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Medium Energy Charged Particle Data for Evaluation

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Introduction:

Medium energy charged particles incident on targets can cause a variety of nuclear reactions. Charged particle transport calculations require access to a large body of cross-section data which results in interest in an evaluated charge particle data library.

Developing an evaluated data library can involve several steps. An index to the literature on measurements and theory is useful to locate information relevant to data evaluation. A computerized compilation of measurements facilitates the intercomparison of different experiments and the determination of how well data are known. Nuclear models, based on theory or phemonological evidence, are compared with experiment and where validated, are used to fill in regions where experimental data are not available. Finally, the selected data is placed into computer readable formats for use in transport calculations.

Bibliography

Specialized indexes to bibliography help the scientist to keep up with his field and catch up with new subjects of interest. Several indexes are relevant to medium energy nuclear data. These are the INIS-ATOMINDEX (1), the Computerized Index to Neutron Data (CINDA) (2), Nuclear Structure References (NSR) (3), Integral Charged Particle Bibliography (ICPND) (4), and Heavy Ion Reactions (HIR) (5). In addition, these data are covered in several reports (6,7,8) not issued on a regular basis.

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Experimental Data Base

Nuclear reaction data are compiled in an international exchange format, EXFOR (9). Atlases containing the results of several measurements of the same quantity in tabular or in graphical form, possibly combined with eye guides, evaluations, or nuclear model calculations, are useful to show what and how well nuclear data are known. The neutron data contained in EXFOR extends above 1 GeV. More than 4000 charged particle data sets extending above 20 MeV have been compiled and are available in EXFOR. However, most atlases containing charged particle are very dated and contain few medium energy data.

Nuclear Model Codes

Nuclear models of several types are used to calculate nuclear data. These codes are referred to in several abstracts (11-15). The nuclear model code ALICE (14) uses Weisskopf-Ewing evaporation, Bohr-Wheeler rotating drop fission competition and the excition preequlibrium models to describe nuclear reactions. The development of ALICE has been primarily based on nuclear reaction physics data below 100 Mev. If the ALICE algorithms are extended to higher energies with empirical corrections to the optical models parameters and spallation neutron angular distributors the modified code, ALICE-P (15), can be used for high energy calculations.

Data Files

A nuclear data file is useful in two ways. Cross-section data are stored and accessed as needed in transport and can also be used for sensitivity studies where the effect on calculated results due to discrete changes in input data are observed. This aids cost-benefit analysis since only those data that significantly effect applications need to be seriously reviewed and improved where necessary.

Evaluations of neutron and proton cross-sections for Fe-56 are available (15) in the new ENDF-VI library for energies up to 1000 MeV. The evaluations contain cross-sections of the following types: total (neutron induced only); elastic scattering (nuclear); nonelastic; product yields; and neutron (double differential), gamma, proton, deuteron and alpha production. A similar evaluation for Pb-208 is in progress (16).

Conclusions

The technical area of medium energy charged particle data is maturing. From isolated measurements and theories a comprehensive approach toward establishing a validated data base extending from low to high energies is emerging.

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References

1. INIS ATOMINDEX, Issued semimonthly. Available from Division of Publications, International Atomic Energy Agency, P.O. Box 100, A-1400 Vienna, Austria. In the U.S., from UNIPUB, P.O. Box 1222, Ann Arbor, MI 48106.

2. CINDA, the Index to Literature and Computer Files on Microscopic Neutron Data. Availability same as Ref. 1.

3. Nuclear Structure References, S. Ramavataram. Supplements published 4-monthly as Recent References issues of the Nuclear Data Sheets journal published by Academic Press. See also the Reaction Index, same publication.

4. Integral Charged Particle Nuclear Data Bibliography, N. E. Holden, S. Ramavataram, and C. L. Dunford. See BNL-NCS-51771. Information is derived from Ref. 3. Annual supplements.

5. Heavy-Ion Reactions, A Current Awareness Bulletin. Updates to the US-DOE Energy Data Base. Issued semimonthly on heavy-ion (A<4) reactions. Available from National Technical Information Service, Springfield, VA 22161 as PB87-900500.

6. Cross Sections of Proton-Nucleus Interactions at High Energies, NRL Report 7593, Dec. 21, 1973 - R. Silberberg and C. H. Tsao.

7. Annotated References on Neutron and Photon Production from Thick Targets Bombarded by Charged Particles, Atomic Data and Nuclear Data Tables 32, 471 (1985) - T. Nakamura and Y. Uwamino.

8. Bibliographic Survey of Medium Energy Inclusive Reaction Data - E. D. Arthur, D. M. McClellan, and D. G. Madland. LA-10689-PR (1986).

9. Data compiled and exchanged in the international exchange format, EXFOR, are available to requestors from the following regional centers or national centers within regional centers.
   U.S. and Canada: National Nuclear Data Center, Brookhaven National Laboratory, Building 197D, Upton, NY 11973
   OECD Countries: Nuclear Energy Agency Data Bank, 91191 Gif-Sur-Yvette, Cedex, France
   USSR: For Charged Particles - CAJaD, Inst. Atomnoi Energii I.V. Kurchatova, 46 Ulitsa Kurchatova, Moscow, D-182, USSR
   For Neutrons- CJD, Inst. of Physics & Energetics, Obninsk, Kaluga Region, USSR
   Others: IAEA Nuclear Data Section P.O. Box 200, A-1400 Vienna, Austria

10. National Energy Software (enter: Software Abstracts ANL-7411 (1986), Revised periodically.

11. Nuclear Program Abstracts, Nuclear Energy Agency Data Bank, Regularly Revised. See Ref. 9.

12. Abstracts of Digital Computer Codes, ORNL-RSIC-13, See Ref. 30.

13. Computer Codes, A Bibliography, DOE/TIC-3386 (1985).

14. M. Blann, Phys. Rev. C28, 1475 (1983) and LLNL Report UCID 20169 (1984).

15. S. Pearlstein, to be published in Astrophysical Journal (1989).

16. T. Fukahori and S. Pearlstein, Brookhaven National Laboratory., Private Communications (1989).