Contribution ID : **108** Type : **Poster**

A Second-generation Low-Background Gamma-Ray Spectrometer

Wednesday, 28 September 2016 14:42 (0:02)

Content

For the ultimate sensitivity in trace radiochemical analysis, the radiation detector must have high efficiency and low background. A well-characterized low-background Ge gamma spectrometer that has been in regular use at NIST since 1990 is being supplemented by a new system, improved in several ways. The relative efficiency of the new Ge detector is nearly three times that of the older system, which alone improves the detection limit substantially. Because the detection limit scales approximately as efficiency divided by the square root of background, the most cost-effective way of improving sensitivity is by buying germanium; a second benefit of a larger detector is improved peak/Compton ratio. Inside any good above-ground shield, the background counting rate is dominated by a continuum of high-energy cosmic-ray muons. This component can be nearly eliminated with an anticoincidence shield. An existing system in our laboratory reduces the continuum by a factor of 15 by closely surrounding the Ge detector with a NaI scintillator. With this arrangement the detection limit for 137Cs is improved by the expected factor of four, but in fact worsened by a factor of two for the cascade decay of 60Co; in addition, the geometry of this system limits the maximum size of the counting sample. In the new system, muons are vetoed by operating in anticoincidence with an umbrella of plastic scintillators covering three adjacent sides of the shield, so that any linear path through the detector must also traverse a scintillator. Muons also contribute to background by creating fast neutrons in the shield, giving characteristic (n,n′) excitation gammas from the shield material and the detector itself. Because the production rate of (μ,n) neutrons per kilogram of shielding is proportional to the atomic mass A, the new shield is constructed of 15 cm of pre-1945 iron rather than lead, thus reducing the fast-neutron flux to a fifth of that in the older lead shield. Its volume is large, to accommodate bulky or irregular samples that our laboratory occasionally needs to survey. The cryostat extends outside the shield to the preamplifier and Dewar though a stepped aperture that was cut by abrasive-jet machining. Both the Ge detector and the scintillators are operated by modern digital spectrometers, the speed of which gives acceptable system dead time from the large scintillation umbrella, and offers time-stamped event-by-event data acquisition.

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Session Classification : Radiometrics

Track Classification : Radiometrics