QUARTERLY REVIEW

FALL 1992

MICHIGAN MEMORIAL PHOENIX PROJECT
THE UNIVERSITY OF MICHIGAN

NUCLEAR REACTOR LABORATORY
FORD NUCLEAR REACTOR
PHOENIX MEMORIAL LABORATORY

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Fifth Year, No. 16

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The Nuclear Reactor Laboratory Quarterly Review is published and distributed to University of Michigan faculty and staff members to inform them of the unique research capabilities of the Nuclear Reactor Laboratory and to make them aware of the types of research in progress.

The Michigan Memorial Phoenix Project was founded on May 1, 1948, as a memorial to the 585 University of Michigan alumni, students, faculty, and staff members who died in World War II. The Project's charter is to explore ways and means by which atomic energy can be a beneficent influence in the life of man. Research support and services provided by the Nuclear Reactor Laboratory and a research grant program are the means by which the Project fulfills its charter.

NEW RESEARCH

FORD NUCLEAR REACTOR

University of Michigan

Chemistry

Professor Henry Griffin is studying the decay properties of intermediate half-life fission products such as strontium-91. Small quantities of uranium-235 are irradiated in the reactor core. Following irradiation and a decay period of 5 to 24 hours to eliminate short-lived fission products, test samples are chemically processed to isolate specific nuclides and counted on an intrinsic germanium detector to quantify the nuclides.

Professor Griffin is studying the radioactive decay of specific products of neutron activation. Typically very low probability radiations are being sought. Metallic compounds are irradiated in the reactor to activate isotopes which have low probability decay rates. In some situations, it is necessary to use radiochemical purification techniques to properly identify the decays of interest.

Professor Griffin is supervising Joseph Stayanoff who is conducting an experiment to study a chemical separation process. He is using barium chloride and strontium chloride dissolved in

a salt solution to monitor the performance of anion/cation chromatographic columns.

Nuclear Engineering

Alice M. Arendt is a doctoral candidate working for Professor Ronald F. Fleming. Ms. Arendt is performing neutron depth profiling of borosilicate glass at the reactor's J beamport. Charged particles are created in glass samples using the neutron beam via (n,p) and (n,alpha) reactions. A silicon surface barrier detector is utilized to measure the energy spectrum of the particles that escape the surface of the sample. By using stopping powers, the energy spectrum of emerging particles can be converted to a depth versus concentration profile. The dissolution of borosilicate glass will be studied by looking at the near surface profiles of boron and lithium. The title of Ms. Arendt's thesis is "Neutron Depth Profiling of Borosilicate Glass".

Physics

Dr. William E. Frieze and Professor David Gidley irradiated high purity nickel to utilize nickel as a positron source. When nickel-58 absorbs high energy neutrons in the reactor core, cobalt-58 is produced. Cobalt-58 is a positron emitter. Major problems associated with nickel as a positron source are high levels of radioactive interference from cobalt isotopes other than cobalt-58 that occur as a result of nickel activation and depletion of the cobalt-58 itself by thermal neutron absorption.

NEUTRON ACTIVATION ANALYSIS

University of Michigan

Chemical Engineering

Mr. Robert Tatterson, a doctoral candidate, is using neutron activation analysis to determine the quantity of iron and barium in two experimental catalysts. The catalysts are being designed for oxidation of methane gas. A potential use for the catalysts is the conversion of methane which is about 95% abundant in natural gas to longer carbon chain molecules. The conversion would allow transportation of this energy source without the need for cryogenics. This process is particularly attractive for native methane sources in lesser developed countries. The title of Mr. Tatterson's thesis is "Methane Activation by Metal Phosphates." Professor Erdogan Gulari is Mr. Tatterson's advisor.

Kelsey Museum of Archaeology

Mr. J. Andrew Darling is investigating the archeology of the Tlaltenango Valley in Zacatecas, Mexico. Included in Mr. Darling's investigation is a recently discovered source of obsidian near the Pueblo of Huitzila that may have been raw material for tool making. Trace and minor element analysis is being performed by neutron activation to characterize the obsidian artifacts found in the region. Matching trace element signatures between the source and artifacts may provide insight into local and regional social interactions. Mr. Darling's faculty advisor is Professor Jeffrey R. Parsons.

Nuclear Engineering

Ms. Yuni Dewaraja, a doctoral candidateworking under the direction of Professor Ronald F. Fleming, is developing the technique of imaging neutron activation analysis. The technique uses an instrument developed by Dr. Ronald H. Fleming of Charles Evans and Associates, Redwood City, California. The instrument combines an energy sensitive germanium gamma ray spectrometer and an electron multiplying microscopic imaging system. In use, the source electrons for the imaging system result from beta decay in a neutron activated sample. Decay events are position correlated to the sample surface by the electron imaging system. The gamma spectrometer provides gross isotopic information about the decay events. Real-time processing the two data streams for coincidence between electron imaging events and gamma spectrometer events allows position sensitive elemental analysis to be performed.

Physics

Rich Vallery, Brian Saam, and Will Loinaz are measuring cobalt-58 production levels at various core locations using neutron activation of nickel foils and pieces. Results of this work will determine the best locations for the production of cobalt-58 positron sources for use in various physics experiments. The students are working under the direction of Professor David Gidley and Dr. William Frieze of the Physics Department and Professor Henry Griffin of the Chemistry Department.

COBALT-60 IRRADIATOR

University of Michigan

Biology

In order to elucidate the function of the Drosophila drosulfakinin (dsk) gene, Dr. Elizabeth S. Norris is mutagenizing adult male flies with low doses of gamma-irradiation to create small deletions. Flies with deletions in the target area will be identified via a loss of a nearby dominant marker gene. Southern blot/PCR analysis will determine the presence or absence of the dsk gene. The phenotype of the dsk deficient flies will then be determined.

Chemical Engineering

Dr. Richard Schwartz is irradiating human bone marrow in growth media at doses that will stop the growth of the cells. Then CD 34 stem cells will be cultured and grown on top of the irradiated bone marrow at various cell concentrations to find the ideal cell concentration. The irradiated bone marrow has been found to provide an ideal substrate for the growth of the CD 34 stem cells.

Electrical Engineering and Computer Science

Jose Roman, a graduate student working on a Ph.D. in electrical engineering, is gamma irradiating soda-lime glass doped with germanium dioxide. He is hoping the gamma-rays

will create oxygen vacancies in the glass to form germanium oxide. He hopes to confirm this phenomenon by looking at the IR of the glass at the 244 nm wavelength. The creation of oxygen vacancies is evidenced by an absorption peak at 244 nm.

Materials Sciences and Engineering

Zhi-Fan Zhang, a graduate student working for Dr. Richard Laine, is crosslinking polymethylsilane fibers, -[MeSiH]x-, using cobalt-60 gamma irradiation. The crosslinked fibers will become infusible and retain their formed shape during pyrolysis processes. The pyrolysis processes will transform the polymethylsilane fibers into SiC ceramic fibers which are currently used for high performance ceramic matrix composite materials.

Florida State University

Heather Whitaker, an undergraduate student working for Professor Kurtis Johnson, is irradiating nylon dosimetric films at various doses and dose rates. The purpose of the experiment is to analyze the relationship between dose rate and optical absorption of the films. The Detector Development Laboratory at Florida State University is conducting a battery of tests to determine the effects of various physical parameters on their method of dosimetry.

Michigan State University

Professor Gary J. Blanchard is gamma irradiating diacetylene monomer to cause it to polymerize to polydiacetylene. The polymerized crystals will be investigated using time domain laser spectroscopies. They are potentially useful for optical signal processing and energy storage applications. Dr. Blanchard will study the ultrafast optical response of these materials in order to determine whether they are suitable for the development of photonic logic gates.

FEATURE ARTICLE

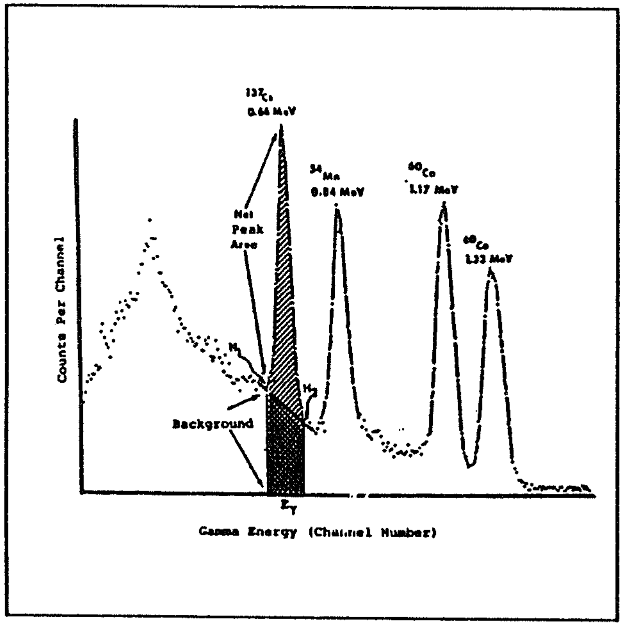
NEUTRON ACTIVATION ANALYSIS

Neutron activation analysis is an analytical technique for identifying and measuring trace quantities of a large number of elements in many types of materials. Sixty-six common and rare earth elements become radioactive when exposed to the neutron flux in a reactor. The subsequent radiation emitted by the decay of activated nuclei is different for each element and its measurement permits identification. Of the 66 radioactive elements, over 50 can be identified and measured quite readily. The method permits measurement of all detectable elements simultaneously; it is rapid and essentially non-destructive.

Quantitative analysis of samples made radioactive by exposure to neutrons in a reactor is commonly called instrumental neutron activation analysis (INAA). This type of analysis is a delayed method; that is, a sample is activated, and the radiation emitted by the resulting radionuclides is measured after a certain delay time.

Following irradiation in a reactor, a sample emits a spectrum of gamma rays corresponding to decay of all the radioactive isotopes that were created in the sample. It might be expected that a line spectrum would result because of the descrete nature of the gamma ray energies. However, gamma rays interact with a detector by differing means; among them Compton scattering and pair production. Quite often, only part of the initial gamma energy will be detected and converted to a pulse. As a result, the spectrum will have a background continuum that represents a record of all types of interactions within the detector.

Superimposed on the continuum are the most important features of the gamma ray spectrum. These are total absorption peaks so named because they result from pulses generated by the total absorption of a radioactive isotope's gamma ray energy by the detector. Most of these pulses arise from photoelectric interactions so it has become customary to refer to these peaks simply as photopeaks. A photopeak contains two important pieces of information: (1) the centroid, a measure of gamma ray energy; and (2) the area, a



measure of source activity. The centroid energy enables an element to be identified. After the element is identified, the area under the photopeak permits determination of the quantity in a sample.

Another technique, called prompt neutron activation analysis (PNAA), involves placing the sample to be analyzed directly in a neutron beam. A detector adjacent to the sample but outside the beam measures gamma rays that are produced by neutron interactions with the sample. In many cases, when a sample is irradiated by neutrons, nuclear capture reactions occur that produce new nuclides in high energy states. The excitation energy ranges from 5 to 10 MeV according to the binding energy of the absorbed neutron. These highly excited states have very short half-lives and revert to the ground state almost immediately. De-excitation typically involves gamma ray emmission by which elements can be identified; it is immaterial whether the product nuclide is radioactive. PNAA is particularly sensitive for analyzing elements with high neutron absorption cross sections such as boron, cadmium, gadolinium, and samarium.

There are practical limits to neutron activation analysis. A number of elements are relatively insensitive to neutron absorption. Calcium is an example. Others, such as rhodium, decay rapidly and make the analysis that follows activation difficult. For other elements including argon, boron, holmium, krypton, lithium, neon, oxygen, silicon, sulfur, thalium, and xenon, techniques such as chemical concentration, filtration, special encapsulation, and special irradiation methods are necessary to perform neutron activation analysis.

Radiochemical neutron activation analysis (RNAA) is a form of INAA in which some radiochemical separation of nuclides is performed to enhance sensitivity. Sensitivity is the lower limit of detection, typically expressed in parts per million (ppm), that can be achieved in an analysis.

Sensitivity depends on the affinity for neutrons of the elements being measured and the ability to reduce background radiation by removing interfering elements either by decay or chemical separation.

Table 1 is a listing of neutron activiation analysis sensitivities for 66 elements. Two values are given. Typical sensitivity is the lower limit of detection for an element found in a matrix of other elements such as in a geological sample. Absolute sensitivity is the absolute limit of detection for an element in a clean matrix such as ultra-pure demineralized water.

Table 1 Neutron Activation Analysis Sensitivities

Element	Sensitivity (ppm) Typical	Absolute	Element	Sensitivity (ppm) Typical	Absolute
Aluminum	800	0.3	Chromium	25	0.1
Antimony	2	0.01	Cobalt	2	0.01
Argon	---	---	Copper	200	0.1
Arsenic	30	0.1	Dysprosium	3	0.01
Barium	1,200	1	Erbium	25	0.1
Bromine	10	0.2	Europium	0.3	0.001
Cadmium	70	0.5	Gadolinium	20	0.1
Calcium	10,000	200	Gallium	15	0.1
Cerium	10	0.1	Germanium	230	0.3
Cesium	3	0.01	Gold	0.1	0.001
Chlorine	80	0.6	Hafnium	2	0.01

Table 1 Neutron Activation Analysis Sensitivities
(Continued)

Element	Sensitivity (ppm) Typical	Absolute	Element	Sensitivity (ppm) Typical	Absolute
Indium	0.1	0.001	Ruthenium	10	0.1
Iodine	10	0.1	Samarium	0.6	0.001
Iridium	0.1	0.001	Scandium	0.3	0.001
Iron	1,500	10	Selenium	15	0.1
Krypton	---	---	Silver	10	0.1
Lanthanum	2	0.1	Sodium	15	0.1
Lutetium	1	0.001	Strontium	1,000	1
Magnesium	3,000	1	Tantalum	1	0.1
Maganese	3	0.01	Tellurium	50	0.1
Mercury	5	0.01	Terbium	2	0.01
Molybdenum	40	0.2	Thulium	2	0.01
Neodymium	120	1	Thorium	2	0.01
Nickel	1,000	10	Tin	500	1
Niobium	6,000	10	Titanium	600	10
Osmium	3	0.01	Tungsten	150	1
Palladium	300	0.01	Uranium	10	0.5
Platinum	3,000	10	Vanadium	10	0.1
Potassium	1,000	10	Xenon	---	---
Praseodymium	180	1	Ytterbium	4	0.1
Rhenium	2	0.01	Yttrium	50	1
Rhodium	---	---	Zinc	60	1
Rubidium	70	1	Zirconium	900	5

NUCLEAR REACTOR LABORATORY

Profile of Services

Neutron Irradiation Services

In-core, pneumatic tube, and beamport irradiations with high energy (fast) and low energy (thermal) neutrons. Thermal neutron range: 8×10^{6} to 1.5×10^{13} n/cm^2/sec.

Neutron Activation Analysis

Identification of trace quantities of sixty-two elements including most metals and rare earth elements utilizing a technique that is almost non-destructive and requires very small sample volumes.

Gamma Irradiation Services

Gamma irradiations utilizing a large cobalt-60 source to sterilize bone and cartilage for reconstructive surgery and to study radiation effects on materials.

Neutron Radiography

Radiographic imaging of low density materials such as plastic, oil, water, and gasoline contained in heavy materials and porous media that cannot be imaged with ordinary x-rays.

Radioisotope Preparation

Production and distribution of large quantities of investigational drugs containing iodine-123, iodine-125, and iodine-131 to almost 150 hospitals and medical research institutions for diagnosis and therapy of adrenal gland cancer and adrenomedulla diseases.

Radiochemical Production

Preparation of bromine-82 labeled motor oil for use in engine oil economy research programs, and bromine-82 labeled toluene for use in oil refinery flow tests.

Testing Programs

Accelerated neutron and gamma aging of reactor materials; fast neutron damage effects in reactor vessel steels; and quality assurance tests of irradiated materials including neutron attenuation properties, strength, gas evolution, radionuclide content, and changes in physical parameters.

Training

Neutron activation analysis and reactor operations laboratories for university students, advanced high school students, and electric utility engineers and reactor operators.

NUCLEAR REACTOR LABORATORY DIRECTORY

Hours of Operation:

Monday-Friday Sept. 1 - April 30 8:00 a.m.- 5:00 p.m.
May 1 - Aug. 31 7:30 a.m.- 4:00 p.m.

Facilities can be made available 24 hours a day, if required.

Tours: Monday-Friday 9:00 a.m. - 4:00 p.m.

Tours should be scheduled at least 48 hours in advance.

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Radioisotope Preparation

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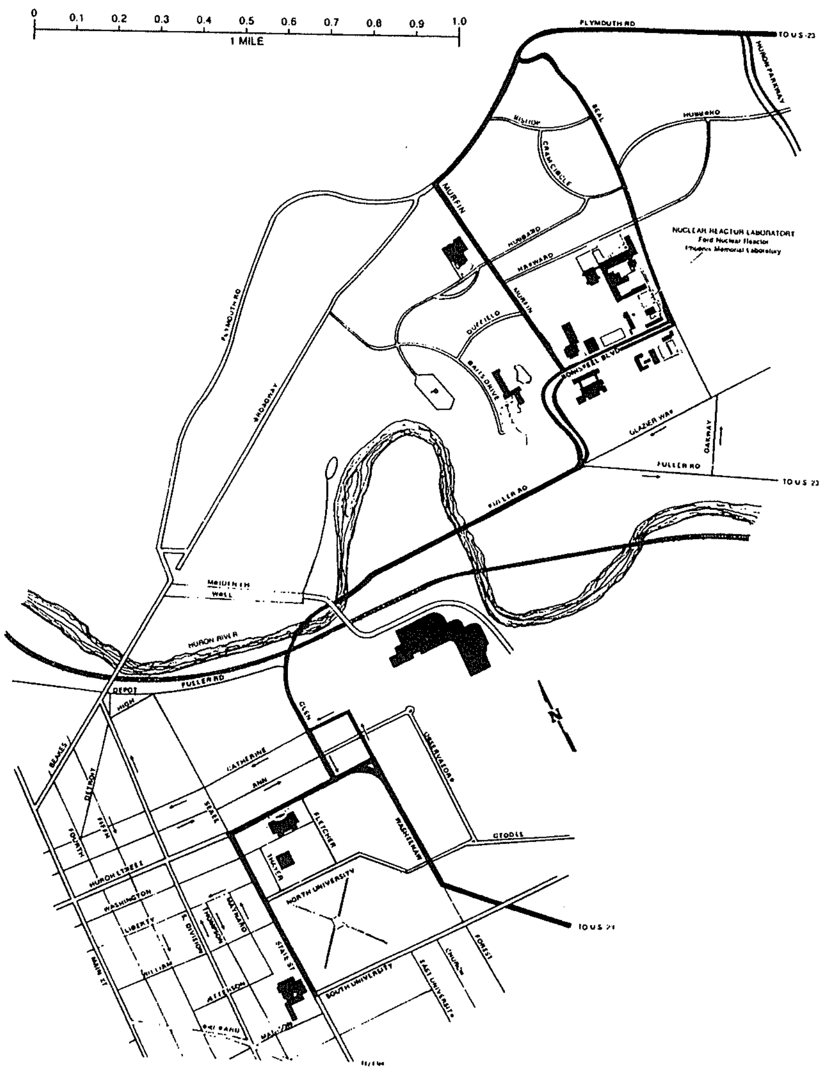

Nuclear Reactor Laboratory Location
University of Michigan Central and North Campus

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