Cross section measurements for (n,xn) reactions by in-beam gamma-ray spectroscopy

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New concepts as fast reactors and accelerator driven systems (ADS) for waste incineration or energy production cause a demand for neutron cross section data over a wide energy range. Precise (n,xn) cross sections are required as these reactions contribute significantly to the neutron balance and the modification of the neutron spectrum. The present existing data base for (n,xn) reactions is scarce, especially for x>2, as previous nuclear data measurement programs had often their emphasis on a neutron energy range below their reaction thresholds. Existing experimental data and also evaluated data on (n,xn) reactions often show large discrepancies. Thus in the frame of the n_TOF project a program to measure (n,xn) cross sections was initiated.

One method to investigate (n,xn) reactions is the detection of promptly emitted gamma-rays in low-lying transitions in the residual nucleus by high-resolution gamma-ray detectors. Using the time-of-flight method to determine the incident neutron energy, this method can also be used at "white" neutron beams. The measured quantities, however, are production cross-sections for strong gamma-ray transitions in the residual nucleus, which have to be combined with nuclear model calculations to give total (n,xn) cross sections. Thus in a combination of measured gamma-ray production cross sections (which contribute in some cases up to 80%-90% to the total (n,xn) cross section) and model calculations cross sections for (n,xn) reactions can be determined where the activation method is not possible, either due to the residual nucleus properties or the lack of monoenergetic neutron sources.

We have studied the possibilities of performing gamma-ray emission measurements on ^{232}Th at the quasi-monoenergetic neutron source of the Cyclotron Research Center in Louvain-la-Neuve, Belgium and on Pb at the GELINA white neutron beam at the Institute for Reference Materials and Measurements in Geel, Belgium. Prompt gamma-ray spectra were recorded using high-purity germanium detectors. To obtain a good compromise between energy resolution and dead time at the GELINA neutron beam, we developed a data acquisition system based on fast flash ADCs and used digital pulse processing techniques. Gamma lines corresponding to low-lying transitions in residual nuclei of different (n,xn) reactions were clearly identified and analyzed in several test measurements at both facilities. Preliminary excitation curves for the production of prompt gamma-rays in ^{206,207,208}Pb in a natural lead sample show good agreement with predictions based on nuclear model calculations. After

these successful tests measurements to obtain ^{232}Th(n,5n) and ^{207}Pb(n,xn) cross sections (the latter ones with an isotopically enriched sample) are planned to be performed in the first half of 2004 in Louvain-la-Neuve and Geel, respectively. Also the feasibility of a measurement with a very active sample like ^{233}U at n_TOF (CERN) is now being considered. Additional tests at this facility will be performed early in 2004.

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