Nuclear Data Activities at LANSCE

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ABSTRACT

Neutron total cross sections have been measured from 5 to 560 MeV on 31 elements and isotopes. For nearly all of the target materials, the data are accurate to better than 1% (both statistical and systematic) in 1% neutron energy bins. Neutron-induced photon production cross section measurements for oxygen have been completed from 4 to 200 MeV. Gamma-ray production cross sections on ^{235}U, ^{238}U and ^{239}Pu are in progress to with the goal of deducing (n,xn) (x=1,2,3…) reaction cross sections. Fission-fragment yields are also being determined from these data. A new array, FIGARO, of high resolution gamma-ray detectors has been commissioned to study angular-momentum effects in nuclear reactions; data for discrete transitions following (n,xn), (n,xp) and (n,xα) reactions on ^{59}Co are being analyzed. Neutron reactions that yield light charged particles have been completed for silicon and the results analyzed in terms of nuclear level densities and the effect of isospin conservation. Similar studies are in progress for ^{92,94,96}Mo over the neutron energy range from threshold to 60 MeV. A program of measurements of neutron capture on radioactive targets is in progress and a large 4-π detector of the capture gamma rays has been designed.

Neutron Total Cross Sections up to 560 MeV

We have completed a new set of total cross section measurements of 31 elements and isotopes spanning the periodic table. These measurements were supported by the Accelerator Production of Tritium (APT) project as part of a program to improve the physics in the modeling codes for neutron transport up to several hundred MeV. We employed the same techniques as used by Finlay et al. [Phys. Rev. **C47**, 237 (1993)] with refinements intended to allow measurements on separated isotopes and improved systematic error control. The goal of the new measurement was 1% statistical accuracy in 1% energy bins with systematic errors less than 1%. This was achieved for all but the smallest samples, for which the statistical accuracy was as large as 3% in 1% bins, and for two isotopic samples where the systematic uncertainties measured up to 3.7%. Stringent checks of systematic errors in this measurement resulted in a reassignment of systematic uncertainties in the previous measurements by Finlay et al. The new data, along with those of Finlay et al., are being used in the development of a global optical potential from 20 to 2000 MeV, and the development of a simple parameterization of the total cross section based on a Ramsauer model. The total neutron cross sections for few nucleon systems (n+d and n+p) are also used to test Faddeev calculations.

Neutron-Induced Photon Production Cross Sections for Oxygen

Photon-production cross sections for neutron-induced reactions on oxygen have been measured over the incident neutron-energy range from 4 to 200 MeV using a BeO sample. The data were taken using the WNR spallation neutron source. Two HPGe detectors were used to measure gamma rays in the range from 150 keV to 8.9 MeV at seven angles. Excitation functions and angular-distribution data have been extracted for 23 γ rays produced in neutron-induced reactions on oxygen and one γ ray from the ^{9}Be(n,t) ^{7}Li reaction. Good agreement is observed with some of the previous gamma-ray measurements, although there is a wide spread in the cross section values. A revaluation of the oxygen cross sections based on the new data has been completed. As part of the evaluation of the data, neutron scattering cross sections were inferred. Good agreement with neutron scattering measurements is obtained. At neutron energies higher than 20 MeV comparison with GNASH model calculations have been performed. A paper is in preparation for submission to Nuclear Science and Engineering.

Measurement of partial gamma ray cross sections on U and Pu

Neutron-induced gamma-ray production cross section data have been obtained at the WNR spallation neutron source for samples of ^{235}U, ^{238}U , and ^{239}Pu with the GEANIE spectrometer as a joint LLNL and LANL endeavor. GEANIE consists of 26 HPGe detectors, 20 of which are escape suppressed with BGO shields. Data have been obtained for both (n,xn) and (n,f) reactions. Analysis of the data to determine cross sections for (n,xn) (x=1,2,3..) reactions is nearing completion.

Neutron-Induced Photon Production Cross Sections for Cobalt

The new FIGARO (Fast neutron-Induced Gamma-Ray Observer) array of high resolution gamma-ray detectors has made its first measurements of gamma rays emitted from cobalt bombarded with neutrons from 1 to 200 MeV. Data for discrete transitions following (n,xn), (n,xp) and (n,xα) reactions on ^{59}Co are being analyzed and will be compared with nuclear reaction model calculations previously used to interpret $^{59}Co(n,x\alpha)$ data taken previously here [S. M. Grimes, C. E. Brient, F. C. Goeckner, F. B. Bateman, M. B. Chadwick, R. C. Haight, T. M. Lee, S. M. Sterbenz, P. G. Young, O. A. Wasson, and H. Vonach, Nucl. Sci. Eng. **124**, 271 (1996)]. Angular moment effects as indicated by the gamma-ray data are being investigated. For the next running period, FIGARO will be upgraded with the addition of neutron detectors for $(n,xn+y\gamma)$ studies and conversion electron spectrometers, the latter on loan from the University of Pittsburgh.

Si(n,xp), (n,xd) and (n,xalpha) Reactions

Inclusive light charged-particle emission spectra and cross sections from neutron bombardment of silicon were measured at 30, 60, 90 and 135 degrees over the neutron energy range from threshold to approximately 60 MeV. Comparisons of our alpha-particle data with Hauser-Feshbach calculations, which include multi-stage emission processes and pre-equilibrium particle emission, indicate that the majority of alpha particles result from compound nuclear reactions. For proton and deuteron emission, direct and pre-equilibrium processes contribute significantly to the emission cross section. These data provide rigorous tests for the calculations while helping to guide the selection of input parameters such as nuclear level densities. The effects of assuming partial or complete isospin conservation are shown to be important for these reactions.

^{92,94,96}Mo(n,xp), (n,xd) and (n,xalpha) Reactions

Previous measurements of charged-particle emission in 15-MeV-neutron-induced reactions on molybdenum isotopes yielded data that were difficult to explain by conventional statistical and pre-equilibrium reaction models. [R. C. Haight, S. M. Grimes, R. G. Johnson, and H. H. Barschall, Phys. Rev. **C23**, 700 (1981).] With the goal of a better understanding of these reactions, measurements have been made at WNR from threshold to 60 MeV incident neutron energy. The wide range of neutron energies should permit a much better separation of contributions from the different reaction mechanisms. The data are presently being analyzed.

Neutron capture on radioactive targets: probing the s-process

Abstract presented at the Second International Conference on Fission and Neutron-rich Nuclei, University of St. Andrews, Scotland, June 28 to July 2, 1999, by J.B. Wilhelmy, M. M. Fowler, R. C. Haight, G. G. Miller, R. S. Rundberg, E. H. Seabury, J. L. Ullmann, (LANL) and M. Heil, F. Kaeppeler, R. Reifarth, F. Voss, and K. Wisshak (Karlsruhe):

The pioneering work of Burbidge, Burbidge, Fowler and Hoyle (BBFH) in 1957 outlined the basic mechanism for heavy element nucleosynthesis in the stellar environment. However, some specifics of the s-process remain poorly determined. Central to these is an understanding of the “branching point” nuclei. These are isotopes that have half-lives such that there is a competition between beta decay and neutron capture. Such isotopes have a critical role in understanding the stellar temperature and neutron density and thus the dynamics of nucleosynthesis. At Los Alamos we have begun a program to irradiate radioactive targets and measure the differential capture reactions that are required to unfold the details of stellar evolution. This program utilizes the high fluence available at the LANSCE neutron spallation source to investigate targets having mass on the order of 1 mg. The radioactive target material is obtained via spallation reactions at high intensity accelerators or from irradiations at nuclear reactors. For purification and preparation of the target material, we have dedicated chemical and isotope separator capabilities housed in hot cell environments. A 162-element 4π BaF_2 detector array that will permit highly segmented, calorimetric measurements on capture gamma rays is being procured for this program.