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Calculation of the Energy-Dependent Efficiency
of Gridded ^3He Fast-Neutron Ionization Chambers

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FINAL REPORT

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I. Introduction

Research and development activities under this contract proceeded along several lines, including development of a gas jet facility for the transport and isolation of fission product activities with half lives in the range $T_{1/2} \leq 2$ sec., studies on the factors affecting the energy and timing resolution of gridded ^3He ionization detectors for delayed neutron spectroscopy and the development of simple models for calculation of the beta-decay characteristics of short-lived fission products near $A = 90$. These activities were carried out by three graduate students and a postdoctoral researcher in addition to the principal investigator. As a result of this work, three publications have appeared in the literature and several additional manuscripts describing studies following the contract period are in preparation. Brief outlines of the activities in the areas noted above follow and reprints of the publications referred to are attached.

II. Research Activities

A. Development of Gas Jet Facility for Fission Product Transport

(M. ZendeI and S.G. Prussin)

A gas jet transport system for the continuous production of short-lived fission products was designed, constructed and installed in a beam port of the Berkeley Research Reactor. The system is of the same nature as that installed at the reactor facility of the Institut für Kernchemie, Universität-Mainz, Germany.

The system consists of a cylindrical chamber which houses a small ($\approx 500\mu\text{g}$) ^{235}U target connected by capillaries to gas supplies, pressure monitors and a small hood facility into which the activity-laden gas exits for chemical manipulations. The chamber and leads are constructed of stainless steel and aluminum and are mounted in an aluminum liner which inserts into graphite annuli fitted into the beam port. The liner is filled with reactor-grade graphite

through which the polyethylene capillaries penetrate in small arcs to minimize streaming of neutrons and gamma-rays. The external end of the liner is covered with boron-loaded polyethylene and steel to reduce gamma ray and neutron fields to negligible levels.

The gas used for transport is a mixture of nitrogen and ethylene and at a reactor power level of 20 to 50 kW, sufficient fission product activity is obtained to test and develop chemical procedures. The system has been used for the delivery of radiochemically pure selenium and for gamma-gamma coincidence studies on short-lived isotopes of this element.

A manuscript describing the system and initial testing is being prepared for publication. Manuscripts describing the experimental studies on the selenium chemistry and decay schemes, performed subsequent to this contract, are also in preparation.

B. Studies on the Characteristics of Gridded ^3He Ionization Chambers for Delayed Neutron Spectroscopy

1. Energy Resolution (S. Samuelson and S.G. Prussin)

During the contract period studies were continued on the factors affecting the energy resolution of commercial ^3He ionization chambers. Using an acoustical isolation chamber constructed to minimize degradation of resolution due to vibration of the grid and anode wires, attempts were made to measure the delayed neutron spectrum from decay of ^{87}Br . The system was located in a room adjacent to the radiochemistry facility at the Livermore Pool Type Reactor (LPTR) and spectra from bromine sources isolated from ^{235}U fission products were summed to achieve reasonable statistical accuracy. Although a resolution approaching 10 keV at thermal energies was achieved under test conditions, the resolution exhibited in the bromine spectrum was only 11.0 - 11.5 keV. The degraded resolution most assuredly arose from the less-than-ideal acoustical isolation and the lack of gain stabilization over the long duration of the measurements (about one week).

Due to the announced shut down of the LPTR and programmatic changes resulting therefrom, further experimentation along these lines was discontinued.

2. Timing Resolution with ^3He Ionization Chambers in Coincidence Experiments (S. Samuelson, H.J. Harrell and S.G. Prussin)

Experimental measurements of n- γ coincidences with gridded ^3He ionization chambers for neutron detection have been hampered by very poor resolving times (about 5 μ sec) which seriously affect data acquisition rates. Such long resolving times derive from the use of anode signals for timing of the neutron event and the large spread in migration times for electrons produced in the grid-cathode volume to arrive at the grid-anode volume.

It occurred to us that since a signal at the grid of the ^3He chamber would begin to develop as soon as electron migration occurred, one might be able to substantially improve the timing characteristics by use of a pickoff from the grid. The anode signal would be used only for a high-resolution linear signal. For this purpose a coincidence circuit comprised of commercially available electronics was assembled and the ^3He detector modified to provide both anode and grid signals. Using neutrons from a ^{252}Cf spontaneous fission source, it was shown that grid signals of sufficient amplitude to observe about 70% of all neutron events could be obtained and that with use of these a resolving time of about 0.4 μ sec was achieved in coincidences between prompt neutrons and gamma rays. It was also shown that at least half of the remaining width resulted from lack of compensation for amplitude and risetime variations in the grid signals. A manuscript describing these studies has appeared in Nucl. Instr. Methods 173 (1980) 505, a reprint of which is attached.

3. Energy Dependent Efficiency of Gridded ^3He Ionization Chambers (W.C. Sailor and S.G. Prussin)

Delayed neutron spectra measured at various laboratories using ^3He ionization chambers have exhibited significant differences. A possible factor contributing to these discrepancies could be the difference between the energy

dependent efficiency function pertaining to the calibration geometry and that pertaining to the actual delayed neutrons measurements. Because of the difficulty in resolving the question experimentally, we developed a Monte Carlo code to calculate the relative efficiency function for one type of ^3He chamber for which the efficiency calibration conditions were well defined. The efficiency function calculated with the code was in good agreement with that obtained experimentally. By comparing the efficiency functions calculated for the calibration geometry and a geometry approximating that attendant to the actual delayed neutron measurements, we were able to show that the use of the calibration data is likely to produce less than 10% errors for neutron energies below 2 MeV, but errors as large as 20-30% could result with neutron energies of 3 MeV.

A manuscript describing these studies has appeared in Nucl. Instr. Methods 173 (1980) 511, a reprint of which is attached.

C. Beta-Strength Functions Near $A = 90$
(Z. M. Oliveira and S.G. Prussin)

As a result of numerous calculations which demonstrate substantial discrepancies between experimental data on delayed neutron emission and a simple statistical description of the beta decay and subsequent neutron emission, we have attempted to examine the influence of a shell model description of the beta-decay on GT-strength functions near $A = 90$. In order to compare the ability of the model to describe the overall characteristics of GT-strength functions, model calculations were performed for the decay of $^{90,92,94}\text{Zr}$ to the corresponding Nb daughters for which mapping of the GT-strengths had been obtained experimentally through use of the p,n reaction. Single-particle spectra were derived through a combination of experiment and theory and the effects of pairing and the GT-residual interaction were included in the simple

BCS and random phase approximations, respectively. The resultant strength functions were found to model the experimental data quite well, both with regard to the overall envelope of the strength function and the fractionation of strength between high and low energy. The results indicated substantial departures from the predictions of the gross theory of beta decay and suggest the possibility of structure in that part of the strength function accessible to the beta decay of neutron rich fission products in this mass region. A manuscript describing these studies has appeared in Nucl. Phys. A139 (1980) 503, a reprint of which is attached.

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