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Thresholds and Q Values of Nuclear Reactions Induced by Neutrons, Protons, Deuterons, Tritons, ^{3}He Ions, Alpha Particles, and Photons

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March 25, 1981

Lawrence Livermore National Laboratory

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FOREWORD

The UCRL-50400 series, *An Integrated System for Production of Neutronics and Photonics Calculational Constants*, describes an integrated, computer-oriented system for the production and application of neutronics and photonics calculational constants.

The system supplies reliable, up-to-date data, selects specific types of data on request, provides output in a variety of forms (ultimately in the form of input to other computer codes), and functions rapidly and efficiently.

The UCRL-50400 series comprises the following volumes:

- Vol. 1, Part A, Rev. 3, *ECSIL: A System for Storage, Retrieval, and Display of Experimental Neutron Data*, September 1976.
- Vol. 1, Part B, *Program ECSX4 (Version 78-1): Conversion of Experimentally Measured Cross-Section Data from the Four-Center-Exchange (X-4) Format to the Livermore ESCIL Format*, December 1978.
- Vol. 2, Rev. 2, *A Bibliography of the Experimental Data of Neutron-Induced Interactions*, July 1976.
- Vol. 3, Rev. 2, *An Index of the Experimental Data of Neutron-Induced Interactions*, July 1976.
- Vol. 4, *Evaluated Nuclear Cross-Section Library*, April 1971.
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- Vol. 7, Part A, Rev. 1, *Major Neutron-Induced Interactions ($Z \leq 55$): Graphical, Experimental Data*, July 1976.
- Vol. 7, Part B, Rev. 1, *Major Neutron-Induced Interactions ($Z > 55$): Graphical, Experimental Data*, July 1976.
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- Vol. 8, Part B, Rev. 1, *Supplemental Neutron-Induced Interactions ($Z > 35$): Graphical, Experimental Data*, July 1976.
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- Vol. 15, Part B, Rev. 1, *The LLL Evaluated-Nuclear-Data Library (ENDL): Graphs of Cross Sections from the Library*, October 1978.
- Vol. 15, Part C, *The LLL Evaluated-Nuclear-Data Library (ENDL): Translation of ENDL Neutron-Induced Interaction Data into the ENDF/B Format*, April 1976.
- Vol. 15, Part D, Rev. 1, *The LLL Evaluated-Nuclear-Data Library (ENDL): Descriptions of Individual Evaluations for $Z = 0$-98*, May 1978.
- Vol. 15, Part E, *Data Testing Results for the LLL Nuclear Data Library (ENDL-78)*, August 1979.
- Vol. 15, Part F, *Experimental and Evaluated Elastic Nuclear Plus Interference Cross Sections for Light Charged Particles*, July 1980.

- Vol. 16, Rev. 2, *Tabular and Graphical Presentation of 175 Neutron-Group Constants Derived from the LLL Evaluated-Nuclear-Data Library (ENDL)*, October 1978.
- Vol. 17, Part A, Rev. 2, *Program LINEAR (Version 79-1): Linearize Data in the Evaluated Nuclear Data File/Version B (ENDF/B) Format*, October 1979.
- Vol. 17, Part B, Rev. 2, *Program SIGMA1 (Version 79-1): Doppler Broaden Evaluated Cross Sections in the Evaluated Nuclear Data File/Version B (ENDF/B) Format*, October 1979.
- Vol. 17, Part C, *Program RECENT: Reconstruction of Energy-Dependent Cross Sections in Resonance Parameters in the ENDF/B Format*, October 1979.
- Vol. 17, Part D, *Program GROUPIE: Calculation of Self-Shielded Cross Sections and Multiband Parameters from Evaluated Data in the ENDF/B Format*, 1980.
- Vol. 17, Part E, *Program EVALPLOT: Plot Data in the Evaluated-Nuclear-Data File/Version B (ENDF/B) Format*, February 1979.
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- Vol. 22, *GAMIDENT: A Program to Aid in the Identification of Unknown Materials by Gamma-Ray Spectroscopy*, January 1980.
- Vol. 23, *ENSL and CDRL: Evaluated Nuclear Structure Libraries*, February 1981.
- Vol. 24, *Thresholds and Q Values of Nuclear Reactions Induced by Neutrons, Protons, Deuterons, Tritons, ^{3}He Ions, Alpha Particles, and Photons*, March 1981.

CONTENTS

THRESHOLDS AND Q VALUES OF NUCLEAR REACTIONS INDUCED BY NEUTRONS, PROTONS, DEUTERONS, TRITONS, ^{3}He IONS, ALPHA PARTICLES, AND PHOTONS

ABSTRACT

I have used the 1977 Wapstra and Bos nuclear mass data tables to derive tables for thresholds and Q values of nuclear reactions induced by neutrons, protons, deuterons, tritons, ^{3}He ions, alpha particles, and photons.

INTRODUCTION

I have used the 1977 Wapstra and Bos nuclear mass data tables[1] to derive tables for thresholds and Q values of nuclear reactions induced by neutrons, protons, deuterons, tritons, ^{3}He ions, alpha particles, and photons. These tables are displayed on the microfiche included with this report.

The threshold of a reaction is defined as the minimum kinetic energy of an impinging particle that makes the reaction energetically possible. For reactions induced by charged incident particles, the real threshold, i.e., the energy at which the reaction has a nonzero cross section, will be at a value somewhat greater than the mass-difference threshold because of coulomb effects--especially if the coulomb barrier is the same or greater than the mass-difference threshold. It is not possible to give a precise value to the real threshold because of tunneling effects. Consequently, the values presented in the tables for thresholds are derived from mass differences only.

The tables for thresholds have three different types of entries: positive entries, negative entries, and dashes. A positive entry is the mass-difference threshold; a negative entry, the negative of the positive Q value associated with an exoergic reaction, indicates an exoergic reaction with a zero threshold. A dashed entry indicates that the mass of the residual nuclei is not known or, in the case of very light nuclei, that the reaction is not possible. For example, a neutron impinging on a deuteron cannot initiate a reaction in which an alpha particle is emitted.

The Q values presented here are defined as the sum of the masses of all particles in the exit channel subtracted from the sum of the masses of all particles in the entrance channel. This difference is multiplied by 931.502 MeV/amu to convert to megaelectron volts.

To calculate the thresholds, I used the following assumption: if the mass of the impinging particle is m, then the threshold for reactions having negative Q values is $-[(A + m)/A]Q$, where A is the mass of the target.

REFERENCE

1. A. H. Wapstra and K. Bos, "The 1977 Atomic Mass Evaluation in Four Parts," At. Data Nucl. Data Tables 19, 177-214 (1977).

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