Argonne Nuclear Data Activities

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Abstract

An investigation of appropriate methods to be used for representing large errors in astrophysical reaction rates has been continued this year. A manuscript on the results obtained from this study to date has been drafted and is undergoing refinements. An experimental investigation of 6-7 MeV γ-ray production via the $^{19}F(p,\alpha\gamma)^{16}O$ reaction from a stopping target of the gas SF_6 was completed. It was determined that this is an excellent target material to use for gamma-ray production purposes. Furthermore, when the gas cell and entrance window are fabricated from aluminum, spurious neutron production is reduced to a minimum for protons with energies smaller than 4 MeV. Use of these gamma rays for the detection of sensitive nuclear weapons materials has been investigated further and it was concluded that the approach – code named FIGARO – is quite resistant to countermeasure techniques which might be attempted by terrorists to avoid detection. Measurements of neutron activation cross sections from 16-20 MeV for reactions associated with the following elements were completed at IRMM, Geel, Belgium, during January – February 2001: Cr, Cu, Mo, Se, Sr, Zn, Zr, V, Tc, and Pb. Progress was made during the past year in the analysis of these data and earlier data taken at IRMM during 1998-2000. Work continued on a nuclear model parameter sensitivity study first undertaken last year, and a journal article on the results of this work has been submitted for publication. Finally, Argonne has begun a program of nuclear structure data evaluations. Software used in this activity was acquired from NNDC-BNL and work has begun on the evaluation of structure and decay data for selected mass A = 143 nuclei. Argonne has also agreed to act as a reviewer of some completed ENSDF evaluations prepared by other researchers in the international network of nuclear structure evaluators.

Neutron Activation Cross Sections

During the past year Argonne continued to work on several aspects of an international collaboration formed to measure neutron activation cross sections for as many materials as can be obtained – including isotopically enriched samples. This project is being conducted under the auspices of a NEA-WPEC subgroup activity led by A. Plompen of IRMM, Geel, Belgium. The energy range is 16-20 MeV and the neutron source is the $T(d,n)^4He$ reaction. In particular, Argonne has been involved in these measurements as well as in calculating coincidence summing corrections for counting data obtained in poor (high counting efficiency) geometries. Such counting arrangements were required due to the small sizes of some of the samples and low cross sections. Argonne also contributed to developing a new method – denoted by the term "spectral indexing" – for adjusting measured time-of-flight neutron spectra. This approach is needed in order to correct for low-energy neutron contamination in the irradiation environment. Recently (January – February 2001) a new round measurements was completed at the Van de Graaff facility of IRMM, Geel, Belgium. Neutron source spectra were measured by the time-of-flight method. Then, the following activation reactions were investigated during this experiment:
Cr-50(n,2n)Cr-49, Cu-65(n,α)Co-62g, Cu-65(n,α)Co-62m, Mo-100(n,np)Nb-99, Mo-92(n,2n)Mo-91m, Mo-92(n,2n)Mo-91m, Mo-92(n,α)Zr-89g, Mo-92(n,α)Zr-89g, Mo-92(n,α)Zr-89m, Mo-92(n,α)Zr-89m, Mo-92(n,p)Nb-92m, Mo-92(n,p)Nb-92m, Mo-92(n,p2n)Nb-90g, Mo-94(n,2n)Mo-93m, Mo-95(n,p)Nb-95g, Mo-95(n,p)Nb-95m, Mo-96(n,np)Nb-95g, Mo-96(n,np)Nb-95m, Mo-96(n,p)Nb-96, Mo-96(n,p)Nb-96, Mo-97(n,np)Nb-96, Mo-97(n,p)Nb-97g, Mo-97(n,p)Nb-97m, Mo-97(n,p)Nb-97m, Mo-98(n,γ)Mo-99, Mo-98(n,γ)Mo-99, Mo-98(n,p)Nb-98, Mo-98(n,p)Nb-98, Mo-98(n,p2n)Nb-96, Mo-98(n,pn)Nb-97g, Mo-98(n,pn)Nb-97m, Se-74(n,np)As-73, Se-74(n,p)As-74, Se-76(n,2n)Se-75, Se-76(n,p)As-76, Se-77(n,p)As-75, Se-78(n,α)Ge-75, Sr-84(n,2n)Sr-83, Sr-84(n,γ)Sr-85m, Sr-84(n,p)Rb-84m, Sr-86(n,2n)Sr-85m, Sr-86(n,2n)Sr-85m, Sr-86(n,p)Rb-86m, Sr-86(n,p)Rb-86m, Sr-88(n,2n)Sr-87, Sr-88(n,p)Rb-88, Zn-64(n,2n)Zn-63, Zn-66(n,2n)Zn-65, Zn-66(n,p)Cu-66, Zn-66(n,p)Cu-66, Zn-67(n,np)Cu-66, Zn-67(n,p)Cu-67, Zn-68(n,α)Ni-65, Zn-68(n,p)Cu-68g, Zn-68(n,p)Cu-68m, Zn-68(n,p)Cu-68m, Zn-70(n,2n)Zn-69, Zr-90(n,α)Sr-87, Zr-90(n,α)Sr-87, Zr-90(n,2n)Zr-89g, Zr-90(n,2n)Zr-89g, Zr-90(n,2n)Zr-89m, Zr-90(n,2n)Zr-89m, Zr-90(n,p)Y-90m, Zr-90(n,p)Y-90m, Zr-90(n,pn)Y-89m, Zr-91(n,3n)Zr-89g, Zr-91(n,nα)Sr-87, Zr-91(n,np)Y-90m, Zr-91(n,p)Y-91m, Zr-91(n,p)Y-91m, Zr-92(n,4n)Zr-89g, Zr-92(n,p)Y-92, Zr-92(n,p)Y-92, Zr-92(n,p2n)Y-90m, Zr-92(n,pn)Y-91m, Zr-94(n,p)Y-94, Zr-96(n,2n)Zr-95, Zr-96(n,α)Sr-93, V-51(n,nα)Sc-47, Tc-99(n,n')Tc-99m, Tc-99(n,p)Mo-99, Tc-99(n,α)Nb-96, Pb-204(n,3n)Pb-202m, Pb-204(n,2n)Pb-203g, Pb-204(n,n')Pb-204m, Pb-204(n,p)Tl-204.

Astrophysical Studies

Work during this past year has focused mainly on an investigation of methods to adequately represent the very large errors encountered in reaction cross sections and astrophysical reaction rates at low energies near the thresholds for charged-particle-induced nuclear processes. The approach used here invokes the log-normal probability distribution. A paper on this work has been drafted and has been undergoing revision during the first months of 2001. This work is being conducted in collaboration with the Nuclear Astrophysics Group at ORNL

Gamma Rays from $^{19}F(p,\alpha\gamma)^{16}O$

This reaction is a prolific source of 6-7 MeV γ-rays when fluorine compound targets are bombarded with protons. The γ-ray yields that result from 1.5-4.0 MeV proton bombardment of a stopping target of SF_6 gas have been measured this past year. It was determined that this is an excellent target material for gamma-ray production purposes. Furthermore, when the target assembly is constructed from aluminum the production of spurious neutrons by (p,n) reactions is minimized for proton energies below 4 MeV. This is important for applications that require a nearly pure primary source of gamma radiation with low neutron contamination. Then, secondary neutron production stimulated by high-energy photon bombardment of certain materials used in the production of nuclear weapons can be measured with reasonable reliability. A technique developed at Argonne – code named FIGARO – is being explored as an application for this fluorine gamma-ray source. Measurements were made at Ohio University during the past year to demonstrate the technique. It was found that FIGARO can be used to locate actinide materials, Li-6, beryllium, and deuterium hidden in containers. The method is quite resistant to countermeasures likely to be used by terrorists to conceal these materials during smuggling out of nuclear centers and across national borders.

Parameter Sensitivity Studies for the Development of Nuclear Models

Working with an experimental database acquired from the ANL/IRMM collaboration – augmented with results from the literature – nuclear model calculations are being performed using the statistical/pre-compound reaction code STAPRE. The objective is to identify those sets of parameters that yield good fits to the data. Then, sensitivity parameters are calculated to examine how the results of nuclear model calculations, e.g., the selection of parameters, can be influenced by experimental data. This – in turn – provides useful guidance on the need for new measurements to better determine cross-section excitation functions. Results obtained from a detailed study of neutron activation reactions on chromium are described in a journal paper that has been submitted for publication.

Nuclear Structure Data Evaluation

During the past year the Technology Development Division hired a physicist – Dr. Filip G. Kondev – who in the future will be working in the Nuclear Data Program at Argonne. Dr. Kondev possesses extensive experience in the field of nuclear structure and radioactivity research. He will work closely with other evaluators in the international ENSDF network. It has been decided via consultation with this community that Argonne should begin its work in the field by performing evaluations for several nuclei in the mass region A = 143. These are isotopes for which the existing evaluations are quite old and are widely acknowledged to be due for updates. Furthermore, Argonne has agreed to contribute to the process of reviewing new evaluations recently completed by other members of this network.