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STATUS OF DOSIMETRY AND ACTIVATION DATA

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Abstract: The need for and the status of dosimetry and activation nuclear data libraries will be presented. Each of the major library systems in the world will be covered. Besides the traditional long-lived fission reactor dosimetry sets, new dosimetry sets containing short-lived products needed for fusion applications will be discussed. A major segment of the talk will deal with activation, especially the needs of fusion. The recent Dutch, United Kingdom, and United States of America collaboration will be presented in detail.

Introduction

The effort spent on the evaluation of reaction cross sections goes in cycles. Presently we seem to be in a rising trend. Reaction cross sections are those cross section data important in the calculation of reaction rates. Most of the evaluation effort is spent on data to calculate the transport of neutrons or photons, especially in the area of criticality, fuel management, and shielding. As will be seen, the increase in interest is largely due to fusion applications.

The major uses of reaction cross sections are fuel production (Pu or tritium), other isotope production, and experimental flux determination. Nuclear data for fuel production are covered in other papers.[1,2] This paper deals with dosimetry cross section data and activation (or transmutation) cross section data. Even though both sets of data nominally deal with the same type of reaction, the production of radioactive isotopes, and the evaluation processes are quite different. The emphasis in the evaluation of dosimetry data is based on precision and accuracy, while the emphasis for activation data is based on completeness. Normally a dosimetry file will contain few reactions (20 to 40), while an activation file will cover many isotopes (over 300) and many reactions (over 5,000).

This paper describes why these reactions are important and why they have increased in importance. Next, this paper deals with the existing cross section libraries. Last, this paper discusses the libraries expected to begin soon, especially the library resulting from the Dutch - United Kingdom - United States collaboration.

Why are Reaction Data Important

The experimental determination of the neutron flux through the production of radioactive nuclei has a long history. The use of reactions that have different energy responses and that produce conveniently measured radiations allows for a fairly easy and straight forward determination of the flux. For fission reactors, the evaluation on the needed dosimetry reactions peaked in the late 1970's. The present interest in fission reactor dosimetry is in determining a reaction that has a response similar to that of atom displacement and in the determination of uncertainties in the cross sections. With the arrival of machines producing fusion neutrons, new interest is occurring in determining reaction cross sections for short-lived dosimetry reactions.

However, the real growth in the interest in reaction data lies in the area of activation (and transmutation) reaction data. Fusion groups around the world recognize that the production of radioactivity is separated from the production of neutrons and energy. Thus, there is a wide spread interest in minimizing the amount of radioactivity produced in a fusion device. Fusion materials programs have already shifted their activities from traditional materials like 316 stainless steels to steels with minimal Ni and Mo content and to vanadium alloys. In addition, the U.S. Department of Energy, Office of Fusion Energy, has set a goal that materials from a fusion device be disposable in near-surface burial rather than in deep geological disposal. Both economic and public perception issues cause the setting of such goals.

Existing Libraries

Even though the same data are used for dosimetry and activation calculations, the data are normally kept in separate files. The prime reasons are that dosimetry data need to be far more accurate than activation data (with a detailed description of the data quality) and there are far fewer dosimetry reactions of interest. This paper will discuss the files separately.

Dosimetry

Although reactions were previously used as spectrum indices, the first large dosimetry library was the ENDF/B-IV dosimetry library.[3] Not only did it have many reactions (36), it was available to anyone. Using ENDF/B-IV as a base, the International Atomic Energy Agency (IAEA) produced the International Reactor Dosimetry File (IRDF). Then ENDF/B-V produced another dosimetry file, which the IAEA used as a base to produce IRDF.[4] These files have been extensively used and checked.[5]

Activation

The first national library to contain a file (or sublibrary) containing just activation data was ENDF/B-V. The evaluations in the ENDF/B-V Activation File were just lifted from the ENDF/B-V Dosimetry File or from the ENDF/B-V General Purpose File. However, the file is quite small, containing just 84 reactions. In addition, the file contains decay data for the products. Except for the dosimetry reactions, no special effort was spent on the evaluations contained in the ENDF/B-V Activation File.

The other national or regional nuclear data libraries have not yet created a separate

activation library. However, in all libraries, evaluations for reactions (especially (n,gamma), (n,2n), (n,p), (n,alpha)) exist. However, just like the reactions contained in the ENDF/B-V activation library, no special evaluation effort was spent for these reactions, and no attempt was made to be complete.

The first genuine activation file was probably the one produced by Gardner and Howerton.[6] at the Lawerence Livermore Laboratory, ACTL. An extensive effort was made to include the important transmutation and activation reactions important to the laboratory. Individual evaluations were performed for the file. The initial library, ACTL-78, contained about 2,200 reactions and about 250 targets, but was not complete, even for the targets given. The current library, ACTL-84, represents a 50% increase mainly due to reactions needed by the laser fusion program.

Slightly later, at the Hanford Site, an intense neutron source was designed based on 35 MeV deuterons incident on Li. In order to calculate delayed personnel dose, the REAC transmutation and activation computer code and data libraries[7] were developed. The emphasis was on the materials likely to be used and tested in such a facility. This resulted in over 1,000 reactions on about 100 targets. Unlike other libraries, which cover the neutron energy range to 20 MeV, this library goes up to 40 MeV. Where possible, the evaluations come from ENDF/B-V[8] or from ACTL-78.[6] However, the bulk of the data (80%) come from the calculations of the systematics computer code THRESH2.[9] These values were estimated because THRESH2 does not produce cross section data for (n,gamma) reactions or for isomeric production reactions. The (n,gamma) reactions were estimated from neighboring nuclei, while the production of each isomeric state was set to the cross section for the production of the ground state.

With the growing interest by the fusion community in producing reduced activation materials, three new and more complete libraries have been produced (U.S., REAC2; Holland, REAC-ECN-2; and the U.K., UKACT1). In each case, the REAC data library was used as a base and then extended.

The REAC2[10] covers 330 isotopes and approximately 6,000 reactions. The intent was to include all stable products (a few are missing) and all unstable products having a half-life greater than five years. Like REAC, the library extends to 40 MeV and is maintained in a point-wise format. There are additional evaluations from the T-2 group at the Los Alamos National Laboratory and from the Hanford Site. The library is maintained by F. M. Mann (Westinghouse Hanford Company).

The REAC-ECN-3[11] and REAC-ECN-2 are the follow-on versions of REAC-ECN-1, which is an outgrowth of REAC. The THRESH results in REAC were normalized at 14 MeV to either experimental data, where available, or to more recent systematics. More isomeric reactions are also included. Finally, the number of targets were increased. There are 9,000 reactions (some containing zero cross sections and others are non-unique) covering 490 targets. The library is maintained in pointwise format by Harm Gruppelaar at the Energy Centrum Nederland (ECN).

The UKACT1 library[12] is an outgrowth of REAC-ECN-1. Changes included the addition of more isomeric reactions and capture reactions. The number of targets was again increased, using the THRESH code. This library covers 625 target isotopes and 7,825 reactions. This library is maintained in the 100 group GAM-II format by Robin Forrest of Harwell Laboratory.

New Libraries

Dosimetry Data

Both ENDF/B-VI and JENDL-III will contain dosimetry data. It was once planned to perform least-square analyses to create a short-lived product and long-lived product dosimetry file for ENDF/B-VI. However, because of funding difficulties, these efforts were dropped. Instead, the evaluations of the reaction cross sections and their uncertainties will be taken from the ENDF/B-VI Standards efforts and from the General Purpose File. The evaluations taken from the Standards efforts will contain cross-material covariances. It is planned to include the Nb93(n,n') reaction from the new ANL evaluation.

The dosimetry file in the JENDL-III library will be created after the general purpose file of JENDL-III is completed.

Activation Data

Even though great strides have been made in the recent libraries, the new libraries promise even more progress. These libraries fall into three categories: 1) new versions of the regional libraries (JENDL-III, ENDF/B-VI), 2) new versions of previously released activation libraries (UKACTL2, REAC-ECN-3, and USACT-88), 3) a new joint activation library (JACT-88).

The JENDL-III will have an activation library, but it will not be released until after the general purpose file is released.

The ENDF/B-VI will also have an activation library. For this version, a list of important activation reactions was compiled and given to the evaluators. Thus, when ENDF/B-VI comes together, the reactions lifted from the general purpose evaluations for the activation file should be of a higher quality than the ENDF/B-V file.

The European files (JEF and EFF) will not include activation files. Europeans will instead rely on the Dutch (REAC-ECN-3) and United Kingdom (UKACTL2) efforts that are due this summer. Better systematics and more targets are the goal of the libraries.

A new version of the REAC library will also be released. It will be renamed USACT-88, to distinguish it from the computer code. The main additions will be the replacement of THRESH calculations with GNASH-P calculations by Bill Wilson of the T-2 group at Los Alamos. These calculations extend up to 100 MeV. The library will also be updated using ENDF/B-VI evaluations and replacing estimated (n,gamma) cross sections with evaluations.

Effort will be focused on a joint activation library after these last three libraries are released. A pointwise format similar to that of ENDF-VI will be used. The intent is to take the best parts of each of the libraries to produce a library for use in Europe and the United States and for the International Tokomak Experimental Reactor (ITER) Project. Harm Gruppelaar of ECN will maintain the file.

Conclusion

The past history and the near future of dosimetry and activation libraries have been presented. Contrasted with the dosimetry libraries, the activation libraries have seen significant interest and growth.

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