Determining neutron flux by means of neutron activated analysis with calibrated probes

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Introduction

The goal of this experiment was to characterize the fast, epithermal and thermal neutron flux of the dry irradiation facility (DRI) at the Rhode Island Nuclear Science Center. Before the performance of this experiment, this room had never been examined for irradiation affects, and thus this experiment could serve as a pioneer analysis of potential uses for this facility.
In order to characterize the flux, a process of Neutron Activation Analysis (NAA) was employed. Once the target probes were irradiated, they were then counted to determine their resulting activity. This activity was then used to calculate the incident flux by means of the equation $A = N\phi\sigma(1- e^{-\lambda t})$.

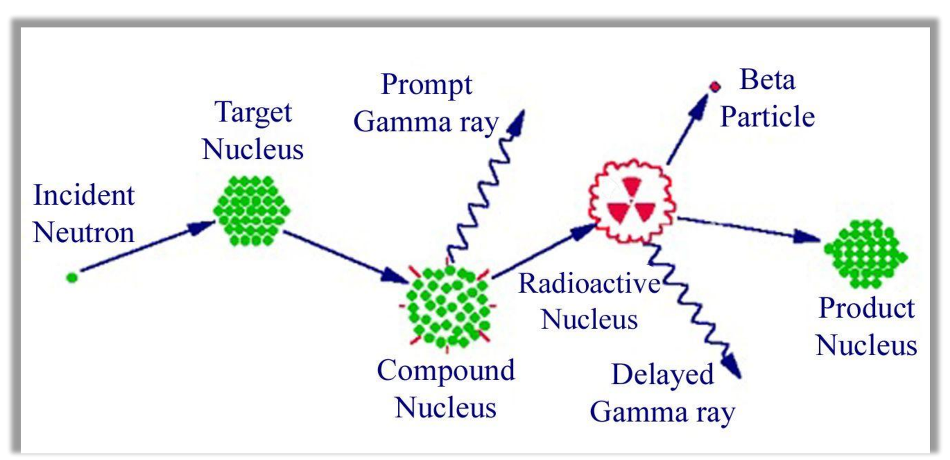


Figure 1. Illustration of NAA Process
Source: http://archaeometry.missouri.edu/naa_overview.html

Because of the location of the DRI on the east-side floor adjacent the reactor pool, it was necessary to slide the reactor core to the east side of the pool by means of its built-in track system. However, because this position eliminated the use of the backup reactor cooling system, the maximum reactor power allowed for the irradiation was 100kW (1/20th of the normal maximum operating power). Thus initial projections were made that the flux in the DRI would not have outcomes higher than 1/20th of the known values for the fast, epithermal and thermal neutron flux counts provided to the reactor rabbit system when the reactor was fully operational and at its maximum operating power of 2MW.

Materials and methods

A major component of success with this experiment depended on the proper choice of target probes. Thus intense research went into discovering which chemical elements would be most effectively activated by thermal, epithermal and/or fast neutrons. Probe usefulness was fundamentally dependent upon it possessing a large absorption cross section and a half life reasonable for the time constraints of the experiment.

Materials and methods (continued)

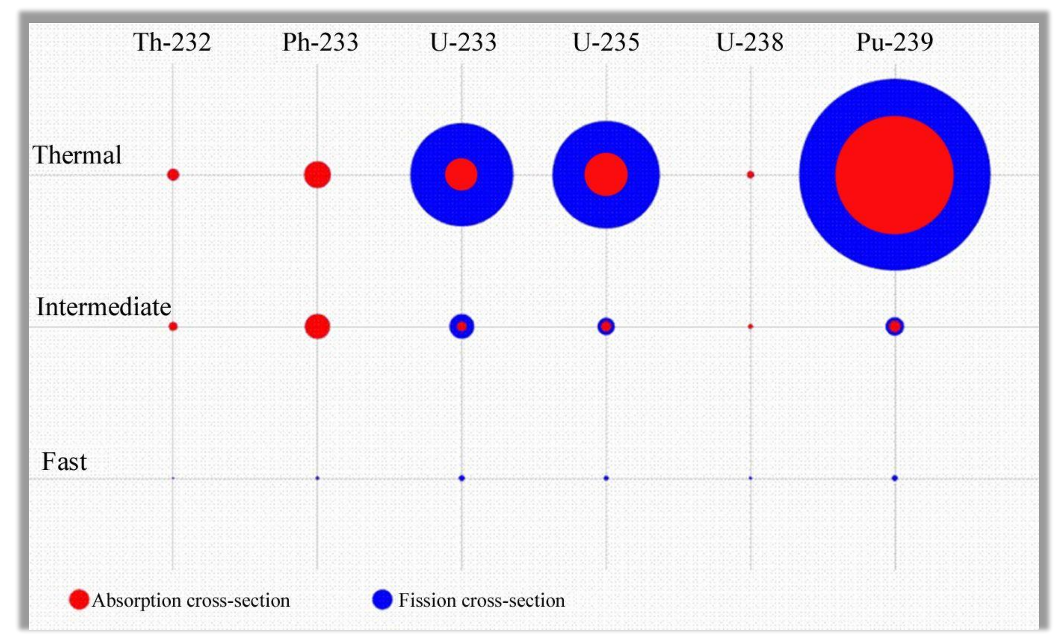


Figure 2. Nuclear cross sections (with inner circle indicating absorption cross section, and outer rim indicating scattering cross section). Source: *Google, neutron cross sections, images.*

This comprehensive analysis revealed that indium-115 would prove useful as a thermal neutron probe, aluminum-27 as a fast neutron probe, and cadmium covered, indium-115, as an epithermal probe.

Figure 3. Sample probe setup made ready for irradiation.

Materials and methods (continued)

Figure 4. Cavity in the DRI in which "probe board" was placed (left) and entrance to DRI room with block shielding (right).

As the above several figures depict, the chosen sample probes were arranged in a pattern from which it would be possible to obtain an estimate of the flux gradient across the DRI cavity. After the samples were set in place, the reactor was wheeled over to the east end of the pool, brought up to power, and them scrammed after the proper irradiation time of the sample probes. With the irradiation complete, the reactor core was brought back into position at the west end of the pool, the probe board was retrieved and the samples were counted.

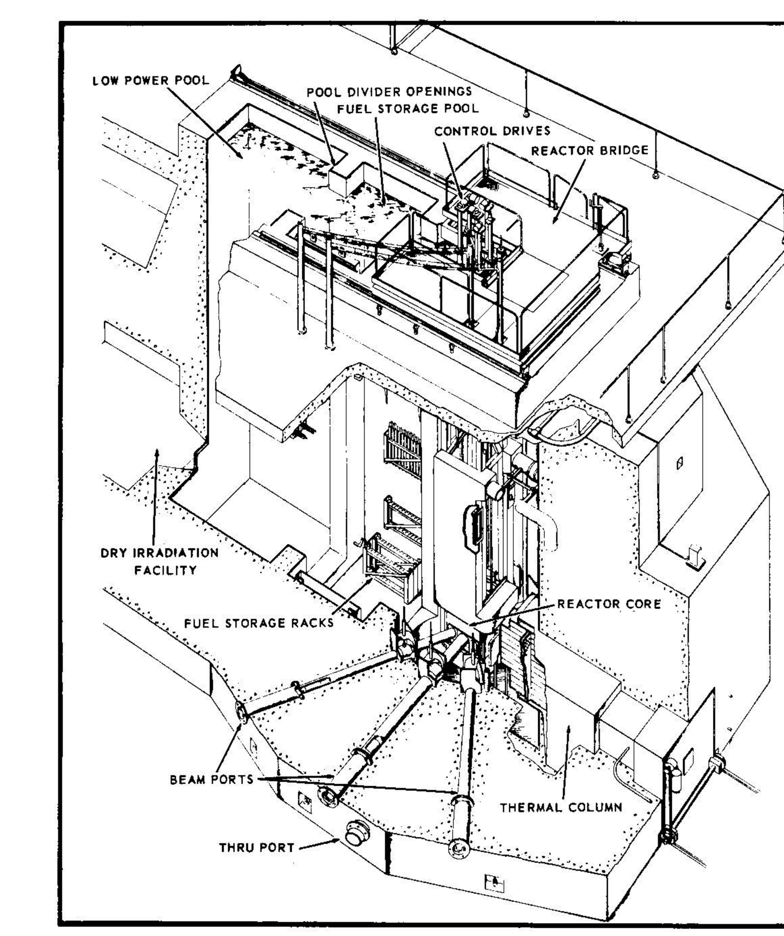
Results

While it was originally calculated that a 5kW irradiation for 300 seconds would produce enough activity for the counting statistics to provide the neutron flux with reasonable error, a hitch was encountered when the reactor was brought over to the east end of the pool and it was discovered that about two feet of water was left between the reactor core and the back of the DRI cavity wall. This shielding was enough to cause a first trial run of the experiment to fail (only irradiation levels equivalent to background were counted). However, with adjustment of the calculations for this additional shielding and with staying in the power and irradiation time limits set by the regulatory safety committee for this largely untested reactor area, another experimental run was performed at 90kW power for 333 seconds which produced enough activity in each sample for reasonable counting statistics to be obtained to calculate the acting flux.

- *Thermal neutron flux (average):* **3.26E+06 n/(cm^2·s)**
- *Epithermal neutron flux (average):* **1.16E+06 n/(cm^2·s)**
- *Fast Neutron flux*: **3.18E+07 n/(cm^2·s)**

Conclusions

These results were surprising in that the fast neutron flux was higher than the thermal neutron flux. It was thought that this could be the result of the shielding being provided by the ~ 2ft of water between the back of the DRI cavity and the reactor core. This reasoning could be additionally supported by the epithermal flux being about 1/4th that of the thermal flux. This high ratio of epithermal to thermal could likely be the result of fast neutrons being moderated into epithermal neutrons as a result of this significant shielding.



REACTOR FACILITY

Figure 5. Schemata of the RINSC reactor

Acknowledgments

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