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Physics of Neutron Production at the Oak Ridge Electron Linear Accelerator, *J. K. Dickens (ORNL)*

The Oak Ridge Electron Linear Accelerator (ORELA) neutron source has been in operation since 1969, and has provided neutrons for a substantial variety of experiments. Goals of these experiments involve understanding of basic nuclear physics, data with astrophysics applications, data for solid-state physics research, as well as research for applied needs such as the operation of, and shielding around, fusion and fission reactors.

Shifting national priorities, however, have resulted in new requests for different potential uses of the ORELA facility requiring, in particular, an improved understanding of flux distribution, $N(E_n)$ vs E_n , as well as a more detailed understanding of the generation of radioactivity for radiological purposes in the process of neutron production. In addition, increasingly sophisticated experiments require a more accurate determination of the neutron beam flux. Consequently, there has been a renewed effort, experimental and theoretical, to provide a more precise description of the neutron beam flux; the progress of this program is the subject of this report.

The ORELA provides a pulsed beam of electrons of 150 MeV nominal energy which impinges on a tantalum target. About 10^{14} neutrons/sec are generated with the accelerator at maximum power of 50 kW. Flowing water through and around the target not only provides necessary cooling, but also acts as a source of moderated neutrons. Usable neutron energies range between 10^{-3} and 10^8 eV.

The high-energy electrons hitting the tantalum target produce a bremsstrahlung (photon) spectrum. Neutrons are generated by photonuclear reactions, $Ta(\gamma, n)$, $Ta(\gamma, 2n)$, $Ta(\gamma, np)$, Recently, a controlled experiment¹ was concluded having two goals: (a) improving the fundamental knowledge of the photon-plus-tantalum interaction process; and (b) determining the radioisotope inventory in the ORELA target for radiological needs. In this experiment, a "slice" of the tantalum target was simulated using two separate thin tantalum foils placed in the electron beam just ahead of the tantalum target, the first foil acting as the radiator and the second as the target. After a short irradiation by the electron beam, the "target" foil was removed to a low background counting room. Yields of twenty-three radionuclides, including isomers, from ^{168m}Lu to ^{180}Ta , having half-lives between 7 min and 1.4 yr, produced by photon interactions with the tantalum "target" foil, were measured on the basis of gamma-ray data obtained using high-resolution detection systems. These results fulfill a practical need for present operation and should provide benchmark results for future theoretical analyses of photonuclear reactions.

The first theoretical calculations involving the ORELA target produced spatial² and energy³ distributions of neutrons in the target. A recent analysis⁴ has been concerned with the effects of neutron-energy moderation by the cooling water. The time that a neutron leaves the target and the time it is detected is measured; from this time of flight the neutron's energy, E_n , is deduced. The accuracy for which E_n may be determined depends partly upon the accuracy of determining the time the neutron leaves the target. This latter determination depends not only on the ORELA pulse characteristics, but also on a time distribution of the moderation of neutrons in the target. The time-dependent spectrum of neutrons in the water-moderated tantalum target has been computed using a modified version of the MORSE multigroup Monte Carlo code with an analytic hydrogen scattering model starting with spatial and energy distributions mentioned above. Distributions of effective neutron distance traversed in the target were estimated with a time- and energy-dependent algorithm for neutrons emitted normal to the target face. An approximate representation of the ORELA

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positron source facility, recently installed near the target, was included in the calculations to determine any perturbations the positron source might create in the computed neutron distributions from the target. The principal effect of the positron source is an increase in the distance for the lower energy neutron spectra, producing no real change in the distributions where the ORELA source is utilized for experiments. Different configurations for the target were investigated to simulate the placement of a shadow bar in the neutron beam. These configurations included neutrons escaping from (a) the central tantalum plates only, and (b) the entire target with the tantalum plates blocked out. Comparisons of the current calculations with the best present experimental estimate of $N(E_n)$ vs E_n determined from a variety of experiments for E_n between 10 eV and 1 MeV are favorable.

Results of the present program should have a practical use for ORELA operations and also for comparisons with calculations needed for future accelerator designs and applications.

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