EDUCATIONAL LABORATORY

NUCLEAR SCIENCE EXPERIMENTS FOR TEACHING LABORATORIES
TURN-KEY TRAINING SOLUTIONS

NUCLEAR SCIENCE EXPERIMENTS FOR TEACHING LABORATORIES

With a half century of experience in the nuclear measurements industry, Mirion Technologies, Inc. is uniquely qualified to provide educational institutions with the tools for highly productive hands-on training in the fundamentals of nuclear physics through vocationally-relevant experiments.

Mirion offers turn-key solutions to set up and/or refurbish physics teaching facilities with cutting-edge digital technology. A relatively modest investment yields a flexible equipment configuration that can serve undergraduate and post-graduate university training in addition to in-house training for industrial users.

Experiment 8: Gamma-Ray Efficiency Calibration
(shown below) demonstrates the procedure for measuring the efficiency of a NaI and a HPGe detector as a function of gamma-ray energy.
MIRION LAB KITS

Mirion has packaged a set of 12 experiments, focusing on various aspects of gamma-ray detection and analysis, which provides an understanding of basic principles to more complex nuclear physics applications.

All of these experiments can be executed with Mirion instrumentation and specialized ancillary equipment offered in two Lab Kits. (Please note that most of the recommended radioactive sources are not included and are readily available.) The Nuclear Science Experiments with Digital Electronics Laboratory Manual provides a step-by-step guide to performing the experiments. The Laboratory Manual is available at https://www.mirion.com/learning-center/lab-experiments, and unlimited copies may be printed as needed.

The experiments are built around Mirion’s Osprey® MCA and Lynx® Digital Signal Analyzers. The versatility of these instruments enables the performance of fundamental experiments in high and low resolution gamma spectroscopy. Their advanced features allow for higher-level experiments, such as coincidence and anti-coincidence, with both hardware gating and event-by-event data collection.

The Osprey and Lynx units are easy to use and feature highly-stable digital electronics, thereby providing the optimum solution for laboratory instruction. The devices are controlled with ProSpect® Gamma Spectroscopy Software which includes a flexible security feature to ensure that the student is only presented with the functions required for the class. This increases the productivity of the training.
THE LABORATORY MANUAL AND KITS GREATLY SIMPLIFY THE PURCHASE OF EQUIPMENT AND IMPLEMENTATION OF THESE EXPERIMENTS (PLUS OTHER EXPERIMENTS OF YOUR OWN DESIGN).

They can be used to create individual student workstations or a central demonstration station, depending on available space and budget. And, of course, lab expansion is just as simple as adding more kits as needs dictate.

LABKIT-Basic

**Starter kit for Experiments 1 to 5**
- Osprey Digital MCA
- ProSpect Gamma Spectroscopy Software
- 802 2x2 NaI Detector
- LabKIT-Table: Apparatus for many of the experiments, including an angular scattering table and base plate, NaI 2"x2" detector shielding, source collimation for LABKIT-SR-CS137, scattering pillar, and absorber holder.
- LabKIT-Abs: Sets of four generic absorber materials, including aluminum, copper, lead, and polyethylene.
- LabKIT-SR-Cs137: 15 MBq (0.5 mCi) Cs-137 source capsule, for use with the LABKIT-Table assembly.

LABKIT-Advanced

**Supplement the starter kit to complete Experiments 6 to 12**
- LYNX MCA
- BE2825 HPGe Detector System
- LabSOCS™ Software
- 802-2x2 NaI Detector
- 2007P Preamplifier
- LABKIT-SRCEHLD: Set of two HPGe Source Holders, including a fixed source holder for measurements at 25 cm and an adjustable source holder for measurements from 0 to 18 cm.
- LABKIT-NAICOLL: NaI 2"x2" detector shielding for use with LABKIT-Table assembly.
- RCP-10-Cable: 10 ft cable bundle including preamp, SHV-SHV, and two BNC-BNC cables.
THE LABORATORY MANUAL PRESENTS THE FOLLOWING TWELVE EXPERIMENTS.

**With LABKIT-Basic, students can perform experiments 1-5. To perform all twelve experiments, LABKIT-Basic and LABKIT-Advanced are required.**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong> Gamma-Ray Detection with Scintillators</td>
<td>In this introduction to gamma-ray detection, students will identify photoelectric effect, Compton scattering, and pair production in a spectrum and perform an energy calibration using known reference sources.</td>
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<tr>
<td><strong>2</strong> Counting Statistics and Error Prediction</td>
<td>Students will perform a series of background and gamma-ray measurements with a NaI detector and apply statistical principles to these measurements.</td>
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<tr>
<td><strong>3</strong> Gamma-Ray Absorption in Matter (Basic)</td>
<td>Students will measure the effective attenuation of a set of materials with varying densities and photon absorption cross sections.</td>
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<tr>
<td><strong>4</strong> Compton Scattering</td>
<td>Using the Compton Scattering table developed specially for this exercise, the principle of Compton scattering and the dependence on angular variation is demonstrated.</td>
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<tr>
<td><strong>5</strong> Half-Life Measurement</td>
<td>Students calculate the half-life of a short-lived nuclide using multi-channel scaling acquisition.</td>
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<tr>
<td><strong>6</strong> Signal Processing with Digital Signal Electronics</td>
<td>Using the built-in Digital Signal Oscilloscope feature of the Lynx MCA, students observe the effects of changing signal processing parameters using several different acquisition modes.</td>
</tr>
<tr>
<td><strong>7</strong> High-Resolution Gamma-Ray Spectroscopy with HPGe Detectors</td>
<td>Semiconductor gamma-ray detection is introduced and students compare HPGe resolution to NaI detector resolution.</td>
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<tr>
<td><strong>8</strong> Gamma-Ray Efficiency Calibration</td>
<td>Using both a NaI detector and an HPGe detector, the concept of detection efficiency is explored.</td>
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<tr>
<td><strong>9</strong> Gamma-Ray Coincidence Counting Techniques</td>
<td>Counting with multiple detectors correlated in time can yield incredible information about fundamental nuclear structures. In this experiment, students learn these techniques by acquiring and interpreting time-stamped list mode data for synchronized detectors.</td>
</tr>
<tr>
<td><strong>10</strong> Positron Annihilation</td>
<td>By using coincidence counting techniques and the Angular Correlation table, students explore the geometrical behavior of positron annihilation events.</td>
</tr>
<tr>
<td><strong>11</strong> Mathematical Efficiency Calibration</td>
<td>Mathematical modeling is increasingly used instead of source based efficiency calibration for improvement in cost, flexibility, and safety. In this experiment, students generate efficiency calibrations using Mirion’s LabSOCS efficiency calibration software and compare against traditional source based calibrations.</td>
</tr>
<tr>
<td><strong>12</strong> True Coincidence Summing</td>
<td>Students observe true coincidence summing and quantify the effect on observed count rate using LabSOCS mathematical efficiency software.</td>
</tr>
</tbody>
</table>
As you can see in this sample, the format of each experiment begins with the goal and the equipment required.

Each description includes the required steps together with the format of the data entry and the results. In some cases, the instructor may wish to produce his or her own laboratory script with this as a starting point.
THEORETICAL OVERVIEW

Gamma rays are produced when a nucleus is excited to a higher energy state.

When a nucleus absorbs energy, it can either emit a particle or create electromagnetic radiation. This energy can be detected using gamma ray detectors.

Gamma rays are emitted when a nucleus decays to a lower energy state. They are used to study the properties of nuclei and to understand the behavior of matter at the atomic level.

Gamma rays are also used in various applications such as medical imaging, radioactive waste management, and security screening.

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EXPERIMENT 1
GAMMA-RAY DETECTION WITH SCINTILLATION DETECTORS

THEORETICAL OVERVIEW

Gamma rays are produced when a nucleus absorbs energy. The energy is released in the form of electromagnetic radiation, which can be detected using gamma ray detectors.

Gamma rays are characterized by their energy, wavelength, and direction. They are used in various applications such as medical imaging, radioactive waste management, and security screening.

Gamma rays are produced when a nucleus decays to a lower energy state. They are used to study the properties of matter and to understand the behavior of matter at the atomic level.

Gamma rays are also used in various applications such as medical imaging, radioactive waste management, and security screening.

EXPERIMENT 1 GUIDE

Objectives:

1. Understand the properties of gamma rays and their interactions with matter.
2. Learn how to use a gamma ray detector to measure the energy of gamma rays.
3. Learn how to analyze gamma ray spectra to identify the source of the gamma rays.

Materials:

1. Gamma ray detector
2. Gamma ray sources
3. ProSpect software

Procedure:

1. Place the gamma ray source in front of the detector.
2. Adjust the MCA settings to correspond with the source.
3. Collect data for at least 10,000 counts in each photopeak.
4. Use ProSpect software to analyze the data and identify the gamma rays.

Analysis:

1. Calculate the energy of the gamma rays using the peak analysis feature in ProSpect.
2. Compare the calculated energy with the known energy of the gamma ray source.
3. Identify the source of the gamma rays based on the energy and peak analysis.

Conclusion:

1. Summarize the findings of the experiment.
2. Discuss the implications of the results for various applications.
3. Reflect on the learning experience and areas for improvement.

References:
