Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 25-26, 2007

Production Cross Sections of Light Particles in Proton Induced Reactions

Hyeong Il Kim and Young-Ouk Lee
Nuclear Data Evaluation Lab., Korea Atomic Research Institute,
150,Deokjin, Yuseong,Daejeon,
hikim@kaeri.re.kr

1. Introduction

Production cross sections of the charged particle induced reactions play a great important role for design of an accelerator-based facility to produce radioisotopes, including system performance, induced radiation doses, material activation, heating, damage, and shielding requirements. Further, the availability of accurate nuclear data directly affects the reliability of all simulations carried out in the design.

For many years, a tremendous effort has been invested in the development of nuclear data libraries. To perform adequate inter- and extrapolation on the energy and angular grids per reaction channel, transport and reactor codes rely on a complete description of a nuclear reaction in a data file, and not only on the data that happen to be available through measurements. For proton induced nuclear data, the ENDF/B-VII.0 [1] and JEFF-3.1 evaluations satisfy this condition. But these libraries mainly contain evaluations for the nuclear reactions induced by neutron rather than proton. That is, the ENDF/B-VII.0 contains the evaluations of 393 materials for neutron but 48 for proton. The JEFF-3.1 contains evaluations of 26 materials. For the purpose of medical applications, although IAEA [2] and KAERI [3] made the evaluation files for several materials, they do not provide a complete description of nuclear reaction because they contain the evaluations for only a few partial channels per reaction.

This work aims to study a considerable detail for charged particle induced reactions, and to set up the optical model potential (OMP) parameters which play a great important role in nuclear reaction calculation. The target material is ^{27}Al which is an important material for design of accelerator-based on facility. The model calculations are based on nuclear model code Talys [4] which is able to produce a complete set of cross sections, yields, energy spectra and angular distributions

2. Model Calculation

Nuclear model calculations need many model parameters such as optical model parameters, nuclear level densities, gamma strength functions. In this work, we are interest in the parameterization of OMP which is the most important process and a first step in nuclear model calculation.

Many OMP parameters are available in the literature and RIPL-2 [5] database, but they usually need to be adjusted in order to produce reasonable physical observables. The OMP parameters used in this work are taken from Ref. [6], and adjusted to reproduce available measurements. The OMP parameterization of proton and neutron is

$$V_V(E)=v_1\left[1-v_2\left(E-E_f\right)+v_3\left(E-E_f\right)^2-v_4\left(E-E_f\right)^3\right],$$

$$W_V(E)=w_1\frac{(E-E_f)^2}{(E-E_f)^2+(w_2)^2},$$

$$W_D(E)=d_1\frac{(E-E_f)^2}{(E-E_f)^2+(d_3)^2}\exp[-d_2(E-E_f)],$$

$$V_{SO}(E)=v_{SO1}\exp\left[-v_{SO2}\left(E-E_f\right)\right],$$

$$W_{SO}(E)=w_{SO1}\frac{(E-E_f)^2}{(E-E_f)^2+(w_{SO2})^2},$$

$$r_V, a_V, r_D, a_D, r_{SO}, a_{SO} \text{ : constant}. \quad (1)$$

where $V_{V,SO}$ and $W_{V,D,SO}$ are the real and imaginary components of the volume-central (V), surface-central (D) and spin-orbit (SO) potential well depths, respectively, r_i is the associated reduced radius and a_i the diffuseness parameter, E is the incident energy in the LAB system in MeV, r_C is the coulomb radius and E_f is the Fermi energy. **Table** 1 shows the OMP parameters for proton and neuron required for both incoming and outgoing processes.

Table 1. OMP parameters for proton and neutron

Parameters	p+^{27}Al	n+^{27}Al
r_V	1.162	1.162
a_V	0.665	0.665
v_1	62.4	75.0
v_2	0.0071	0.0071
v_3	1.7 x 10^{-5}	1.9 x 10^{-5}
v_4	7 x 10^{-9}	7 x 10^{-9}
w_1	14.2	12.8
w_2	75.0	75.0
r_D	1.290	1.290
a_D	0.510	0.538
d_1	13.6	13.0
d_2	0.0224	0.0224
d_3	11.50	11.50
r_{SO}	1.0	1.0
a_{SO}	0.58	0.58
v_{SO1}	6.0	6.1
v_{SO2}	0.0035	0.0035
w_{SO1}	-3.1	-3.1
w_{SO2}	160	160
E_f	-9.93	-10.39
r_C	1.329	0

Using the OMP parameters in Table 1, we calculated the nuclear reactions for ^{27}Al target with incident proton energies from 0.1 MeV to 150 MeV. Figure 1 shows the non-elastic scattering cross section compared to the measurements and the ENDF/B-VII.0. For the OMP parameterizations of deuterons, tritons, helium-3 and alpha particles, we use a simplification of the folding approach of Watanabe [7].

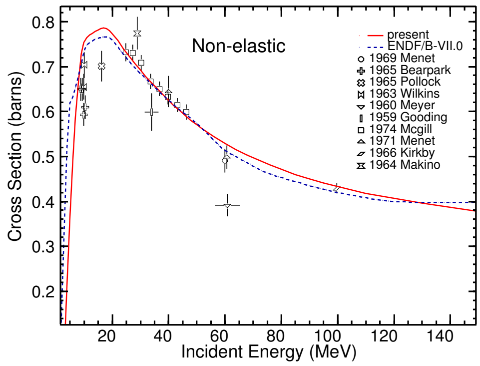

Figure 1. Non-elastic scattering cross section.

3. Results and Discussion

We obtained the production cross sections of light particles (neutron, proton, deuteron, triton, helium-3, and alpha) and compared the results to the ENDF/B-VII.0 and the measurements available. Other libraries such as the JEFF-3.1, IAEA and KAERI evaluations do not contain these productions. Figures 2 and 3 show that our results reproduce the measured data well, but the ENDF/B-VII.0 has a strange shape for alpha productions and do not contain helium-3 ones.

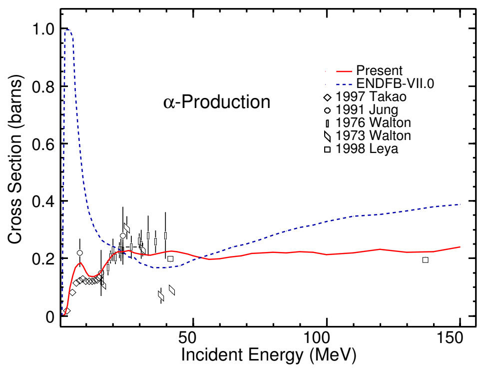

Figure 2. Production cross sections of alpha.

It is natural that a complete calculation for all possible channels in proton induced reactions needs the reasonable parameterizations of many nuclear models as well as OMP. But the well reproduced cross sections of light particles promise the good production data for residual nuclides, because they involve in the usage of the appropriate parameters. In future work, we will produce data files that provide a complete representation of nuclear data needed for transport, radioactivity, and shielding applications over the incident proton.

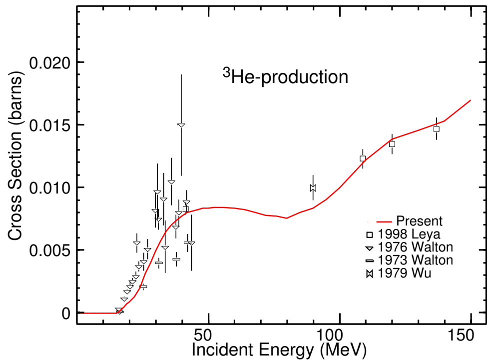

Figure 3. Production cross sections of ^{3}He.

Acknowledgements

This work has been performed under the auspices of the Korean Ministry of Science and Technology as the long-term R&D project.

REFERENCES

[1] M.B. Chadwick, P. Oblozinsky, M. Herman, et al., ENDF/B-VII.0: Next generation evaluated nuclear data library for nuclear science and technology, Nuclear Data Sheets, Vol. 107, p. 2931, 2006.

[2] S. M. Qaim, et al., Carged particle cross-section data base for medical radioisotope production: diagnostic radioisotopes and monitor reactions, Tech. Rep. IAEA-TECDOC-1211, IAEA, 2001.

[3] Y.-O. Lee, et al., KAERI Charged Particle Cross Section Library for Radioisotope Production, Tech. Rep. KAERI/TR-1946/2001, KAERI, 2001.

[4] A.J. Koning, S. Hilaire and M.C. Duijvestijn, TALYS: Comprehensive nuclear reaction modeling, Proceedings of the International conference on Nuclear Data for Science and Technology-ND2004, Sep. 26 – Oct. 1, 2004, Santa Fe, USA.

[5] IAEA-CRP, Reference Input Parameter Library (RIPL-2), http://www-nds.iaea.org/ripl2/, 2003.

[6] A. J. Koning and J. P. Delaroche, Local ang global nucleon optical models from 1 keV to 200 MeV, Nucl. Phys. A, Vol. 713, p. 231, 2003.

[7] S. Watanabe, High energy scattering of deuterons by complex nuclei, Nucl. Phys. Vol. 8, p. 484, 1958.