Name: _____

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ROYAL MILITARY COLLEGE OF CANADA

CCE101 LABORATORY

Radiation Detection Experiments

Department of Chemistry and Chemical Engineering

RADIATION DETECTION EXPERIMENT

INTRODUCTION

Radioactivity is ever present in the background, e.g., from natural sources in the Earth and cosmic radiation. It may also be produced artificially for beneficial purposes such as medical diagnostics and therapy. The analytical techniques based on the SLOWPOKE-2 reactor at Royal Military College (RMC), e.g., neutron activation analysis (NAA) and neutron radioscopy, have been developed for many different applications within and without delayed neutron detection. An introduction to radiation counting will be presented. In a set of three experiments, a) a small, long-lived radioactive source will be counted, b) the shape of the neutron flux in the SLOWPOKE-2 pool will be observed, and c) a sample will be irradiated in the reactor and analyzed.

A. Counting of a Standard Check Source

Radiation sources of long half-lives are used to check the calibration of radiation counters and are usually included in their acquisition. In this experiment, a check source will be used to show that radioactive decay is a random process. Each count will be slightly different, but should follow a bell-shaped distribution around a mean value. In essence, counting such a source is a random number generator. The results can be used for data analysis in Excel, by producing a histogram of the counts, determining the mean and median and deciding on outliers.

B. Neutron Flux Distribution around a Reactor Core

The SLOWPOKE-2 reactor at RMC has an upright cylindrical reactor core, 22 cm×22 cm, located inside and near the bottom of a vertical reactor container, which itself is suspended in the reactor pool. With the use of a moveable borated ion chamber in the reactor pool that can detect neutrons, the drop in neutron intensity or flux from the reactor core can be determined. Theoretically, it should be exponential radially and a cosine, axially. By taking several radial measurements in the pool, the experimental results can be compared to the expected exponential function using Excel.

C. Gamma-ray Spectroscopy of an Irradiated Sample

When neutrons interact with the nuclei of most elements, they become slightly radioactive, emitting beta and gamma radiation. Since, with the latter radiation, specific numbers and energies are emitted for each element, the elements in a sample can be identified and even quantified, down to part per million (ppm) or part per billion (ppb) levels. This nuclear analytical technique is called NAA. A sample will be irradiated and its gamma ray spectrum will be counted, from which the elements will be identified.

SAFETY MEASURES

Work in the nuclear facilities including SLOWPOKE-2 reactor is accompanied by an inherent radiation hazard; normal laboratory safety procedures must be followed. Laboratory coats, safety glasses and disposable gloves must be worn when handling solutions. A technician must be consulted immediately in the event of a spillage or other incident.

All personnel working in the SLOWPOKE-2 Facility must pass a Workplace Hazardous Material Information System (WHMIS) and Radiation Safety Trainings provided on site and work safely in accordance with acquired trainings. Officer cadets receive radiation protection training from the RMC Radiation Safety Officer (RadSO) as part of the safety orientation before they start experiments in the laboratory.

Before any project is permitted to be conducted in the SLOWPOKE-2 facility, the proposed project is assessed for physical, radiological and chemical hazards by the Director of the SLOWPOKE-2 facility and the RadSO. Other specialists are consulted for advice, and calculations of the dose rate of the sample after irradiation are performed as necessary. In general, all proposed projects should follow as low as reasonably achievable (ALARA) principles. If the safety hazards are considered to be under control and risk minimized, the project/experiment form is signed by a project supervisor, the Director of the SLOWPOKE-2 facility and the RadSO before the project is allowed to proceed. Experimental work cannot commence until appropriate MSDS safety sheets have been consulted.

Samples of unknown composition should be irradiated for no more than 30 seconds initially. The neutron flux level should also be chosen in accordance with the sample matrix and expected sample composition to minimize radioactivity.

To monitor radiation levels in the area several stationary gamma and neutron meters are installed in various locations of the SLOWPOKE-2 facility. Readings from the meters installed in close proximity to the irradiation site controllers show how long the irradiated sample should stay inside the shielded compartment before it can be safely removed for further analysis or use. A wide collection of portable detectors is also available for this purpose. Other meters installed next to the reactor provide operational status signals directly to the Military Police Station at Canadian Force Base Kingston to increase radiation safety awareness.

To monitor personnel exposure to radiation, regular users of the SLOWPOKE-2 facility must wear a thermoluminescent dosimeter with X ray and gamma capability, a separate dosimeter for neutrons (both provided by Health Canada's National Dosimetry Service), as well as a personal alarming device (SOR R/F) that is monitored internally by the RMC RadSO.

Occasional workers and visitors are always accompanied by certified reactor operators or authorised users and must wear a personal alarming device, with their use and dose recorded in the appropriate dosimeter log and monitored by the RadSO.

All abnormal levels of radiation recorded by the personal dosimeters or stationary detectors are investigated internally and reported to the Canadian Nuclear Safety Commission.

PROCEDURE

A. Counting of a Standard Check Source (Design Lab)

1. A laboratory radiation counter and a check source will be provided, along with written and verbal instructions on their use.

2. With the check source on the detector holder, count the source repeatedly, recording your results in your laboratory notebook.

3. Transfer the counting data to the Excel program.

B. Neutron Flux Distribution around a Reactor Core (Reactor & Control Rooms, 1st floor)

1. The borated ion chamber, which is suspended from the top of the reactor pool, will be moved radially out from the reactor container wall with the supervision of a licensed operator. The readings are displayed on an analog meter in the adjacent control room.

2. For each position suggested by the licensed operator, move the borated ion chamber, wait (<1 min) until the needle on the analogue display is steady, and then record the value in your laboratory notebook. You will have a set of data starting at the reactor container wall (closest position to the core) and moving out into the reactor pool.

3. Transfer the counting data to the Excel program and plot the experimental data so that a comparison can be made to the theoretical shape (exponential, radially).

C. Gamma Ray Spectroscopy of an Irradiated Sample (Counting Lab, 2nd floor)

1. In the second floor laboratories of the SLOWPOKE-2 Facility where samples are sent to the reactor for irradiation and then returned for counting, a sample containing elements of interest will be irradiated by SLOWPOKE-2 staff for seconds and then transferred to an intrinsic germanium detector for counting. The attached multichannel analyser (MCA) will reveal the gamma ray spectrum, of which a printout will be available. The MCA sorts the counts coming into the detector into small energy channels so that the spectrum is a plot of the counts for each energy (peaks) vs. its energy (keV). Using a table of expected gamma rays, identify the peaks for the elements in the sample and any other peaks of interest. Once found, the staff will explain the reason for each peak. Report your findings in your laboratory notebook.

Report

This report in its entirety shall be prepared on a spreadsheet and a printout submitted to the instructor in charge.

Experiment A

1. Copy the data to an Excel spreadsheet.

2. Use the spreadsheet to calculate:
    a. Mean count value for the source in 1 minute
    b. Median count value for the source in 1 minute
    c. Identify the maximum count value in your results
    d. Identify the minimum count value in your results
    e. Calculate the standard deviation (σ) by taking the square root of the mean (Poisson distribution)
    f. Count the number of measurements which fall numerically exactly within two standard deviation ($\pm 2\sigma$) of the mean. This will give the number of measurements that are within the range of mean $\pm 2\sigma$.
    g. What percentage of total counts (40) fall within the range you determined in part f? (Note: in nuclear counting a confidence limit of 2σ should include 95.5% of all values. This limit is highly desirable for nuclear counting, although in some occasions a 3σ limit with 99.7% is reported.)

Experiment B

1. Copy the data from the movable detector to an Excel spreadsheet.

2. Plot the neutron intensity versus distance from the source.

3. What type of curve (or function) best describes your data. Comment.

Experiment C

Identify the peaks for the elements in the sample and report them in ascending energy (keV) on your spreadsheet.