The Performance of $CeBr_3$ Detectors
James McQuaid
Berkeley Nucleonics Corporation

Introduction

High-resolution scintillation detectors are now offering improved performance with lower intrinsic background. Standard cerium bromide ($CeBr_3$) detectors are now available from BNC in 2x2 inch encapsulated sizes with greatly improved sensitivity. This paper discusses the merits of $CeBr_3$ from the standpoint of energy resolution and reduction of intrinsic background from actinium-227 (^{227}Ac) contamination.

Detector Resolution

$CeBr_3$ detectors have several advantages over lanthanum bromide ($LaBr_3$) detectors even though $LaBr_3$ is widely accepted as the highest resolution scintillation detector. $LaBr_3$ boasts a resolution of 3% at 662 keV and $CeBr_3$ has a resolution of about 4% at 662 keV. This allows both detectors to achieve distinct separation of the 609 keV peak of bismuth-214 (^{214}Bi) from the 662 keV peak of cesium-137 (^{137}Cs) (which cannot be accomplished with sodium iodide (NaI(Tl)) detectors). Generally, the ability to resolve spectra at high energies can be accomplished quite well with NaI(Tl). Resolving lower energy spectra of uranium (U) and plutonium (Pu) is important, and it is in this lower energy region that the resolution of $CeBr_3$ outperforms that of $LaBr_3$ [1]. This is noted when observing the plutonium-239 (^{239}Pu) spectrum as shown in Fig. 1. The primary ^{239}Pu peaks (332, 375 and 414 keV) stand out clearly with $CeBr_3$. Also the X-rays at ~105 keV and the 201 keV gamma line are more pronounced with $CeBr_3$. The low energy lines of weapons-grade uranium are also better resolved with $CeBr_3$. At even lower energies the resolution of LaBr3 continues to fall off dramatically such that the resolution of the 60 keV energy line of americium-241 (^{241}Am) is worse than NaI(Tl).

Filename: SPEC0085.N42 CeBr Pu-239 Primary peaks are 332, 375 and 414

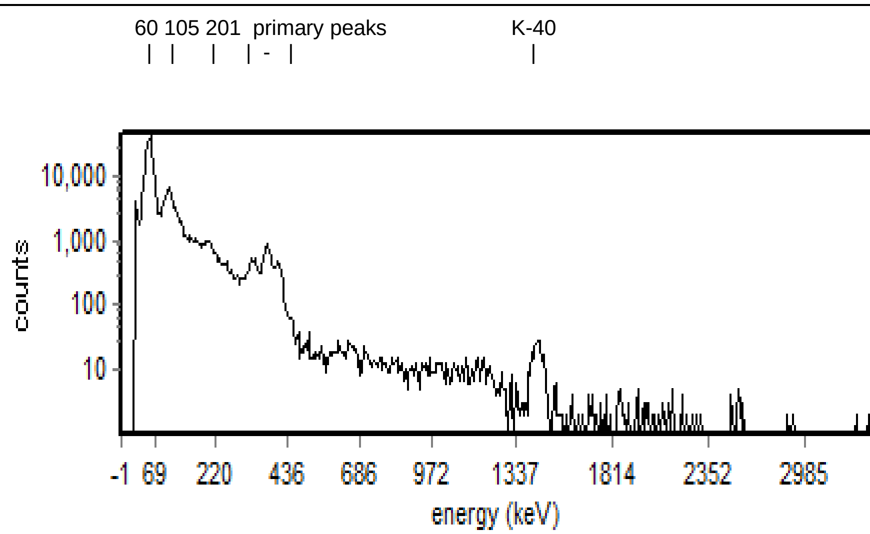

Fig.1. $CeBr_3$ spectrum of ^{239}Pu

Intrinsic Background

The typical background for $CeBr_3$ detectors is primarily from ^{227}Ac (the parent nucleus is uranium-235 (^{235}U)). This contribution to background from the ^{227}Ac contamination is approximately 0.02 counts/sec/cm^3 [2]. The concentration of ^{227}Ac atoms per cerium (Ce) atoms is of the order of $4x10^{-16}$. Even though this is a small amount of contamination, it does represent a significant contribution to the background, especially in the 1.2 to 2.2 MeV region of the energy spectrum as seen in Fig. 2. Ac, Ce, and lanthanum (La) are all chemically homologous elements and therefore, they are extremely difficult to separate one from another. Through the selection of material being screened before processing, the ^{227}Ac background can now be essentially eliminated (about 0.001 counts/sec/cm^3 [2]). Also seen in Fig. 2 is the much higher background in the $LaBr_3$ detectors. In addition to the ^{227}Ac, there is significant contamination from lanthanum-138 (^{138}La) which is responsible for a very high background near 32 keV and continuing up to the 1461 keV region. Another region of background in $LaBr_3$ begins at about 1520 keV through 2800 keV. This is from natural uranium (primarily the ^{214}Bi progeny) giving $CeBr_3$ a sensitivity greater than $LaBr_3$ by an order of magnitude in this region of the spectrum. The reason this is so important is that detection of weapons-grade Pu and weapons-grade U relies on the detection of the 2615 keV energy line to verify its presence. Depending on the activity and the distance to the source, a longer acquisition may be necessary for verification. Therefore, it is not only important to have the highest sensitivity at this energy ($CeBr_3$ improves it by a factor of 10) but with $LaBr_3$, high background in this region could mislead first-line responders with a false positive for weapons-grade material.

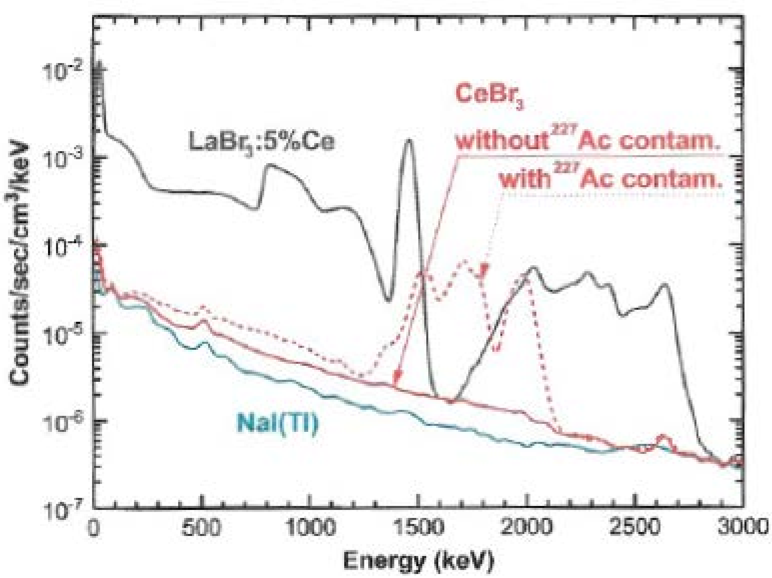

Fig. 2. Intrinsic Activity Spectrum of $CeBr_3$, $LaBr_3$ and NaI(Tl) 2x2 Spectrometers

References

[1] Comparison of $LaBr_3$: Ce and NaI(Tl) Scintillators for Radio-Isotope Identification Devises, B. D. Milbrath, et. al., Pacific Northwest National Laboratory (PNNL)

[2] P. Schotanus, et al., Nuclear Instruments and Methods in Physics Research A 729 (2013) 596-204