Photon Activation Analysis of Toxic Elements

I have read with interest Lisk's account of several analytical techniques available today for the study and monitoring of toxic elements in biochemical and geochemical systems (*1*). While discussing the sensitivity of the technique of neutron activation analysis (NAA) for trace element analysis in various samples, Lisk points out that NAA "cannot be used to determine certain important elements such as lead." My purpose in this technical comment is to point out that photon activation analysis (PAA), a technique not mentioned by Lisk, can be used for the detection of Pb and other elements in different types of sample matrices.

For several reasons, PAA has not received as much attention in the past as NAA. But recent technological developments in the area of nuclear detectors and analyzers have paved the way for the use of PAA in various sample matrices. Hislop and Williams (*2*) have used PAA to analyze samples of the lunar materials returned on the Apollo 12 mission and other biological materials. They used the bremsstrahlung radiation from the Harwell 45-Mev linear accelerator (linac) for activation of the samples and a high-resolution, solid-state nuclear spectroscopy system for the analyses of the complex γ-ray spectra. They reported that PAA is particularly valuable for the determination of Fe, Ca, Ti, Sr, Zr, Cs, Sb, Tl, As, Rb, Pb, Hg, and Ni. By using chemical separation of the irradiated samples, they were able to obtain sensitivities as high as 0.02 μg. Kato and Oka (*3*) used the 300-Mev linac at Tohoku University for the PAA of 52 elements (chemical purity, 99.9 percent or better). Sensitivities for PAA with 30- and 60-Mev bremsstrahlung were reported by them for 13 elements which have nuclear properties unfavorable for NAA. Lutz (*4*) has presented a review of PAA with emphasis on its use in biological, geochemical, oceanographic, and forensic matrices. He has listed calculated sensitivities for 60 elements after activation with photons having energies of 25, 30, and 35 Mev. Aras *et al.* (*5*) have reported the use of PAA for the quantification of 14 elements present in urban particulate materials. The elements assayed include, among others, Pb, As, Cr, Ni, and I. They also have discussed the advantages, reproducibility, accuracy, and sensitivity of PAA for both light and heavy elements in various matrices.

Kuttemperoor (*6*) has studied the photon activation of several elements including Pb, using the bremsstrahlung radiation from the 25-Mev betatron at the Milwaukee School of Engineering. The photonuclear reactions $^{204}Pb(\gamma,n)^{203}Pb$ or $^{204}Pb(\gamma,\gamma)^{204m}Pb$ can be used for the detection and unambiguous identification of trace amounts of Pb in various samples. The reaction $^{204}Pb(\gamma,\gamma)^{204m}Pb$ was used by Chattopadhyay and Jervis (*7*) for the determination of Pb in soil samples. They irradiated the samples with 35-Mev x-ray photons and determined the activity of ^{204m}Pb having an energy of 0.375 Mev and a half-life of 67 minutes. Concentrations of the order of 10 parts per million (ppm) have been reported with the use of a Ge(Li) detector without chemical separation, and detection limits of about 0.001 μg may be achieved by radiochemical separation of ^{203}Pb prior to γ-ray detection (*7*). Lutz (*8*) has used PAA to determine the concentrations of Pb in biological and environmental samples. He irradiated the samples using the electron accelerator at the National Bureau of Standards, inducing the photonuclear reaction $^{204}Pb(\gamma,n)^{203}Pb$. The most prominent γ-ray from ^{203}Pb (energy, 0.279 Mev; half-life, 52.1 hours) was used for the identification of Pb. Sensitivities of the order of 0.3 ppm in beef liver and 43 to 47 ppm in orchard leaves were reported by Lutz. Bryan *et al.* (*9*) and Guinn (*10*) have studied the activation of forensic samples by PAA. They have analyzed several samples of moonshine whiskey and have reported Pb concentrations of the order of 4 to 80 mg per liter of whiskey.

The technique of PAA is nondestructive and is favored over NAA and atomic absorption for the detection of Pb. It is also preferred in the detection of a number of other biologically important elements such as C, O, Si, N, F, Mg, Fe, and Ni. Another advantage of PAA over NAA for biological samples is that one can avoid the creation of ^{24}Na due to the presence of ^{23}Na which is very abundant in any biological sample.

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16 July 1974

Infant Hue Discrimination?

Fagan (*1*) concluded that infants 4 to 6 months of age are capable of hue discrimination. He based his argument on their preference for fixating checkerboard patterns composed of Munsell squares chosen to differ in hue but equated for brightness and saturation, as opposed to unpatterned targets of either hue. In addition, he reported a Kendall rank correlation coefficient of .82 between the percentages of total fixation to patterned targets and his index of hue differences. However, there are problems associated with both the stimulus array and the data analysis that seriously weaken his conclusion.

In order to create a checkerboard pattern varying in hue but not in brightness, Fagan used pairs of Munsell squares of different Hue but of the same Value. In the Munsell system, stimuli of a given Value have the same luminous reflectance, *Y* in terms of the Commission Internationale de l'Eclairage (C.I.E.) designation. Thus, other things being equal, samples of the same Value appear approximately equal in lightness. This is true for infants, however, only if their luminosity function is a close approximation to the C.I.E. photopic luminosity function, which was determined for adults. The study cited by Fagan to support this possibility utilized such a restricted wavelength range (450 to 650 nm, in 50-nm steps) that it cannot be regarded as conclusive (*2*). In addition, the yellow, crystalline lens of the eye probably absorbs differently in infants than in adults (*3*). On this basis alone it is improbable that adults and