, $\text{T}(p,n)$, $\text{D}(d,n)$ reactions. The fragments were recorded by a ionization chamber. The main source of error (1.6%) was concluded to be in determining the amount of fissioning nuclei in the plutonium and uranium foils. A comparison of the results obtained with experimental data found by other authors was presented.

Cross sections for γ -ray production in inelastic interactions of 14 MeV neutrons on 17 nuclei ($\text{Li}, \text{Be}, \dots \text{Al}, \dots \text{Fe}, \dots ^{235}\text{U}$) were measured (18). The time-of-flight method and a total absorption spectrometer with $\text{NaI}(\text{Tl})$ crystal were used.

In order to study the gamma radiation from inelastic scattering of fast neutrons, a nuclear reactor of the IRT type (19) with neutron flux falling as $\exp(-0.72E)$ for $E > 1$ MeV was used as neutron source.

Gamma-ray spectra for most of the elements in the Mendeleev periodic table and for more than 20 separated isotopes were measured in an external neutron beam $\text{Ge}(\text{Li})$ detectors. At present, an atlas of energies and intensities of γ radiations from inelastic scattering of fast neutrons on elements for the energy range of E_γ from 100 KeV to 2-5 MeV is put together in atomic number order.

B) Facilities

The possibility of obtaining localized pulsed sources of mono-energetic neutrons of nanosecond duration created by laser radiation incident on special targets was investigated (20). In particular, neutron emission (of e.g. up to 10^6 neutrons/sec.), depending on the laser energy, was measured. In order to achieve the conditions of ignition and heating of the thermonuclear plasma by multibeam laser light, a method of preparation and selection of spherical shell filled with deuterium-tritium mixture was devised (21). Experimentally supported calculations indicate that for laser energies between 10^2 and 10^4 joules one can obtain $10^9 - 10^{14}$ neutrons in 10^{-11} sec on a source diameter of approximately 10 microns. By further increasing the laser energy to 10^6 joules, experiments of this type can examine how unique are the possibilities of conducting neutronic and nuclear experiments at neutron densities exceeding solid particle densities, e.g., exotic nuclear reactions with neutrons, neutron-neutron scattering. It was shown that the investigated elements can be inserted in the target composition.

A neutron time-of-flight spectrometer at the exit of the synchrocyclotron LIYAF(22) in Gatchina was used for studies of the physics of fission and of reactions of the (n, γ) type. A proton beam of 1 GeV energy falls on a lead target; the duration of the neutron pulse without slowing down was 8-10 nsec. At a current of 1 μ A and 50 Hz frequency the total intensity is approximately 10^{14} ns/sec.

CBNM-EURATOM (Geel)

A) Measurements

Liskien informed that CBMN Activities were described in NEA-NDC(E)-162 "U" Volume III.

Two new items were not included in that report

- measurements of neutron total, scattering and capture cross sections in the 10 ev to 4 keV energy range.

These data were needed to normalize integral experiments on fission products performed at RCN Petten.

- Measurements of cross-sections for the reactions $^{103}\text{Rh}(n,n')$ and $^{115}\text{In}(n,n')$ (population of isomeric state) from threshold to 7 MeV. These data were needed for reactor neutron dosimetry. Relative data below 3 MeV yet available.

B) Facilities

The modernization of the two accelerators (Linac, VDG) was going on as described in the progress report; the delay was of the order of 1 month.

V.B. REPORTS ON NUCLEAR DATA ACTIVITIES IN COUNTRIES NOT REPRESENTED ON INDC

The final report on Nuclear Data activities in the NDS Service area will be published as INDC(SEC)-50 and distributed.

VI. REPORTS OF TECHNICAL AND AD-HOC-SUB-COMMITTEES⁽⁺⁾

VI.A. Standards Sub-Committee

The report was introduced by Liskien, who stressed the importance of good data retrieval from the 4-Centres, and the usefulness of simultaneous evaluation of standards in which ratio measurements were taken into account. The importance of very carefully determined neutron energy and γ -ray intensity standards had led to the establishment of an ad-hoc group to deal with neutron energy standards. He mentioned that a γ -ray standard in the high energy region (above 1.5 MeV) which uses ^{242}Cm and ^{13}C as sources had been set up by Legrand, who expected that the accuracy of this standard should be of the order of 5%.

The final report will be published under separate cover as soon as possible.

(+) Discussed on Friday morning

VI.B. Discrepancies Sub-Committee

The Sub-Committee had been unable to discuss all the points on its agenda, but had agreed to a report format, similar to the one adopted by the corresponding NEANDC Sub-Committee. The Report would consist of three sections, namely: 1) data description, 2) nature of discrepancies, and 3) recommendations and/or suggestions. More detailed information would be given in appropriate Appendices.

Rowlands, Fuketa, Smith, Cierjacks, Usachev and Vlasov highlighted various parts of the report. In particular, Smith mentioned new measurements on ²³⁸U inelastic scattering that would be reported in ANL/NDM-16; major changes to existing evaluations were foreseen.

Usachev distributed a paper on cross-section modifications suggested by an analysis of integral measurements (Appendix XI).

During the presentation, Action n. 31 was agreed too.

The final report will be published under separate cover as soon as possible.

VI.C. Ad-hoc Sub-Committee on INDC/NEANDC Relationship

A short discussion took place on the coordination of INDC and NEANDC meetings. It was decided that a time schedule for next meetings should be agreed by the Chairmen of the two Committees (Action n. 32). The Sub-Committee was then abolished.

VII. REPORTS OF POLICY SUB-COMMITTEES⁽⁺⁾

VII.A. Energy Application Sub-Committee

The Sub-Committee Report (Appendix XII) was limited to the areas of fission product, reactor dosimetry and fusion nuclear data. A short discussion on FPND Newsletter also took place.

Rose, Motz, Smith and Cierjacks pointed out that National Data Centres and INDC members should be informed about the FPND Questionnaire distribution list. This should be done also for any "Questionnaire" circulated by the NDS. (Action n.33). Smith felt that the FPND Newsletter should be monitored by the INDC, and a number of actions were agreed for

(+) Discussed on Friday afternoon

this purpose (see Actions n. 34, 35, 36, 37 and 38). Schmidt said that the next FPND Panel had been deferred to the first half of 1977.

Vlasov commented on nuclear data for reactor dosimetry activities at NDS. Smith and Motz warned against too ambitious programs and redundancy with similar work carried out elsewhere. Schmidt agreed with Smith. Vlasov indicated that NDS activities in reactor dosimetry would be directed towards the following objectives: a) data compilation and evaluation and b) coordination of activities on benchmark measurements for integral testing in microscopic data.

The above activities will be carried out in cooperation with existing groups, for benefit of 'small' and developing countries.

VII.B. Non-Energy Applications Sub-Committee

The report is given in Appendix XIII. Berenyi pointed out to the Sub-Committee which action⁽⁺⁾ should be fulfilled within the next ten months. Rose warned against the complexity of industrial gauging in practical cases.

Cross pointed out that i) a preliminary survey on nuclear structure data requirements for medicine showed that needs were small; and, ii) data needs for activation analysis were not discussed. A working paper on data needs for biomedical purposes discussed during the Sub-Committee meeting is given in Appendix XIV (see Action n. 39).

VIII. MEETINGS

VIII.A Past Meetings

Highlights of Washington, Paris (Atomic Masses) and Kiev Conferences were presented. See Appendix XV, XVI and XVII.

VIII.B Present Meetings

About 30 papers had been submitted to the "Nuclear Theory Consultant Meeting" at ICTP (Trieste) scheduled for December 1975.

(+) NOT reported in the Action list

VIII.C. Future Meetings

Schmidt said that the IAEA Specialists Meeting on Nuclear Data Requirements for Shielding had been deferred to October 1976 (see Actions n. 41, 42 and 43). Smith indicated that the 1976 Lowell International Conference on the Interactions of Neutrons with Nuclei was shaping up as scheduled.

The scopes of the Seminar on Nuclear Theory for Applications planned to be held at ICTP-Trieste in 1977 were briefly outlined by Schmidt.

The Seminar will consist of three workshops, each about 2 weeks long, on

- (a) Nuclear reaction theories
- (b) Nuclear fission theory
- (c) Nuclear theory computer codes

The subject matter will be directed towards applications and be mainly for benefit of developing countries.

The discussion on an IAEA International Nuclear Data Conference, to be held in the 1978/79 period, was mainly focused on the usefulness of such a Conference (Appendices XVI and XVII). The prevailing belief was that the Conference should be dropped in favour of relatively small meetings (e.g. specialist meetings), felt to be more effective.

Alternatively, IAEA co-sponsorship to national or regional conferences on nuclear data was strongly recommended in order to ensure participation of developing countries at the most important meetings.

After discussion of the proposed sequence of conferences outlined in Rose's paper, the IAEA co-sponsorship of the 1979 "Washington Conference" (to be held probably at Seattle) was recommended.

In addition the possibility of having an IAEA co-sponsorship to the next NBS Panel on Nuclear Standard Reference Data, to be held in Spring 1977, will be explored (Actions n. 44 and 45). It was clearly stated that these actions would not imply, for the moment, any official commitment for the organisations concerned.

A P P E N D I C E S

AGENDA

8th INDC Meeting, Vienna, 6-10 October 1975

(Background references are listed in Attachment A)

(WP = Working paper; names = lead speakers)

MONDAY
SESSION A

I. Introductory Items (15 m)

9:30 - 9:40 - Opening of the meeting (10 m)

9:40 - 9:45 - Announcements (5 m)

MONDAY
SESSIONS A+B

II. Committee Business (2 h 45 m)

9:45 - 9:55 A. Consideration and approval of complete minutes of the 7th INDC Meeting (10 m)

9:55 - 10:05 B. Consideration and adoption of agenda of 8th INDC Meeting (10 m)

10:05 - 10:15 C. Attendance of Observers (10 m)

10:15 - 10:45 D. Review of actions arising from the 7th INDC Meeting (30 m)

10:45 - 11:00 E. Membership of standing, and new and old ad-hoc subcommittees (15 m)
(e.g. new ad-hoc Subcommittee on INDC/NEANDC Relationship)

11:00 - 11:30 Coffee break (30 m)

11:30 - 12:00 F. Final approval of Revised Draft of INDC Methods of Work (Schmidt) (30 m)

12:00 - 12:30 G. Future of the Energy/Non-energy Applications Subcommittee (30 m)

- 12:30 - 12:45 H. INDC Correspondents and documents distribution, new items (atomic and molecular data for fusion, reduction of L-distribution, etc.) (Lorenz) (15 m)
- 12:45 - 13:00 I. Guidelines for shorter INDC Meetings minutes (Chairman) (15 m)

13:00 - 14:00 Lunch Break

MONDAY
SESSIONS C+D

Meetings of all four standing subcommittees (3 h)

14:00 - 17:30

TUESDAY
SESSIONS A+B

III. Neutron nuclear data (1 h 30 m)

- 9:30 - 9:45 A. Report on 11th Four Centre Meeting (Lemmel) (15 m)
- 9:45 - 10:00 B. Additional information from neutron data centres other than NDS (15 m)
- 10:00 - 10:30 C. Two years publication cycle of CINDA (WP Lemmel) (30 m)
- 10:30 - 11:00 D. International exchange and assessment of use of evaluated neutron data (Smith, Usachev) (30 m)

11:00 - 11:30 Coffee break (30 m)

IV. "Non-neutron" nuclear data (1 h 30 m)

- 11:30 - 12:00 A. Progress reports on activities, services and co-ordination of "non-neutron" nuclear data centres and groups (WPs all members concerned) (30 m)

- 12:00 - 12:30 B. Report on meeting on CPND* compilation for applications (Lemmel) (30 m)
- 12:30 - 13:00 C. Discussion of recommendations from "non-neutron" nuclear data meetings April/May 1974, including plans for 1976 meeting (WP Lorenz) (30 m)

13:00 - 14:00 Lunch break (60 m)

TUESDAY
SESSION C

V. Atomic and Molecular Data for Fusion (2 h)

- 14:00 - 14:30 A. Presentation (Schmidt, Lorenz, Phillips) (30 m)
- Background
 - Survey report
 - Consultants' Recommendations
 - Recommendations by IFRC
- 14:30 - 15:00 B. Manpower needs for A+M programme component (Schmidt) (30 m)
- 15:00 - 16:00 C. Discussion (60 m)

16:00 - 16:30 Tea/Coffee break (30 m)

TUESDAY
SESSION D

VI. Coordination of nuclear data activities
(measurements and evaluations) (1 h)

- 16:30 - 16:50 A. Status of development of regional nuclear data centres (Fuketa, Gemmell, Mehta) and of national nuclear data committees (Lorenz, members) (20 m)
- 16:50 - 17:15 B. Neutron data for reactor neutron dosimetry (Vlasov) (25 m)
- 17:15 - 17:30 C. FPND Newsletter (Lammer) (15 m)

* CPND = Charged Particle Nuclear Data

WEDNESDAY
SESSIONS A+B

VI. Coordination of nuclear data activities
(measurements and evaluations) (cont'd) (3 h)

9:30 - 11:00 D. WRENDA for fission, fusion and safeguards (WP Rose,
WP Usachev, WP Lemley) (90 m)

11:00 - 11:30 Coffee break (30 m)

11:30 - 11:50 D. WRENDA (continued) (20 m)

11:50 - 12:35 E. Nuclear data measurement in developing countries,
etc. (WP Fuketa, WP Mehta, WP Rose, WP Schmidt)
(45 m)

12:35 - 13:00 F. Status of NDS targets and samples programme
(Lemley) (25 m)

13:00 - 14:00 Lunch break (60 m)

WEDNESDAY
SESSIONS C+D

VII. NDS programme (3 h)

14:00 - 14:30 A. NDS activities and services (Schmidt/NDS Staff)
(30 m)

14:30 - 15:30 B. NDS composition and responsibilities (Schmidt/Lorenz)
(60 m)

15:30 - 16:00 Discussion (30 m)

16:00 - 16:30 Tea/Coffee break (30 m)

16:30 - 17:30 Discussion (continued) (60 m)

THURSDAY
SESSIONS A+B

VIII. Progress reports on nuclear data measurements,
facilities and evaluations (3 h)

- 9:30 - 11:00 A. Additions to submitted progress reports (90 m)
-
- 11:00 - 11:30 Coffee break (30 m)
-
- 11:30 - 12:30 A. Additions to submitted progress reports (cont'd) (60 m)
- 12:30 - 13:00 B. Reports on nuclear data activities in countries
not represented on INDC (30 m)
-
- 13:00 - 14:00 Lunch break (60 m)
-

THURSDAY
SESSIONS C+D

IX. Reports of technical and ad-hoc subcommittees (2.5 h)

- 14:00 - 15:00 A. Standards subcommittee (60 m)
- 15:00 - 16:00 B. Discrepancies subcommittee (60 m)
-
- 16:00 - 16:30 Tea/Coffee break
-
- 16:30 - 17:00 C. Ad-hoc subcommittee on INDC/NEANDC relationship (30 m)
- 17:00 - 17:30 Non-Agenda items (30 m)

FRIDAY
SESSIONS A+B

X. Reports of policy subcommittees (3 h)

- 9:30 - 11:00 A. Energy applications subcommittee (90 m)
-
- 11:00 - 11:30 Coffee break (30 m)
-
- 11:30 - 13:00 B. Non-energy applications subcommittee (90 m)

FRIDAY
SESSIONS C+D

XI. Meetings (2 h)

- 14:00 - 14:40 A. Past meetings (40 m)
- Washington Conference, March 1975 (Motz)
 - Atomic Masses etc. Conference, Paris, June 1975 (Wapstra)
 - Kiev Conference, June 1975 (Usachev)
- 14:40 - 15:00 B. Present meetings (20 m)
- TND Advisory Group Meeting, Karlsruhe, November 1975 (Lorenz)
 - Nuclear Theory Meeting, Trieste, December 1975 (Schmidt)
- 15:00 - 16:00 C. Future meetings (90 m)
1. 1976 IAEA Advisory Group Meeting on A+M data for fusion (10 m)
 2. 1976 IAEA Specialists Meeting on Nuclear Data Requirements for Shielding (10 m)
 3. 1976 Lowell International Conference on the Interactions of Neutrons with Nuclei (Smith) (10 m)
 4. 1977 Seminar on Nuclear Theory for Applications (10 m)
 5. 1978 IAEA Advisory Group Meeting on Nuclear Data for Fusion (10 m)
 6. 1978/79 Advisory Group Meeting on Nuclear and Atomic Data for Medical Purposes (10 m)
- 16:00 - 16:30

Tea/Coffee break (30 m)

- 16:30 - 17:00 7. 1978/79 International IAEA Nuclear Data Conference (WP Rose) (30 m)

17:00 - 17:30 XII. Committee business (Part II) (30 m)

- A. Review of actions arising from this meeting (Benzi) (15 m)
- B. Other business (10 m)
- C. Next (9th) INDC Meeting and adjournement (5 m)

Report to the INDC on U.S. Data Study

The Division of Physical Research of the US Energy Research and Development Administration (ERDA) has requested the Brookhaven National Laboratory to review the compilation and evaluation of nuclear structure and charged particle reaction data. Lead author in the study is Dr. Sol Pearlstein. The main objectives of the study are recommendations that if implemented should provide the research community with data compilations and evaluations that are updated at a reasonable frequency and with specialized data services that are required.

As part of the study the authors interviewed evaluators from many countries in order to obtain realistic estimates of the manpower required. Basic and applied research scientists the world over were surveyed by mail for the special insight they might provide. Before making their recommendations the authors combined these results with those of previous studies. At present, only the draft recommendations have been completed with the final report due to ERDA 15 October 1975.

The authors recommend that the U.S. effort in the evaluation and compilation should be a coordinated effort of several national laboratories and research groups. Significant participation by evaluators outside the U.S. is expected. Help in the coordination of these activities will be given by the IAEA's Nuclear Data Section. The U.S. activities would be consistent with the cooperation implemented for charged particle reaction data at the meeting held in Vienna September 1975.

The proposed evaluation network would contribute to three data files maintained in the US.

- 1) a complete bibliographic file,
- 2) a file of selected experimental data, and
- 3) a file of recommended data.

These files would be the source for several publications. The use of a centralized master data file would ensure consistency in values appearing in overlapping publications.

To accomplish the objectives of the study in a cost effective manner the report recommends that:

- 1) an evaluator network be established
- 2) unnecessary duplication of evaluation effort be eliminated
- 3) supporting services be centralized
- 4) international cooperation be used to share evaluation tasks
- 5) current efforts not be disrupted with smooth transitions made in new directions.

A working paper for the INDC Subcommittee
on Non-energy Applications

B. Rose, AERE, Harwell, UK

COMPILATION OF CROSS-SECTIONS FOR ION BEAM ANALYSIS OF MATERIALS

Abstract

Rutherford back-scattering and nuclear reaction analysis using ion beams are increasingly being applied by materials scientists for the quantitative analysis of solid surfaces. However, information regarding the appropriate scattering or reaction cross-sections, and thus the most suitable reaction to use, is difficult to obtain, being distributed throughout the literature of nuclear physics.

The group under Dr. G. Dearnaley at AERE proposes to compile a handbook of all the charged-particle scattering and reaction cross-sections measured to date, in a form suited to the needs of materials scientists, and to draw up a list of important cross-sections which are either unmeasured or insufficiently accurate, for the attention of nuclear physicists.

Historical background

The first application of Rutherford scattering of energetic ions to surface analysis was made in 1954 by Sylvan Rubin⁽¹⁾ working at the Stanford Research Institute, who measured the composition of deposits on the inner wall of gun barrels for the US Army.

A much more widely-publicized application took place in 1967, when alpha particles from a radioactive source carried by Surveyor 5 were scattered from the lunar surface to obtain an analysis of its composition.⁽²⁾ The results, for example the unexpectedly high titanium concentration, were well confirmed by analysis of lunar material collected during Apollo missions.⁽³⁾

More recently, both ion back-scattering and nuclear reaction analysis have been applied to the determination of near-surface composition of semi-conductor devices⁽⁴⁾⁽⁵⁾, alloys⁽⁶⁾ and corrosion films.⁽⁷⁾ Specially-equipped laboratories have been installed at IBM Thomas J. Watson Research Laboratory, at Bell Laboratories, and at the Naval Research Laboratory, Washington. To quote from a recent and valuable report⁽⁸⁾ by Dr. E.A. Wolicki of Nuclear Science Division, N.R.L.:

"In the past few years the field of surface analysis has seen the development of a surprising number of promising new physical methods based on the use of high-energy ion beams. Improvements and advances continue to be reported at a rapid pace at the time of this writing (December 1972) and the field can well be said to be scientifically most interesting and exciting".

The technique consists of irradiating a material sample with a beam of ions, such as protons, deuterons, ^3He or ^4He , and others, in the energy range from about 500 keV up to 5 MeV. These irradiations are performed in vacuum, and the ion species, usually from a Van de Graaff accelerator, is magnetically analysed so as to have a well-defined energy. Scattered particles or reaction products emitted from the target samples are detected, commonly with silicon surface-barrier detectors (9) and their energy spectrum is displayed with a multichannel pulse-height analyzer.

The energy spectrum so produced will be determined by the atomic species present in the surface of the target: in Rutherford scattering there is a simple relationship between the mass of the target atom and the scattered energy, while the energy loss suffered by ions that penetrate below the surface can be employed to measure the depth variation of composition. Depth resolutions of about 200 Å have been achieved. (4) If nuclear reactions are employed, the emission can be highly specific to a chosen nuclear species, and isotopic tracers have been widely used to study, for example, oxidation processes in an environment enriched in ^{18}O . Nuclear resonances in the $^{18}\text{O}(\text{p},\alpha)$ reaction at well-defined energies allow the corrosion film to be analysed as a function of depth. (10)

Although the methods described make use of sophisticated accelerator equipment, there is no lack of such facilities throughout the world, for over 300 Van de Graaff laboratories were established for nuclear research. The greatest concentration exists in the USA, where already university accelerator facilities are being applied to industrial analysis problems (e.g. California Institute of Technology, Kansas State University, etc.). In Britain, good use is being made of the accelerators at Harwell, which offer a wide range of ion energies together with a unique ion microbeam facility. (11) In Holland, the Philips organization is shortly to install a new Van de Graaff laboratory specifically for surface analysis, while in the USA Bell Laboratories is engaged in extending the energy range of its present facility to over 5 MeV, for the same purpose.

Proposed approach

A knowledge of the scattering or reaction cross-sections pertaining to the ion-target combination studied is essential in obtaining a quantitative materials analysis by the techniques described above. At sufficient-

ly low energies it has usually been assumed that the Rutherford scattering law

$$\sigma_R \propto \frac{Z_1^2 Z_2^2}{E_0^2}$$

applies, where

- σ_R = Rutherford scattering cross-section
- Z_1 = ion atomic number
- Z_2 = target atomic number
- E_0 = incident ion energy

For the commonly-encountered $^{16}\text{O}(\alpha, \alpha)$ alpha scattering process, however, there are significant (30%) departures from Rutherford scattering due to nuclear resonances at around 3 MeV. Such resonances, leading to large increases in cross-section at certain energies and angles of observation, have been utilised by Dearnaley et al. (12) to study corrosion films. In nuclear reaction analysis it is necessary to know not only the cross-sections for the specific reaction chosen for analysis, but those of possible competing reactions due to other constituents in the sample. A careful selection of ion energy and angle of observation may then be required.

The information needed for such work is spread very widely throughout a large body of literature extending over many years of research into low energy nuclear physics. There is no single compilation available, although several incomplete sources exist. The most valuable reference work consists of the series of compilations (13) under the title "Energy levels of Light Nuclei", pioneered by F. Ajzenberg-Selove and T. Lauritsen. However, this work lists principally the original papers that contain the sought-after cross-sections, and the discussion of the data is intended for nuclear physicists.

Such information is nowhere to be found in a form that is readily accessible to the materials scientist who now needs to be able to apply ion beam techniques to the analysis of his specimens. Likewise, most nuclear physicists are unaware of the subtleties of semiconductor device fabrication, or of corrosion, in order to be able to cope with the unexpected analytical problem.

There is thus a need for a compilation of data, aimed specifically at the materials investigator, which will enable him both to choose an appropriate reaction or scattering method, and to analyse the resulting spectra. We propose to employ a small multi-disciplinary team to compile this data, together with references to the use of various reactions, etc. in materials analysis, and relevant observations, pitfalls, precautions,

etc. drawn from our experience and that of others. For example, in a number of published analyses the difference between cross-section ratios measured in the centre-of-mass and laboratory systems of coordinates was overlooked, introducing a systematic 8% error in oxygen determination by (α, α) scattering.

The Handbook would thus include an introductory section dealing with the principles of the method, and experimental technique. Factors such as the choice and preparation of suitable standard targets for intercomparison purposes have so far proved more pressing than the need for further data, although we anticipate that we shall discover a lack of specific data during the course of our compilation. Equally important to disseminate are the techniques of particle discrimination, pulse pile-up rejection and other methods well-known in the nuclear field, together with an awareness of the consequences of ion channeling in crystalline targets.

Figure 1 illustrates the kind of nuclear cross-section data which would follow, covering a range of ion energies up to about 5 MeV and appropriate detection angles. Ion species are to include protons, deuterons, ^3He and ^4He , and occasionally tritons (where their advantage outweighs the difficulties of handling ^3H). Some heavy-ion reactions induced by beams such as ^7Li , ^{11}B and ^{19}F in hydrogen analysis will also be included. Target nuclei will extend from the lightest (hydrogen) up to medium-weight species (titanium) with emphasis on those materials of greatest technological importance, including silicon, oxygen, carbon, hydrogen and nitrogen.

Experience in nuclear cross-section determination is essential in discriminating between conflicting data, and arriving at the most reliable information.

Finally, where data is found to be lacking, recommendations will be prepared in the form of a list of outstanding data requirements. By this means, the proper representations could subsequently be made to the data-gathering organizations (e.g. the IAEA International Nuclear Data Committee, Subcommittee on Non-energy Applications) so that the deficiencies could be widely published. The measurement of some of these required cross-sections could be the subject of a follow-up program.

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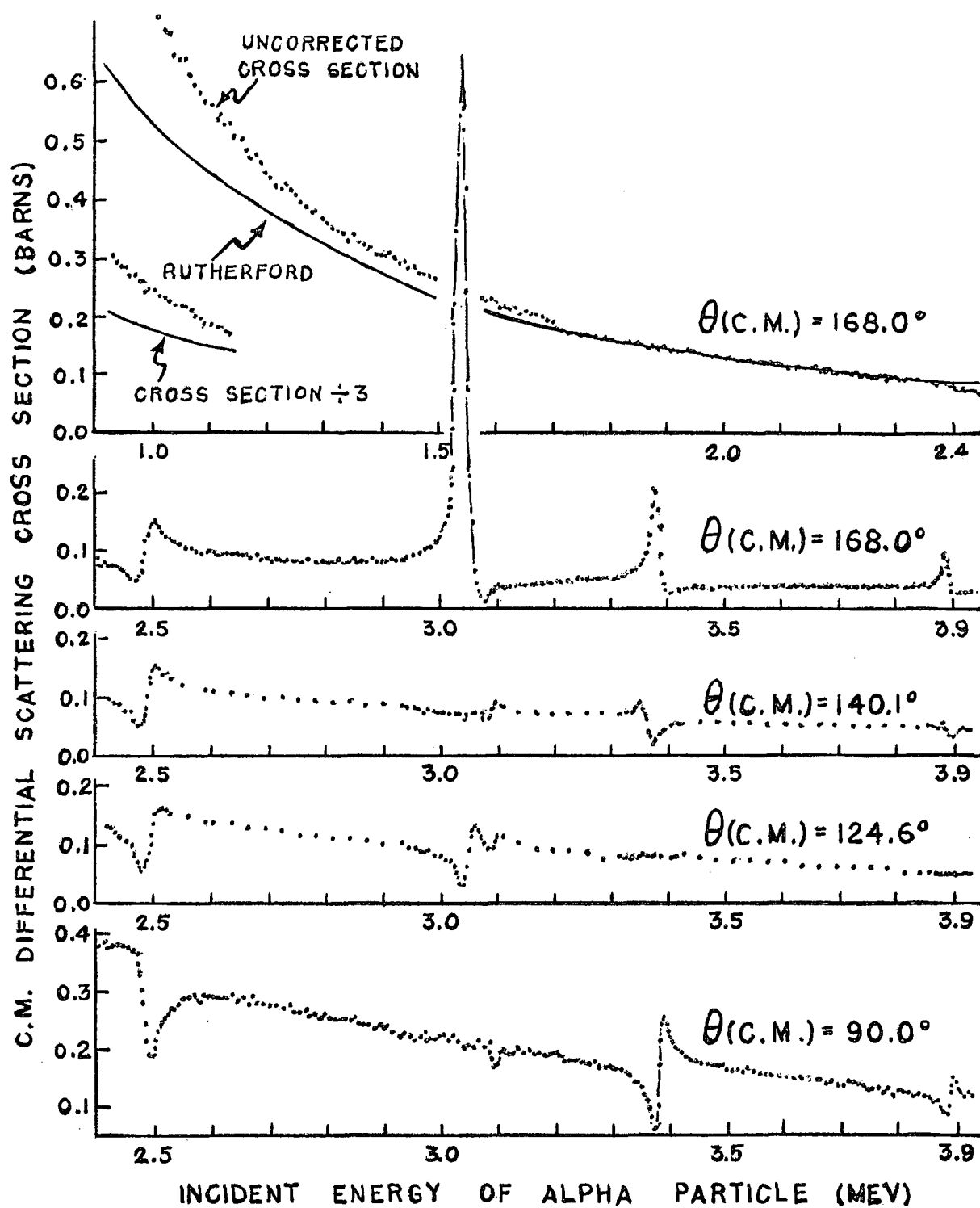


Fig.1 The $\text{O}^{16}(\alpha, \alpha)\text{O}^{16}$ experimental cross sections at 168.0° in the region of 0.94 to 2.4 Mev and at 168.0° , 140.1° , 124.6° , and 90.0° in the 2.4- to 4.0-Mev energy range.

MEMORANDUM

To: INDC Members and Participants

24 March 1975

From: A. Lorenz



Subject: Recommendations from non-neutron nuclear
data meetings held in 1974

As requested by the subcommittee on non-energy data at the 7th INDC Meeting (October 1974), please find attached the summaries of the Recommendations from the Consultants' Meeting on Charged Particle and Photonuclear Reactions (24-26 April 1974), Meeting I, and the Specialists' Meeting on Nuclear Data for Applications (29 April-3 May 1974), Meeting II.

The recommendations from both meetings are regrouped according to the bodies or organizations they are addressed to. Each recommendation is referenced to one of the two meetings (Mtg I and Mtg II) and to the numeration of the recommendations used in the original reports (e.g. A.1, C.3, etc.).

In order to adequately reflect the views you expressed at the last INDC meeting, or the opinion you have formulated since then, in our future deliberations, we would appreciate your comment on the feasibility of implementing the appropriate recommendations in your country, and on the overall aspect of the proposed establishment of international cooperation in the field of non-neutron nuclear data.

RECOMMENDATIONS TO THE INDC

1. Ascertain the needs for the compilation and evaluation of selected nuclear data. (Mtg II, Rec. C.3)
2. Recirculate the (Guide to authors) recommendations to editors of nuclear physics journals. (Mtg II, Rec. E.7)
3. Investigate the need for angular and energy distribution data compilation in the scope of an international effort to compile charged particle and photonuclear reaction data. (Mtg I, Rec. B.5)

RECOMMENDATIONS TO NATIONAL AUTHORITIES AND INTERNATIONAL ORGANIZATIONS CONCERNED

1. Support mass-chain compilation and evaluation activities. (Mtg II, Rec. B.1)
2. Support the compilation and evaluation of selected nuclear data (Mtg II, Rec. C.1)
3. Guarantee the free exchange of all experimental nuclear structure and decay data between all groups and individuals concerned. (Mtg II, Rec. D.4)

RECOMMENDATIONS TO THE IAEA

1. Consider including training of nuclear data compilers and convening training courses in compilation and evaluation of nuclear data as part of the IAEA fellowship programme. (Mtg II, Rec. B.4)
2. Establish a Central Information Office within the Nuclear Data Section to serve as a Referral Centre for nuclear structure and decay data information. (Mtg II, Rec. E.1, E.2, and E.5)
3. Continue publishing compilations and evaluations of selected nuclear data in IAEA publications (Mtg II, Rec. E.6)
4. That the Director General take the necessary steps to implement the recommendations set forth in INDC(NDS)-59 and INDC(NDS)-60, and bring them to the attention of national and pertinent international authorities. (Mtg I, Rec. C.1 and Mtg II, Rec. F.1)

5. That the Director General bring the conclusions and recommendations of this meeting to the attention of national and international organizations. (Mtg II, Rec. F.2)

RECOMMENDATIONS TO IAEA NUCLEAR DATA SECTION

1. Assist in coordinating the working programmes of existing and new compilation centres and groups. (Mtg II, Rec. B.3)
2. Promote and coordinate required nuclear data compilations and evaluations in smaller countries. (Mtg II, Rec. C.3)
3. Promote the establishment of an international evaluated nuclear data file
 - containing single values with uncertainties
 - whose scope is based on INDC determined needs
 - whose format is based on one of the existing formats.(Mtg II, Rec. D.1)
4. Ascertain that the content of the International File of Evaluated Data be disseminated to all interested parties. (Mtg II, Rec. D.5)
5. Advertise the services provided by the Central Information Office through all available channels. (Mtg II, Rec. E.3)
6. Conditional upon a positive response from IAEA Member States, convene future meetings on nuclear structure and decay data to implement the proposed system of international cooperation. (Mtg II, Rec. F.3)

RECOMMENDATIONS TO ALL CENTRES AND GROUPS COOPERATING IN THE COMPILATION OF NUCLEAR STRUCTURE AND DECAY DATA

1. Adopt the Oak Ridge Nuclear Data Project bibliographic keywords and reference system. (Mtg. II, Rec. A.1)

2. Existing and new centres and groups should coordinate their efforts, communicate with each other, profit from each other's experience, and be closely associated with experimental nuclear physics laboratories. (Mtg II, Rec. B.2 and C.2)
3. Publish mass-chain compilations and evaluations more often. (Mtg II, Rec. B.5)
4. Coordinate their effort in order to insure a continuous updating of the proposed international file of evaluated data. (Mtg II, Rec. D.3)
5. Keep the proposed Central Information Office (for nuclear data information) informed of all developments. (Mtg II, Rec. E.4)
6. The Oak Ridge Nuclear Data Project should provide copy of the references Master file to nuclear data centres, and to neutron data centres upon request. (Mtg I, Rec. A.1)

RECOMMENDATIONS TO ALL CENTRES AND GROUPS COOPERATING IN THE
COMPILATION OF CHARGED PARTICLE AND PHOTONUCLEAR REACTION DATA

1. Adopt the Oak Ridge Nuclear Data Project bibliographic keywords and reference system. (Mtg I, Rec. A.1)
2. Continue building up and maintaining charged particle and photonuclear reaction data files. (Mtg I, Rec. B.1)
3. New centres and groups should consult with the two existing charged particle and Photonuclear Reaction Data Centres. (Mtg I, Rec. B.2)
4. Existing centres should supply copies of their masterfiles, upon request, to the existing neutron data centres for dissemination to the user community. (Mtg I, Rec. B.3)
5. Consider the use of existing computer formats for the exchange of charged particle and photonuclear reaction data. (Mtg I, Rec. B.4)

Working paper submitted to the INDC meeting September 29, 1975

Japanese Nuclear Data Committee,
Subcommittee on Nuclear Data for Safeguards
Techniques

The Second Request List of Japan for Safeguards Techniques will be submitted to CCDN in October, 1975. The original requests were collected from the Japanese users and researchers in October, 1973. A total number of the collected requests were 95. These requests have been examined and screened by Subcommittee on Safeguards Techniques in Japanese Nuclear Data Committee. A total number of screened requests were 49. These requests contain the following quantities:

Quantity	Number of Requests	
	Original	Final
(1) Total gamma ray yield	15	12
(2) Half life	17	1
(3) Fission half life	10	4
(4) Decay heat	7	5
(5) Capture cross section	12	8
(6) Fission cross section	11	2
(7) Photofission yield	7	7
(8) Charged particle cross section	1	1
(9) Fission product mass yield spectrum	8	4
(10) Delayed neutrons emitted per fission	7	5
<hr/>		
Total	95	49

These requests are needed for:

- (1) assay of Pu isotopes by gamma ray spectroscopy or by calorimetry or by neutron coincidence method, (2) active assay of mixed fuel and irradiated fuel, (3) non destructive assay of nuclear fuel by gamma ray spectroscopy of photofission products and (4) detection of failed fuel by gamma ray spectroscopy of fission products.

The criteria for priority are the same as those of INDC(NDS)-50/U+S. First priority-(1) is given 10 requests, Second priority-(2) to 10 requests and finally, Third priority-(3) to 29 requests.

For the 8th INDC Meeting

WORKING PAPER : SESSION V. A.

Nuclear Data Requests for Fusion Reactor Development from Japan

WORKING GROUP on Nuclear Data for Fusion Reactors, JNDC

Three researchers individually submitted the nuclear data requests for fusion reactor development at the suggestion of the Research Committee on Nuclear Fusion Reactor and the Japanese Nuclear Data Committee of the Atomic Energy Society of Japan. The requests are now under a screening procedure in the Working Group on Nuclear Data for Fusion Reactors, JNDC, which will be finished in November 1975, and the requests will be sent to CCDN in accordance with the WRENDA procedure.

In the following table, the items of the above requests are simply listed for reference.

Some gross requests from viewpoints of the blanket chemistry and metallurgy have also been submitted to the Committees, but these are to be refined and are not included in Table 1.

Table 1 Provisional Simplified List of Items of the Nuclear Data Requests for Fusion Reactor Development from Japan

(The following requests are all for neutron incident reactions)

[TARGET]	[QUANTITY]	[ENERGY RANGE]
3 Li 6	Elastic & Differential Elastic	1.0+6 - 1.5+7 eV
	Total Photon Production & Gamma Spect.	threshold* - "
	N,ND	threshold - "
	N,T	3.0+6 - "
3 Li 7	Elastic & Differential Elastic	1.0+6 - "
	Inelastic & Energy Differential	threshold - "
	Total Photon Production & Gamma Spect.	" - "
	N,2N , Neutron Spectra & Angular Dist.	" - "
4 Be	N,NT & Neutron Spectra	" - "
	Total Photon Production	" - "
	N,2N	" - "
4 Be 9	N,T	" - "
	Inelastic	" - "
	Total Photon Production & Gamma Spect.	" - "
6 C 12	N,2N , Neutron Spectra & Angular Dist.	" - "
	N,ALPHA	" - "
	Inelastic & Energy Differential	5.0+6 - "
8 O 16	N,N3ALPHA	threshold - "
	N,P	" - "
	N,ALPHA	8.0+6 - "
9 F 19	N,NALPHA	threshold - "
	Inelastic	1.0+6 - "
	Absorption	thermal - "
13 Al 27	Inelastic	threshold - "
	Capture & Gamma Spectra	thermal - "
	Total Photon Production	threshold - "
	N,2N	" - "

* Threshold for particle emission in case of "Total Photon Production".

(Table 1 Continued)

[TARGET]	[QUANTITY]	[ENERGY RANGE]
13 Al 27	N,P	threshold - 1.5+7 eV
	N,D	" - "
	N,T	" - "
	N,ALPHA	" - "
20 Ca	Elastic & Differential Elastic	1.0+6 - "
	Capture & Gamma Spectra	thermal - "
	Total Photon Production & Gamma Spect.	5.0+5 - "
22 Ti	Inelastic	threshold - "
	Total Photon Production	" *- "
	N,2N	" - "
	N,P	" - "
	N,ALPHA	" - "
23 V	Inelastic	" - "
	Capture & Gamma Spectra	thermal - "
	Total Photon Production	threshold - "
	N,2N	" - "
	N,P	" - "
	N,ALPHA	" - "
23 V 50	N,2N	" - "
	N,ALPHA	" - "
23 V 51	N,P	" - "
	N,ALPHA	" - "
	N,NALPHA	" - "
24 Cr	Inelastic & Gamma Spectra	" - "
	Capture & Gamma Spectra	thermal - "
	N,2N	threshold - "
	N,P	" - "
	N,ALPHA	" - "
24 Cr 52	N,2N	" - "

(Table 1 Continued)

[TARGET]	[QUANTITY]	[ENERGY RANGE]
26 Fe	Inelastic & Gamma Spectra	threshold - 1.5+7 eV
	Capture & Gamma Spectra	thermal - "
	Total Photon Production	threshold*- "
	N,2N	" - "
	N,P	" - "
	N,ALPHA	" - "
28 Ni	Inelastic & Gamma Spectra	" - "
	Capture & Gamma Spectra	thermal - "
	Total Photon Production	threshold - "
	N,2N	" - "
	N,P	" - "
	N,T	" - "
	N,ALPHA	" - "
29 Cu	Inelastic & Gamma Spectra	" - "
	Capture & Gamma Spectra	thermal - "
	Total Photon Production & Gamma Spect.	threshold - "
41 Nb	Capture & Gamma Spectra	thermal - "
41 Nb 92	N,ALPHA	threshold - "
41 Nb 93	Inelastic	" - "
	Inelastic ^{93m} Nb	" - "
	Capture & Gamma Spectra	thermal - "
	Capture ^{94m} Nb	" - "
	Total Photon Production & Gamma Spect.	threshold - "
	N,2N	" - "
	N,P	" - "
	N,ALPHA	" - "
	N,NALPHA	" - "
41 Nb 94	Capture	thermal - "

* Threshold for particle emission in case of "Total Photon Production".

(Table 1 Continued)

[TARGET]	[QUANTITY]	[ENERGY RANGE]
42 Mo	Elastic & Differential Elastic	1.0+6 - 1.5+7 eV
	Inelastic, Energy Dif. & Gamma Spect.	threshold - "
	Capture & Gamma Spect.	thermal - "
	Total Photon Production & Gamma Spect.	threshold*- "
	N,2N	" - "
	N,P	" - "
	N,ALPHA	" - "
	Above cross sections for the isotopes are also requested	
42 Mo 92	Capture	thermal - "
42 Mo 94	N,2N	threshold - "
82 Pb	Total Photon Production & Gamma Spect.	" - "
93 Np 237	Fission Cross Section	" - "

* Threshold for particle emission in case of "Total Photon Production".

WORKING PAPER: SESSION VI E

Co-operation between JAERI (Japan) and KAERI (Korea) in Nuclear Data Measurements and Evaluations (T. Fuketa, JAERI, Japan)

In case of receiving researchers from KAERI to JAERI, the measurement and/or evaluation of nuclear data is assigned to one of the high priority items in JAERI. Funds for the sending researchers are left to KAERI's choice, probably by JICA or Colombo funds, and the possibility seems to depend upon the order of priority of the application in Korea.

Proposed themes (as of December 1974*) for the nuclear data measurement and evaluation which Korean physicists may join at JAERI are as follows:

1) Nuclear Data Measurements

[Samples]	[Reaction Types]	[Neutron Energy]	[Remarks]
(1-1) Nb	Elastic & Inelastic Scatt. Cross Sections	around 20 MeV	5.5 MV V.d.G. TOF October 1975 [#]
(1-2) 90,92,94Zr	Same as the above	4 - 8 MeV	5.5 MV V.d.G. TOF April 1975 [#]
(1-3) ⁷¹ Ga and 155,157Gd	Total & Capture Cross Sections	1 eV - 100 keV	Linac TOF April 1975 [#]
(1-4) ^{143,145,146,148} Nd and ¹⁸³ W	Same as the above	1 eV - 100 keV	Linac TOF March 1976 [#]

2) Nuclear Data Evaluations

2.1 Evaluation work related to the fission product nuclear data.

A more specific theme would be an evaluation work related to the decay heat by the transplutonic fission products for example.

A JNDC group work on the evaluation of the neutron cross sections of the fission product nuclides is now entering into the last stage. Therefore, for the JAERI-KAERI program in very near future, an evaluation work on the neutron cross section of a few FP nuclides might not fit too well at JAERI.

[#] Earliest date to start.

All measurements in the above are related to the requests in WRENDA 74.

* M. Cho from KAERI and S. Tanaka, A. Asami and T. Fuketa from JAERI met at JAERI on 2nd December 1974, and made a brief preliminary discussion

Convenient time to start this work: any time by the end of 1976.

2.2 Evaluation of the neutron inelastic scattering data of ^{238}U .

The main part of the work would be the theoretical calculation by using computer codes ELIESE-III, CASTHY, JUPITOR, Etc.

Convenient time to start this work: any time by the end of 1975.

2.3. Systematic studies on the neutron resonance parameters including the compilation and data processing by computer.

For example:

- a) Review and/or evaluation of the resonance parameters of specific nuclides (FP, fissile, etc.),
- b) Review and/or evaluation of the strength functions,
- c) Compilation of the resonance parameters by using COMFORD (a computer file).

Convenient time to start this work: any time by the end of 1976.

In the above cooperation, KAERI planned to ask financial support for samples from the IAEA, but it is rather difficult to make a specific coincidence of a visiting period of researcher, a machine availability and a sample availability beforehand. Therefore, we propose that a KAERI physicist joins one of the above JAERI's programmes to start with.

KAERI is also planning to make the measurements at the neutron energies of 14 MeV and thermal.

INDC Meeting - Session VI E

Working paper on Co-ordination of Nuclear Data Activities

Nuclear Data Measurements in Developing Countries

Prompted by the INDC initiative to stimulate nuclear data measurements in laboratories in developing countries the Nuclear Physics Division at Harwell has investigated how best to encourage and support such work at Dacca, Bangladesh. The nuclear physics laboratory there is within the Atomic Energy Centre and work is done by staff of the centre together with staff and students of the University of Dacca. The laboratory was visited in November 1974 by Dr. A.T.G. Ferguson who attended the Bose Memorial Symposium. Dr. M.K. Mehta of the Bhabha Atomic Research Centre, Bombay, India was also present. It was recognised that one of the dangers to be avoided was uncoordinated attempts to steer Dacca in two diverse directions. The difficulties of serious collaboration over long distances was obvious and hence collaboration with their nearest scientific neighbours seems most profitable. It was agreed that to give some unity to the programme they would join with BARC in a programme of data measurements relevant to the Thorium Cycle. It was agreed that Dacca would propose a programme in this field to be agreed with BARC. On the basis of this agreed programme Harwell would place a modest research contract with Dacca. This would provide funds against which it was envisaged Dacca could draw small essential items - targets, electronic components etc. from Harwell stores and other sources. Summer visits to Harwell aimed for example at calibrating counters against local standards would also be supported. So far the proposals from Dacca are still awaited.

A.T.G. Ferguson
Nuclear Physics Division
Hangar 8

18 September 1975

INDC Meeting - Session VI E

Working paper on Co-ordination of Nuclear Data Activities

Information about the International Seminars in Physics and Chemistry,
Uppsala, Sweden

The University of Uppsala arranges international seminars in physics and chemistry for research training in Swedish laboratories sponsored by the Swedish International Development Authority (SIDA), IAEA and UNESCO. The aim of the Seminars is to initiate the creation of research groups at universities or national laboratories in developing countries. This assistance is given in order to improve the conditions and prospects for local research work.

The major part of the time is spent on research work, each participant entering as a member of a small team of scientists at a suitable laboratory mostly belonging to the University. Besides the research work there are complementary programmes and courses offered.

Training courses can also include topics closely related to nuclear data measurements.

As an example, the Seminars have assisted the Atomic Energy Centre in Dacca to set up research groups in X-ray fluorescence, gamma ray spectroscopy and ion-solid interactions. Scientists from the Centre have joined groups at the Neutron Physics Laboratory, Studsvik and the Tandem Accelerator Laboratory, Uppsala, where they have made neutron scattering and neutron capture gamma-ray spectroscopy measurements.

H. Condé

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76-10200

Translated from Russian

THE ADJUSTMENT OF GROUP CONSTANTS ON THE BASIS OF EVALUATED
INTEGRAL EXPERIMENTS AND THE LATEST EVALUATED
MICROSCOPIC NUCLEAR DATA

Yu.G. Bobkov, V.A. Dulin, Yu.A. Kazanskij, L.N. Usachev
Institute of Physics and Power Engineering

ABSTRACT

The adjustment of constants on the basis of the results of 48 integral experiments and a set of evaluated microscopic data from the United Kingdom Nuclear Data Library (UKNDL) and the BNAB-70 26-group system is reported.

The conditions for methodical and mathematically formalized use of integral experiments in obtaining nuclear data for reactors were established with the publication of a generalized perturbation theory [1] and the first application of the least-squares method to this problem [2]. Two other ways of using the least-squares method were described in Refs [3] and [4]. Two of the authors of this paper used the least-squares method described in Ref. [4] in a paper presented at the first Kiev Conference [5], and then introduced their own model of error correlations [6] and used an algorithm taken from "the systematic planning of experiments" (see Ref. [7]). In this algorithm there is no matrix conversion operation, so that the number of adjustable parameters is greatly increased compared with Ref. [5].

The essential aspects of using integral experiments in nuclear data work are dealt with briefly below.

A fundamental point in using integral measurements is that the theoretical model must be consistent with the experimental conditions. All the experiments used in this paper are evaluated to some extent and the authors are confident that any possible inconsistencies between experiment and theory are within the assigned errors. Data from 48 integral experiments were used in this work, the bulk of them being experiments on BFS assemblies [8] (29 experiments, 12 of which are experiments on reactivity ratios and 17 on cross-section ratios). In addition data on k_{eff} for ZPR assemblies, cross-section ratios for ZPR-III (48) and ZPR-VI (7), as well as certain other data were employed.

In the evaluation of the integral experiments the following effects were taken into account:

1. Finiteness of the dimensions of the samples used in the measurements of reactivity coefficients and certain cross-section ratios [9];
2. The effect of the heterogeneous structure of the critical assemblies;
3. The effect of the group approximation used in the 26-group calculation on the values of the functionals.

It should be noted that the theoretical methods of introducing corrections and the values of these corrections were checked by means of additional experiments (measurements with samples of different dimensions, variation of the degree of heterogeneity of the critical assemblies, etc.) [10].

Table 1 shows the characteristic values of the corrections made for a number of functionals measured on the BFS-30 critical assembly. Column 0 of this table shows the value of the functional measured directly in the experiment and the experimental error. Columns 1-3 show the value modified by appropriate corrections. Column 3 also shows the final error in the evaluated experimental value. Column 4 shows the theoretical value of the functional based on the initial system of constants and column 5 shows the adjusted theoretical value.

In making the adjustment it was assumed that there was no correlation between the errors of the different integral experiments, i.e. the covariation matrix of the integral experiments is diagonal. All the 48 functionals used were calculated on the basis of the 26-group system of constants, in which σ_c and σ_f of ^{235}U , ^{238}U and ^{239}Pu and $\sigma_{\text{absor.}}$ of ^{10}B are data from UKNDL [11], and the ^{56}Fe capture cross-section corresponds to the latest evaluation performed in the Nuclear Data Centre in 1975 and reported at this Conference. The remaining cross-sections in the calculation were the same as those in BNAB-70. We shall refer to such a system of constants as mixed.

The description of the set of integral experiments before and after adjustment can be characterized by the parameter

$$M_{\ell}^2 = \left[\sum_{i=1}^N \left\{ (E_i - c_i^{\ell}) / c_i^{\ell} \right\}^2 / \Delta_i^2 \right] / N$$

where E_i is the evaluated experimental value of the i^{th} functional, C_i^{ℓ} is the calculated value of this functional based on the " ℓ " system of constants and $*/$ is the error in the experimental value. We find that $M_{\text{BNAB-70}}^2 = 14$, $M_{\text{mixed}}^2 = 10$ and $M_{\text{adj.}}^2 = 0.7$.

The changes in the values of the constants with adjustment are given in Table 2, column 0. Only the principal data are given. Column 1 shows the changes in the values of the constants when the experiments on k_{eff} of the ZPR-III assemblies are omitted from the total set and adjustment is performed on the basis of the remaining set, column 2 shows the changes when k_{eff} of the ZPR-III and k_{eff} of the BN-350 and SNEAK reactors are omitted, and column 3 the changes when all the experiments on reactivity ratios are omitted. As can be seen from Table 2, the change in the values of the constants behaves quite conservatively with respect to the omission of the different types of experiments.

The system of constants obtained through adjustment was included in the catalogue of the M-26 reactor programme and the results of the adjustment were checked by direct calculations. The results of these are in good agreement with calculations based on perturbation theory. The adjusted system of constants describes the spectra of the BFS assemblies much better than the BNAB-70 system.

Using the above set of microconstants and integral experiments, it is possible to calculate the conversion ratio of plutonium breeders to within 3%.

The changes in the values of the microconstants shown in Table 2 largely correspond to the trends in the results of the latest microscopic measurements. This applies to σ_{cap} of ^{238}U , the latest evaluation of which is being presented by V.A. Tolstikov at this Conference, and to σ_{fis} of ^{239}Pu , particularly in the range below 200 keV. The fission cross-section of ^{238}U increases somewhat more than would be expected from the micro-experiment. It is important to note that a number of quantities vary by less than the assigned error; these include ν_F of ^{239}Pu , α of ^{239}Pu , σ_c of ^{238}U and σ_c of ^{56}Fe .

It is characteristic that the variation of the above quantities became small only after the latest, most reliable evaluations were used for the cross-sections in relation to which the adjustment was carried out. For example,

*/ Translator's note. Gap in original.

α of ^{239}Pu increased by 30% when adjusted on the basis of ENAB-69, by 11% when adjusted on the basis of ENAB-70 and by only 4% when adjusted on the basis of UKNDL data. A similar situation also applies for σ_c of ^{56}Fe .

In conclusion we would stress that work on making data more precise may be considered complete when microscopic data cease to vary during the adjustment process.

Table 1

No. of experiment	0	1	2	3	4	5
P5/F5 ⁺	1.78 \pm .018	1.6 ⁺	⁺	⁺	1.52	1.7
P10/P5 ⁺	.97 \pm .006	1.05 ⁺	1.02 ⁺	1.01 \pm .04 ⁺	0.858	1.02
P8/F5 ⁺	.0401 \pm .0 ³ 8	.0401	.0415	.0420 \pm .0 ² 15	.0432	.0430
P9/F8 ⁺	1.1 \pm .02	1.10	1.102	1.11 \pm .02	1.06	1.11

Table 2

Type of cross-section	Energy, MeV	0	1	2	3	4 μ /
CAP PU -239	0.8<E<10.5	0.7	-0.2	-0.2	2.9	50
CAP PU -239	0.1<E<0.8	-0.5	-0.6	-0.7	0.9	15
CAP PU -239	0<E<0.1	8.6	7.6	+6.2	10.8	10
CAP U -238	0.8<E<10.5	-7.9	5.5	-3.7	-5.5	20
CAP U -238	0.1<E<0.8	-9.7	-7.7	-8.0	-8.8	10
CAP U -238	0<E<0.1	-7.0	-10.7	-10.7	-2.7	15
FIS PU -239	0.8<E<10.5	4.5	3.0	4.0	3.7	6
FIS PU -239	0.1<E<0.8	-0.1	0.2	0.5	0.5	3
FIS PU -239	+0<E<0.1	4.3	3.1	2.9	5.7	3
FIS U -235	0.8<E<10.5	-4.0	-5.2	-4.6	-0.7	4
FIS U -235	0.1<E<0.8	-2.77	-2.2	-1.9	-1.5	3
FIS U -235	0<E<0.1	-1.5	-2.5	-2.5	-0.3	3
FIS U -238	0.8<E<10.5	8.5	8.0	8.6	8.4	5
NUP U -238	0.8<E<10.5	-1.7	-2.4	-1.78	-0.7	3
CAP U -235	0.8<E<10.5	37	36	37	22	50
CAP U -235	0.1<E<0.8	20	15.9	14	15	15
CAP U -235	0<E<0.1	-3.7	-2.7	-3.8	2.8	10
NUP PU -239	0.8<E<10.5	-0.1	-0.13	0.1	-0.33	3
NUP PU -239	0.1<E<0.8	-0.4	-0.35	-0.2	-0.37	1
NUP PU -239	0.1>E>0	-0.7	-0.57	-0.4	-0.66	2
NUP U -235	0.8<E<10.5	-1.0	-1.1	-1.0	-0.63	3
NUP U -235	0.1<E<0.8	-1.7	-1.7	-1.4	-1.3	1
NUP U -235	0.1>E>0	-0.7	-1.5	-1.1	-0.8	2

* / Column 4 shows the accuracies of the microconstants.

+ original figures hardly readable.

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9 October 1975

Subcommittee Report - Nuclear Data for Energy Applications

The subcommittee reviewed the areas of Fission Product Nuclear Data, Reactor Dosimetry and Nuclear Data for Fusion to the extent possible in the short meeting period.

A. FPND As proposed previously, the NDS is planning to issue a Newsletter on FPND starting next month. A proposed format was distributed by M. Lammer and submissions from some 250 individuals have been requested during the past few months, a number of which have now been received. This effort by NDS was endorsed by the subcommittee with the following comments and observations:

1. The format might be altered from experience gained in this initial cycle.
2. The list of contributors may well increase after this initial issue. Limits to contributions may have to be imposed, perhaps by page limits and by the number of separate contributions.
3. Possible misuse of this service could occur if individuals try to quote it as initial publication.

Since the NDS will only photocopy individual submissions, it is not their responsibility about just what is contained in any contribution. The subcommittee felt the potential for misuse was probably no greater than for the usual progress reports.

The NDS plans to hold an Advisory Group Meeting in early 1977 and Schmidt asked for consideration of the priority of various topics. A balance between integral and microscopic information is desired and it is expected that results from a number of new experiments, calculations and evaluations will be available. Amiel made the following recommendation:

Ask interested labs to remeasure chain yields, discrepancies exceed 5%. We should also ask the people who presented at the FPND panel at Bologna reviews on chain yield in thermal and fast fission of ^{232}Th , ^{233}U , ^{235}U , ^{238}U and ^{239}Pu to update their compilations and evaluations and circulate through the NDS their revised lists together with the indicated discrepancies.

The subcommittee noted the UK response to the Lott proposal on fission product energy release information. The point is well made that available data must be able to permit accurate estimates of decay heat for irradiation periods far in excess of 10^5 seconds. The UK experiment at Zebra to verify decay heat after a 6 months decay period may well be important. It is, however, expected that already available information on the long-lived activities are in a much better state for this purpose than are the data for much shorter half-lives. These short periods should, therefore, be emphasized as of higher priority at the present time.

The subcommittee endorsed Schmidt's letter of July 3, 1975, which requested that Lott prepare a summary of afterheat experimental and calculation results for the 1977 Meeting on FPND.

Motz informed the committee that an extensive survey of selected fission product yields in ten or so fast assemblies was being published by the Los Alamos Nuclear Chemistry Group. Detailed information will be available in December 1975.

B. Reactor Dosimetry. M. Vlasov of the NDS reviewed his draft Status of Neutron Cross Section Data for Reactor Radiation Measurements document, INDC(NDS)-47/L, which was distributed. He hopes to have the completed document ready soon now that the ENDF/B-IV evaluated files are available for comparison. This review is a very comprehensive undertaking with an intent to arrive at a recommended cross section set during the next two years. Vlasov also distributed a "Survey of Benchmark Neutron Fields for Data Testing and Calibration for Reactor Fuels and Materials Dosimetry". Requests to laboratories are being made to obtain information for this survey.

The subcommittee was of the opinion that this was quite useful work in a field which is growing in importance. The evaluation of data and benchmark experiments, while very important, can be extremely demanding and limited or individual efforts such as those at NDS must focus on specific areas and avoid duplication of other programs.

Gemmell attended some of the Euratom Petten Dosimetry Meeting in September. He noted that very few users seemed to be present, but considerable exchange between the measuring experts was apparent. Although improvement in the agreement of direct integral measurements with calculated activities from microscopic cross sections was noted, discrepancies of 7 to 8% are still prevalent.

C. Nuclear Data for Fusion. Schmidt requested consideration of his proposal to hold an Advisory Group Meeting in 1978 on this subject. The subcommittee regarded this as a most appropriate and important subject and felt that the timing should be excellent. Several integral experiments are being completed on lithium assemblies, sensitivity calculations are being performed and a considerable amount of microscopic cross section measurements are underway or planned. Since, however, a difficult and extensive neutron energy regime, generally 5 to 15 MeV, is involved, it is expected that much more data will be required. Thus a status in the 1977/78 time frame should be very useful in appraising the status of this field.

Motz agreed to prepare a summary of data problems and current references in fusion for use by the NDS.

HTM

8/10/75

To: INDC Members

From: S. Amiel

Proposed Recommendation:

Ask interested labs to remeasure chain yields, where discrepancies exceed 5%. We should also ask the people who presented at the FPND panel at Bologna reviews on chain yield in thermal and fast fission of ^{232}Th , $^{233,235,238}\text{U}$ and ^{239}Pu to update their compilations and evaluations and circulate through the NDS their revised lists together with the indicated discrepancies.

This, I believe, will encourage people to renormalize and experimentally update their values of independent, fractional and cumulative fission product yields as well as delayed neutron data; - these can then be presented and discussed on the 2nd IAEA FPND panel.

NUCLEAR DATA FOR ENERGY APPLICATIONS

SUBCOMMITTEE ASSIGNMENTS

DOSIMETRY	- Cierjacks
FPND	- Rowlands Amiel
SAFEGUARDS	- Fuketa
TND	- Michaudon
FUSION	- Motz

Berenyi 9/10/75

Report on the Non-Energy Applications Sub-Committee to the INDC

- I. In the field of non-energy applications the main problem is to clarify and quantify the needs for nuclear and related atomic data. Therefore, the members of the sub-committee reported first on the results in connection with this task. The forms to fulfil the tasks are different ones in the different countries. In some countries there are formal or ad hoc committees (study groups) to deal with the question (e.g. UK, USA, India, France), in others the task to be solved by personal contacts and interviews (e.g. FRG, Holland, Canada, Hungary). In USSR nuclear data needs in geological survey emerged e.g. during the last Kiev Conference.
- II. Several working papers were discussed in the sub-committee, namely Rose's report on the Washington Conference, Wapstra's report on the Paris Conference on Atomic Masses, Cross' paper on nuclear data needs for biomedical purposes and that of Rose on cross-section needs for ion beam analysis (all these papers have been distributed for every member of INDC).

On the basis of these reports and the discussion some sub-fields of non-energy applications where needs may arise have been fairly defined. These are as follows:

- (i) Fast neutron therapy: neutron cross sections (elastic, inelastic and interaction) at neutron energies higher than 15 MeV for the major constituents of the human body (H, O, C, N, Ca, P) as well as cross sections and neutron spectra for the $\text{Be}(\alpha, n)$ reaction by which fast neutrons are produced.
- (ii) Medical isotope production: measurements or/and a proper compilation for charged particle excitation functions for certain isotopes; the accuracy needed here might be usually not better than 25%.
- (iii) Radiation protection: among others the W-values (energy loss per ion pair) in various counter gases and tissue constituents are interesting in this sub-field.
- (iv) Ion beam analysis of materials: the needs appear to be established and compilation effort has already begun which will more clearly define those areas of ignorance where gaps exist in the data.

- (v) Industrial gauging: differential electron multiple scattering data in the energy range up to 4 MeV were claimed take of importance in the inferred design of industrial scattering gauges.

III. In the course of the discussion in the subcommittee it became clear that one should not deal with non-energy applications in general by forming study groups, committees or perhaps sending out questionnaires covering the very broad field of non-energy applications of nuclear data. The more efficient way seems to be to focus the efforts in national and international respect to one or at most several subfields of the non-energy applications during a certain period.

That is why the following actions are recommended.

- (i) Concerning the biomedical applications the situation seems to be mature to make a more or less complete summary on the needs in this particular field during the next 18 months. This report would include the areas of nuclear medicine, biomedical research using tracers, neutron radiotherapy and radiation protection (paragraphs i-iii in the earlier section). Dr. Cross is asked to make this report for the next INDC meeting after having further information from Drs. Rose, Mehta, Smith, Usachev, Legrand and others. NDS might also organize an official consultants meeting in this field. (Cross, members concerned, NDS).
- (ii) It is also recommended to collect the needs to undertake the necessary preparatory work to a report similar to that in the biomedical field (cf. III.i) in one or two of the following topics: geological surveying, ion beam analysis, industrial gauging etc. during the next period. Such work might also be carried out in the form of official consultants meeting at IAEA and in the frame of the Non-Neutron Nuclear Data Working Groups of the International Committee on Radionuclide Metrology in Paris. (Members concerned, Legrand, NDS).
- (iii) The questionnaires from NDS to non-energy users of nuclear data should also be distributed. However, one must not expect much from them on the basis of rather negative experiences of numerous questionnaires. Anyway, members of the sub-committee are asked that they try to help the success of this questionnaire with personal interviews and forming local meeting according to the recommendations of the earlier INDC meeting. (NDS, members of the subcommittee).

WORKING PAPER FOR NON-ENERGY APPLICATIONS SUBCOMMITTEE

NUCLEAR DATA NEEDS FOR BIOMEDICAL PURPOSES

W.G. Cross

The major areas of biomedical applications of nuclear data are:

- Nuclear medicine (diagnostic and therapeutic radioisotopes)
- Radiotherapy (gamma rays, neutrons, pions and heavy ions)
- Biochemical and physiological research, using tracers
- Radiation protection
- Biological aspects of environmental problems.

The following discusses data needs in some of these areas - nuclear medicine, biochemical research and radiotherapy using neutrons.

The commonest diagnostic use of radioactivity involves inserting a radioactive isotope into a patient and measuring its subsequent distribution in the body (by emitted gamma radiation) and the change of this distribution with time. The amount inserted is the minimum that has been found empirically to give the required spatial and time resolution with the detection equipment available. Doses to various parts of the patient are calculated and these influence the choice of isotope. This requires data on half lives, average beta energies, intensities and energies of the main gamma rays, X-rays, conversion and Auger electrons. However, since a low dose to the patient is only one of several factors affecting the choice of an isotope, high accuracy of dose calculations is unnecessary. Most isotopes used are chosen to have a relatively simple gamma spectrum, having one predominant line that can be easily isolated from others by a NaI spectrometer. Energy accuracy of 1 keV is more than adequate. Gamma doses are usually dominated by one or a few intense lines and the intensities of weaker lines are relatively unimportant.

The most demanding requirements for absolute intensities are for calibration sources (which are much the same as used in other scientific fields) and for the standardization of isotope strength by pharmaceutical manufacturers. For the latter, accuracies of a few percent are adequate but lower accuracy would not seriously hinder diagnostic usage.

At present about 120 isotopes, listed in Table I, are used in medical diagnostics. While this number had grown rapidly over the last 10 years, experts consulted believe that the number will decrease in future, as the less successful isotopes are eliminated. The ideal isotope decays by electron capture or low energy positrons, emits a single gamma line of 100 to 500 keV, has a half life of 30 minutes to a few hours, can be produced cheaply and free from undesirable radioactive contaminants, and can be attached to a wide variety of chemical compounds. While a few isotopes far off the beta

stability line, whose decay schemes are not yet well known, may prove useful in the future the number is not expected to be large.

A second diagnostic technique uses activation analysis, either in vivo or in vitro, to determine the amounts of elements naturally present in the body. Half lives down to a few minutes can be used. Biological variations from one person to another make high accuracy of measurement unimportant. Measurements are normally made relative to a sample containing a known mass of the element.

In biochemical research using radioactive tracers there are fewer restrictions on the properties of nuclides than in diagnostic uses. Nevertheless, because measurement requirements are easier (e.g.; pure beta emitters can be used since absorption is not important) the number of widely used isotopes is considerably smaller than in clinical diagnosis. Of the tagged compounds commercially available, about 98% are tagged with ^3H or ^{14}C and the remainder with isotopes having a half life of a week or more. Intensity measurements are usually made relative to a sample of stock material.

Radioactive isotopes are also used in therapy, both for cancer and for other conditions. In calculating doses, high accuracy is again not very important because of variability in the movement of the radioisotope in the body. The isotopes used are among those in Table I, although the desirable properties of an isotope are quite different from those for diagnostic use.

Decay schemes for all but about 16 of the isotopes listed in Table I have been revised in Nuclear Data Sheets since the beginning of 1970. Of the remainder, 7 were revised in 1968 and 9 in 1966 (either for Nuclear Data Sheets or the 1968 edition of Lederer et al's Table of Isotopes) and all those except ^{11}C are under revision at present. With the possible exception of a few half lives there does not appear to be an urgent need, in nuclear medicine, for new decay

data or for more mass chain compilation work than is already underway.

A need for repackaged decay data, in a form suitable for medical dose calculations should be largely met by the new compilation of Dillman for the MIRD committee. This includes most of the isotopes of Table I and should be published in the fall of 1975. A sample format is shown. The input data are taken from current Nuclear Data Sheets tapes. Dillman is now working on a similar 500-isotope compilation.

Isotope Production for Nuclear Medicine

Because electron-capture and positron-emitting isotopes are preferred for diagnostic medicine, many isotopes must be made by charged particle or gamma-n reactions. It is generally agreed that many required charged particle excitation functions are not available. They are needed both for the desired production reactions and also for the coincident production of unwanted nuclides, in order to choose the best reaction mode and bombarding energy. Accuracies of 25% will usually be adequate for making this choice. The charged particle reactions compilation of the Karlsruhe group (published by Landolt-Börnstein) contains not only measured excitation functions but also their systematics, so that unmeasured cross sections can be estimated, often to sufficient accuracy. The very high price of these 3 volumes is probably a deterrent to widespread use. While updating the compilation of charged particle experimental results is valuable for many applications, it appears to me that more calculations, based on established systematics, would be the most efficient way of satisfying the data needs of medical isotope producers.

Nuclear Data Needs for Neutron Therapy

If reliable, cheap D-T generators were available, with outputs of 4×10^{13} n/sec (about 100 rad/min at 1 m) and target half lives of 100 h or more, D-T neutrons would probably be used almost exclusively. Enough nuclear data exists to go ahead with 15-MeV neutron therapy, although one would like to have more data on the spectra of alpha particles from O and C. Some improved data for shielding calculations are also needed but these will presumably be obtained in connection with fusion programmes. Existing D-T generators for therapy have outputs about 10 times lower than desired and are useful for therapy only on an experimental basis.

The most promising alternative source is the $^9\text{Be}(d,n)$ reactions, using 35-50 MeV deuterons from cyclotrons. For 50 MeV deuterons the neutron spectrum peaks at 21 MeV and extends to about 50 MeV. High mean energy is needed to reduce attenuation in the body, although cyclotron neutrons of lower energies have been used for tumors close to the surface. Several cyclotrons are now used on an experimental clinical basis. The beam intensity is adequate and target deterioration is not important.

The main new data requirements for therapy with cyclotrons are:

(a) The cross section of the $^9\text{Be}(d,n)$ reaction and more accurate neutron spectra at a variety of deuteron energies and target thicknesses.

(b) Cross sections for 15 - 50 MeV neutrons in major body elements (H,O,C,N,Ca,P), needed to calculate dose distributions in the body. Prime needs are cross sections and angular distributions for elastic scattering and inelastic scattering to the first excited state of ^{12}C , inelastic scattering cross sections and secondary neutron spectra for the other levels and elements, (n,p) and (n, α) cross

sections and spectra of the protons and alpha particles. The required accuracy varies a great deal with the data but decreases with neutron energy above the peak of the spectrum. There are few data available above 20 MeV. Considerable use might be made of cross sections for proton scattering which are easier to obtain and some of which exist, along with enough comparisons between proton and neutron data to check the extrapolation to neutrons.

(c) Cross sections for calculating transmission of 15 - 50 MeV neutrons through beam collimators and shielding. The elements involved are Fe, Pb, possibly W and the elements in concrete. Secondary gamma spectra and activation cross sections are also required.

(d) Some atomic data, in particular the number of eV/ion pair (W) for protons in tissue and in detector gases.

Other neutron source reactions - e.g.; D-D, D-T, $^9\text{Be}-^3\text{He}$, $^9\text{Be}-p$ or $^7\text{Li}-p$, all using high energy bombarding particles, may turn out to have advantages over $^9\text{Be}-d$. Enough cross section and neutron spectral data are required to assess the relative merits of these reactions. For this purpose high accuracy is not required. Measurement of neutron and gamma doses and neutron spectra will probably be done with a combination of ion chambers, scintillators and a variety of activation and damage track detectors of different thresholds. Cross sections for these reactions will be required. Therapy with neutrons from ^{252}Cf is expected to increase. The data required for measuring doses and spectra are the same as are required for reactors.

The rate of development of neutron therapy will depend on the results of experiments and clinical experience with existing installations, on the availability of cheaper

neutron sources and on the confidence with which dose distributions can be calculated and measured. Better data can contribute significantly to the latter.

Table I: Radioactive Isotopes used in Medicine

3	Ga66	Il26
7	Ga67	Il29
11	Ga72	Il30
14	Ge68-Ga68	Il31
13	As72	Il32
15	As73	Il33
18	As74	Xel27
22	Se73	Xel33
24	Se75	Csl27
28-Al28	Br77-Se77m	Csl29
30	Br82	Csl31
32	Kr81	Csl37-Bal37m
35	Kr83m	Csl34
37	Kr85	Bal28-Csl28
38	Kr85m	Bal33
40	Rb81-Kr81m	Bal35m
42	Rb84	Cel39
43	Rb86	Dyl57
45	Sr82-Rb82	Tml67
47-Sc47	Sr85	Erl71
49-Sc49	Sr90-Y90	Ybl69
51	Y87-Sr87m	Wl88-Re188m
52	Mo99-Tc99m	Irl90m-Osl90m
54	Ru97	Osl91m-Irl91m
52-Mn52m	Rul03	Ptl95m
53	Pdl03	Aul95
55	Cdl09-Agl09m	Aul98
59	In111	Aul99
57	In115m	Hgl97
58	Sbl17	Hg203
60	Sn113-In113m	Tl201
64	Sn117m	Pb203
67	Il23	Bi204
62	Il24	Bi206
65	Il25	Ra224
		Pu237
		Am241

L. T. Dillman: Radionuclide Decay Schemes

133 Xe

INPUT DATA

54 XENON 133 HALF LIFE = 5.31 DAYS

DECAY MODE- BETA MINUS

TRANSITION		MEAN NUMBER/ DISINTE- GRATION	TRAN- SITION ENERGY (MEV)	OTHER NUCLEAR DATA
BETA MINUS	1	0.0002	0.0429*	ALLOWED
BETA MINUS	2	0.0163	0.2660*	ALLOWED
BETA MINUS	3	0.9830	0.3460*	ALLOWED
GAMMA	1	0.0162	0.0796	M1, AK= 1.36 AL(T) = 0.200
GAMMA	2	0.9997	0.0809	M1, AK= 1.46 K/(L+M)= 4.65
GAMMA	3	0.0000	0.1606	M1, AK= 0.210 K/(L+M)= 3.75
GAMMA	4	0.0000	0.2230	M1, AK(T) = 0.0839 AL(T) = 0.0112
GAMMA	5	0.0000	0.3028	M1, AK= 0.0390 AL(T) = 0.00494
GAMMA	6	0.0002	0.3839	E2, AK= 0.0170 AL(T) = 0.00270

*ENDPOINT ENERGY (MEV).

REF.- ALEXANDER, P. AND LAU, J.P., NUCL. PHYS.
A121, 612 (1968).

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neutron sources and on the confidence with which dose distributions can be calculated and measured. Better data can contribute significantly to the latter.

Table I: Radioactive Isotopes used in Medicine

H3	Ga66	Il26
Be7	Ga67	Il29
Cl1	Ga72	Il30
Cl4	Ge68-Ga68	Il31
N13	As72	Il32
Ol5	As73	Il33
F18	As74	Xel27
Na22	Se73	Xel33
Na24	Se75	Cs127
Mg28-Al28	Br77-Se77m	Cs129
P30	Br82	Cs131
P32	Kr81	Cs137-Bal37m
S35	Kr83m	Cs134
Ar37	Kr85	Bal28-Cs128
K38	Kr85m	Bal33
K40	Rb81-Kr81m	Bal35m
K42	Rb84	Cel39
K43	Rb86	Dyl57
Ca45	Sr82-Rb82	Tml67
Ca47-Sc47	Sr85	Erl71
Ca49-Sc49	Sr90-Y90	Ybl69
Cr51	Y87-Sr87m	Wl88-Re188m
Mn52	Mo99-Tc99m	Irl90m-Osl90m
Mn54	Ru97	Osl91/m-Irl91m
Fe52-Mn52m	Ru103	Ptl95m
Fe53	Pdl03	Aul95
Fe55	Cdl09-Agl09m	Aul98
Fe59	In111	Aul99
Co57	In115m	Hgl97
Co58	Sbl17	Hg203
Co60	Sn113-In113m	Tl201
Cu64	Sn117m	Pb203
Cu67	Il23	Bi204
Zn62	Il24	Bi206
Zn65	Il25	Ra224
		Pu237
		Am241

INPUT DATA

54 XENON 133 HALF LIFE = 5.31 DAYS

DECAY MODE- BETA MINUS

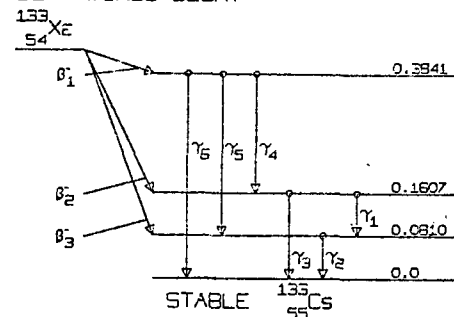
TRANSITION		MEAN NUMBER/ DISINTE- GRATION	TRAN- SITION ENERGY (MEV)	OTHER NUCLEAR DATA
BETA MINUS	1	0.0002	0.0429*	ALLOWED
BETA MINUS	2	0.0163	0.2660*	ALLOWED
BETA MINUS	3	0.9830	0.3460*	ALLOWED
GAMMA	1	0.0162	0.0796	M1, AK= 1.36 AL(T) = 0.200
GAMMA	2	0.9997	0.0809	M1, AK= 1.46 K/(L+M)= 4.65
GAMMA	3	0.0000	0.1606	M1, AK= 0.210 K/(L+M)= 3.75
GAMMA	4	0.0000	0.2230	M1, AK(T) = 0.0839 AL(T) = 0.0112
GAMMA	5	0.0000	0.3028	M1, AK= 0.0390 AL(T) = 0.00494
GAMMA	6	0.0002	0.3839	E2, AK= 0.0170 AL(T) = 0.00270

*ENDPOINT ENERGY (MEV).

REF.- ALEXANDER, P. AND LAU, J.P., NUCL. PHYS.
A121, 612 (1968).

XENON-133

BETA-MINUS DECAY



OUTPUT DATA

54 XENON 133

HALF LIFE = 5.31 DAYS

DECAY MODE- BETA MINUS

RADIATION		MEAN	MEAN	EQUI-
		NUMBER/ DISINTE- GRATION	ENERGY/ PAR- TICLE	LIBRIUM DOSE CONSTANT
		n_i	E_i (MeV)	Δ_i (g-rad/ $\mu\text{Ci-h}$)
BETA MINUS	2	0.0163	0.0750	0.0026
BETA MINUS	3	0.9830	0.1006	0.2106
GAMMA	1	0.0061	0.0796	0.0010
K INT CON ELECT		0.0084	0.0436	0.0007
L INT CON ELECT		0.0012	0.0742	0.0001
GAMMA	2	0.3603	0.0809	0.0621
K INT CON ELECT		0.5261	0.0450	0.0504
L INT CON ELECT		0.0848	0.0756	0.0136
M INT CON ELECT		0.0282	0.0799	0.0048
GAMMA	3	0.0000	0.1606	0.0000
GAMMA	4	0.0000	0.2230	0.0000
GAMMA	5	0.0000	0.3028	0.0000
GAMMA	6	0.0002	0.3839	0.0001
K ALPHA-1 X-RAY		0.2552	0.0309	0.0168
K ALPHA-2 X-RAY		0.1321	0.0306	0.0086
K BETA-1 X-RAY		0.0712	0.0349	0.0053
K BETA-2 X-RAY		0.0150	0.0359	0.0011
L X-RAYS		0.0823	0.0043	0.0007
KLL AUGER ELECT		0.0402	0.0253	0.0021
KLX AUGER ELECT		0.0177	0.0296	0.0011
KXY AUGER ELECT		0.0029	0.0339	0.0002
LMM AUGER ELECT		0.4894	0.0033	0.0034
MXV AUGER ELECT		1.1847	0.0009	0.0025

8/10/75

The Status of Nuclear Mass Determinations

A.H. Wapstra

A fuller status report, constituting part of the closing address to the Fifth International Conference on Atomic Masses and Fundamental Constants, will be sent to the members of the Subcommittee on Non-energy applications. The following is a short summary.

Along the line of beta-stability, new measurements changed masses of some rare earth nuclides by about 30 keV. The reported accuracy along this line is now better than 10 keV everywhere. Many more masses are now known far from stability than only a few years ago, among them the first ones measured by mass spectroscopy (^{11}Li , $^{28-32}\text{Na}$). Even more mass differences between such nuclei are known, in cases where the absolute masses are not. It now appears that magic numbers (for which extra stability exists) far from stability are different from those near stability; this has been explained theoretically too (Hartree-Fock calculations). Thus, atomic mass formulae and extrapolation procedures (Garvey-Kelson) have to be revised.

Special cases: L.G. Smith's determinations of the H and D masses are somewhat in doubt; his instrument has been moved after his death to Delft Technological University where his measurements will be repeated. His measurements on $^{12-13-14}\text{C}$ and $^{14-15}\text{N}$ yield (n, γ) reaction energies that have been used to improve the calibration for γ -rays of several MeV by an order of magnitude.

The National Bureau of Standards is working on a method to measure the numbers of atoms in an enriched ^{28}Si crystal with a precision of 1 part in 10^9 . This would allow to replace the weight standard (the Paris kilogram) by an atomic weight one if the atomic weight of ^{28}Si would be known with the same accuracy. The present accuracy is 3 in 10^9 ; Delft will work on improvement.

The newest data indicate that Cohen and Taylor's last mass-energy conversion constant (is c^2/F) is high by about three reported standard errors.

Report on the
Third All-Union Conference on Neutron Physics,
Kiev, 9-13 June 1975

by
J.J. Schmidt

Purpose:

1. Participation in the Conference upon invitation;
2. Discussions on USSR participation in future meetings of the Nuclear Data Section (NDS);
3. Discussions with representatives of the three USSR nuclear data centres (at Obninsk, Moscow and Leningrad)

Summary

1. Neutron Physics Conference

The Third All-Union Conference on Neutron Physics was held at the October Palace of Culture in Kiev from 9-13 June 1975. The Conference was sponsored by the Ukrainian Academy of Sciences and the USSR State Committee on the Utilization of Atomic Energy. As in the Second Conference on Neutron Physics held in Kiev in June 1973 there was invited participation by scientists outside the USSR. Of the 350 participants - about twice as many as in 1973 - 50 were from the following countries and organizations: Australia, Bulgaria, Czechoslovakia, Egypt, France, FRG, GDR, Hungary, Netherlands, Poland, Sweden, UK, the Joint Institute for Nuclear Research Dubna, and the IAEA. Simultaneous interpretation into English was provided.

Similarly to the Nuclear Cross Sections and Technology Conference held in Washington, D.C., USA, in March 1975, the participation from developing countries outside Europe was extremely small, again probably due to lack of financial support.

In altogether 84 papers the Conference gave a broad survey of fundamental and applied aspects of neutron physics work in the USSR with a strong emphasis on neutron data needed for fast reactor development. The conference programme is reproduced in the attachment.

Regrets were expressed that neither Soviet scientists could participate in the recent Conference on Nuclear Cross Sections and Technology which took place in Washington, D.C., in March 1975 nor US scientists in the present Kiev Conference. At both conferences IAEA/NDS was asked to arrange for a suitable exchange of the proceedings of the conferences between both countries.

A little booklet was made available to the participants containing annotations of all contributions reviewed at the conference in keywords of the INIS system, however, unfortunately without abstracts.

2. USSR participation in IAEA/NDS meetings

The interest and possible participation of Soviet scientists in the following NDS meetings was discussed:

- Atomic and Molecular Data for Fusion,
Vienna, 30 June - 1 July 1975;
- Transactinium Isotope Nuclear Data,
Karlsruhe, 3-7 November 1975; and
- The use of Nuclear Theory in Neutron Nuclear Data Evaluation,
Trieste, 8-12 December 1975.

3. Nuclear data centre discussion

I had extensive discussions with representatives of the three Soviet nuclear data centres on matters of future cooperation and exchange and related technical problems, particularly in the field of "non-neutron" nuclear references and data, and evaluated neutron data.

Detail

1. Neutron Physics Conference

In format, the Conference consisted entirely of presentations of invited papers and review summaries of individual contributions. Of the total of 84 papers, 60 were delivered by Soviet scientists and 24 by scientists outside the USSR.

The Conference was heavily oriented towards neutron data needs, measurements and evaluations for fast fission reactors and heavy nuclei with the exception of very few papers that were devoted to neutron data for thermonuclear fusion, soil investigation and astrophysics. The fact that fundamental as well as applied scientists work closely together on neutron physics and data problems for nuclear technology deserves particular mentioning.

A strong activity in the evaluation of neutron data for fission reactors is noted in which mainly groups at Minsk and Obninsk participate, in close collaboration with the Nuclear Data Centre Obninsk. Results were reported on new neutron data evaluations for U-235, Pu-240, C-12, Fe, Cr, Ni and Au covering neutron energies between 10^{-4} eV and 15 MeV. They will form part of a comprehensive evaluated neutron data library called SOKRATOR which is designed to become the basic nuclear data reference source for nuclear energy applications in the USSR and Eastern Europe. The data contained in this library will be made available to IAEA/NDS for international distribution and comparison with similar libraries in other countries.

Several reports dealt in detail with nuclear data requirements for nuclear fission and also fusion (one report) reactor technology, including needs for fission product and actinide nuclear data, in close similarity to the needs expressed at the Washington nuclear data conference. In deriving accuracy requirements for nuclear data from mathematical sensitivity studies the possibility to improve nuclear data not only by microscopic but also by integral experiments in critical facilities is explicitly taken into account. The neutron data requirements for fusion are based on given accuracy requirements for the prediction of the tritium breeding ratio in normal (D-T) fusion reactors and of both the tritium and plutonium breeding ratios in hybrid fusion reactors. The Soviet requests for fission and fusion reactor nuclear data belong to the best founded requests submitted for inclusion in the IAEA/NDS WRENDA request lists.

The scientifically most interesting part of the conference were the three sessions devoted to fission research on heavy nuclei. It was also in this area where the most vivid interaction between Soviet and other scientists took place. Much new empirical and theoretical material was presented on the double-humped fission barrier problem and the properties of the nuclear states in the so-called second well, which are responsible for the shape of actinide neutron fission cross sections needed in nuclear technology.

2. USSR participation in IAEA/NDS meetings

2.1. Atomic and molecular data for fusion

The USSR is strongly interested in the proposed new Agency programme on atomic and molecular A+M data for fusion and will send one or two experts to the Agency's forthcoming Consultants Meeting on A+M data for fusion. A delay of this meeting by three weeks to the 21 and 22 July 1975 was asked by representatives of the State Committee (meanwhile effected) in order to accommodate Soviet participation in the meeting.

2.2. Other NDS meetings

The USSR will probably send three participants to the Advisory Group Meeting on Transactinium Isotope Nuclear Data in Karlsruhe, November 1975, one of whom will review the status of alpha decay data of actinides.

Informal discussions were held with Profs. Solovev from JINR Dubna and Usachev from FEI Obninsk, Soviet Member of INDC, as well as with Drs. Malov from JINR Dubna and Ignatyuk from FEI Obninsk regarding the potential participation of the two latter scientists in the Consultants Meeting on the Use of Nuclear Theory in Neutron Nuclear Data Evaluation at ICTP Trieste, December 1975, as reviewers of the theory and systematics of nuclear level densities which will form one of the major subjects of this meeting.

3. Discussions with representatives of the USSR nuclear data centres

Detailed discussions were held with Dr. V. Manokhin, head of the Nuclear Data Centre at FEI Obninsk, Dr. L.L. Sokolovski, deputy head of the Nuclear Data Centre at the Kurchatov Institute in Moscow, and Dr. I.A.

Kondurov, head of the Data Centre at the Leningrad Nuclear Physics Institute Gatchina, with the following major results and information:

- the Obninsk and Kurchatov centres are responsible for the coordination of neutron and "non-neutron" data activities respectively in the USSR. The Kurchatov and Gatchina centres share the responsibility for the compilation of "non-neutron" nuclear references and data;
- the Kurchatov and Gatchina centres are strongly interested in a technical cooperation and exchange with data centres outside the USSR, particularly in the US, which should proceed through the IAEA Nuclear Data Section, with primary emphasis at present on charged particle nuclear data for fusion and nuclear structure and decay data of fission products;
- both centres, similarly to the Obninsk centre in the field of neutron data, compile already references on "non-neutron" nuclear data from the Soviet scientific literature and are willing (Kurchatov centre) to compile charged particle nuclear data from the USSR in exchange to data from other countries and (Gatchina centre) to share the work on A-chain nuclear data compilations with other centres;
- both centres are strongly interested in participating in all future NDS meetings on "non-neutron" nuclear data compilation and in achieving international agreements on common data exchange procedures and formats.
- the Obninsk centre will make available to NDS major new parts of its SOKRATOR library of evaluated neutron data (for U-235, Pu-240 and several reactor structural materials) and an updated version of the previous ABBN 26 group cross section library for exchange with other centres and dissemination to interested users.

The discussions were finished with more than 50 technical actions on the participants. A detailed report is available from the Nuclear Data Section as NDS Memo 294.

Attachment

Third All-Union Conference on Neutron Physics

Kiev, 9-13 June 1975

Programme

1. Nuclear data needs for fission and fusion reactors and astrophysics
2. Experimental methods of neutron physics
3. Nuclear data needs and their evaluation
4. Fundamental properties of the neutron
5. General problems of the interaction between neutrons and nuclei
6. Experimental study of the interactions of thermal and resonance neutrons with nuclei (two sessions)
7. Experimental study of the interaction of fast neutrons with nuclei
8. Cross sections and other characteristics of neutron fission of heavy nuclei (three sessions)
9. Summary of the Conference

10/10/75

Atomic Weights and Isotope Abundances

A.H. Wapstra

The Commission on Atomic Weights of the International Union of Pure and Applied Chemistry met in Madrid on September 3-6, 1975.

It was decided that, in future, the reports of this Commission will give evaluated values for (terrestrial) isotope abundances of all elements, made compatible with the adopted atomic weights.

Isotope abundances quite different from the terrestrial averages have been found in the OKLO uranium mine in Gabon. They agree with the hypothesis that, in this mine, a natural fission chain reaction has occurred, depleting ^{235}U by about one third and producing fission products. But for this case, though, newer measurements of isotope abundances indicate that fewer measurable deviations from the average abundances occur than have been reported previously.