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ALPHA PARTICLE ANALYSIS USING PEARLS SPECTROMETRY

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ABSTRACT

Alpha particle assay by conventional plate-counting methods is difficult because chemical separation, tracer techniques, and/or self-absorption losses in the final sample may cause either non-reproducible results or create unacceptable errors. PEARLS (Photon-Electron Rejecting Alpha Liquid Scintillation) Spectrometry is an attractive alternative since radionuclides may be extracted into a scintillator in which there would be no self-absorption or geometry problems and in which up to 100% chemical recovery and counting efficiency is possible. Sample preparation may include extraction of the alpha emitter of interest by a specific organic-phase-soluble compound directly into the liquid scintillator. Detection electronics use energy and pulse-shape discrimination to provide discrete alpha spectra and virtual absence of beta and gamma backgrounds. Backgrounds on the order of 0.01 cpm are readily achievable. Accuracy and reproducibility are typically in the 100 ± 1% range. Specific procedures have been developed for gross alpha, uranium, plutonium, thorium, and polonium assay. This paper will review liquid scintillation alpha counting methods and reference some of the specific applications.

LIQUID SCINTILLATION ALPHA SPECTROMETRY

Liquid scintillation has been recognized as an attractive method for counting alpha emitting radionuclides from the initial development of the method.[1,2] A common approach has been to use the readily available commercial liquid scintillation equipment employed for low-energy particle counting. The technique is useful and accurate for samples of known nuclide purity and known uniform matrix composition, and can provide backgrounds on the order of 10 to 20 cpm. Samples of unknown composition frequently exhibit variable quenching and backgrounds. The presence of beta and gamma radiation will increase backgrounds and may interfere with alpha detection. Because alpha particles produce high specific ionization in the solvent, they have only about 10% light production efficiency per MeV when compared with beta and gamma radiation. Consequently, alpha emitters in the 5MeV range create electronic signals similar to those generated by betas with energies on the order of 0.5Mev. Energy resolution is on the order of 20%.

A significant improvement in energy resolution may be obtained if the detection system is designed exclusively for alpha counting. When the nuclide of interest is extracted into the liquid scintillator extractant solution and counted using the detection arrangement outlined in the figure and standard electronics of the type used for sodium iodide-gamma spectrometry, reproducible spectra with an energy resolution on the order of 5% are possible. Beta and gamma decay events may be segregated from the alpha emissions by electronically processing the differences in pulse shape, a beneficial aspect of the large differences in specific ionization. To achieve effective pulse shape discrimination (PSD), samples must be deoxygenated. This is easily accomplished by sparging the scintillator/sample for 1 or 2 minutes with argon or nitrogen gas. Color or chemical quenching will also degrade PSD.

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PEARLS (Photon-Electron Rejecting Alpha Liquid Scintillation) spectrometry — maximizes the advantages of liquid scintillation detection by coupling solvent extraction methods with detectors and electronics having the ability for improved energy resolution and for pulse shape discrimination between alpha-produced and beta/gamma-produced pulses. Electronic components are connected as shown in the figure. The PSD information is used to gate the multichannel analyzer and remove the beta/gamma background interference from the alpha spectra. Representative spectrum for a radon experiment is included in the figure. Backgrounds are effectively reduced to as low as 0.01 cpm while retaining 100% counting efficiency.

Complete details of alpha detection, chemical extraction processes and PEARLS spectrometry are being prepared for publication in a monograph.[3]

There appear to be many potential applications for high resolution liquid scintillation techniques. To date the PEARLS detection concept has been coupled with solvent extraction separation techniques and applied to assay of uranium and thorium in phosphate fertilizers,[4,5] analysis of polonium in a uranium mill circuit[6,7] and determination of plutonium and transplutonium actinides in a variety of sample types.[6] A portable PEARLS spectrometer has been developed for field measurements.[8]

CONCLUSIONS

The application of liquid scintillation detection may be readily extended to assay alpha radionuclides in numerous sample types. The accuracy and reproducibility of the method is almost always better than with plate-counting methods. Commercially available beta liquid scintillation systems may be used, but the potential problems associated with interference from beta and gamma radiation must be recognized. Commercial systems may not be easily adapted to perform PSD. The use of equipment designed for alpha liquid scintillation, along with appropriate PSD electronics and extractive scintillators, will permit the collection of useful energy spectra, the rejection of nearly all beta and gamma background, and in most cases, improve the accuracy of the determination. Sample concentration by solvent extraction, 100% efficiency, and low virtual background may result in detection thresholds which are lower than in other methods. The opportunity to provide an alpha detection technique of improved accuracy coupled with increasing demands for rapid, accurate low-level radiation monitoring in a variety of applications provide an incentive to continue development of this method.

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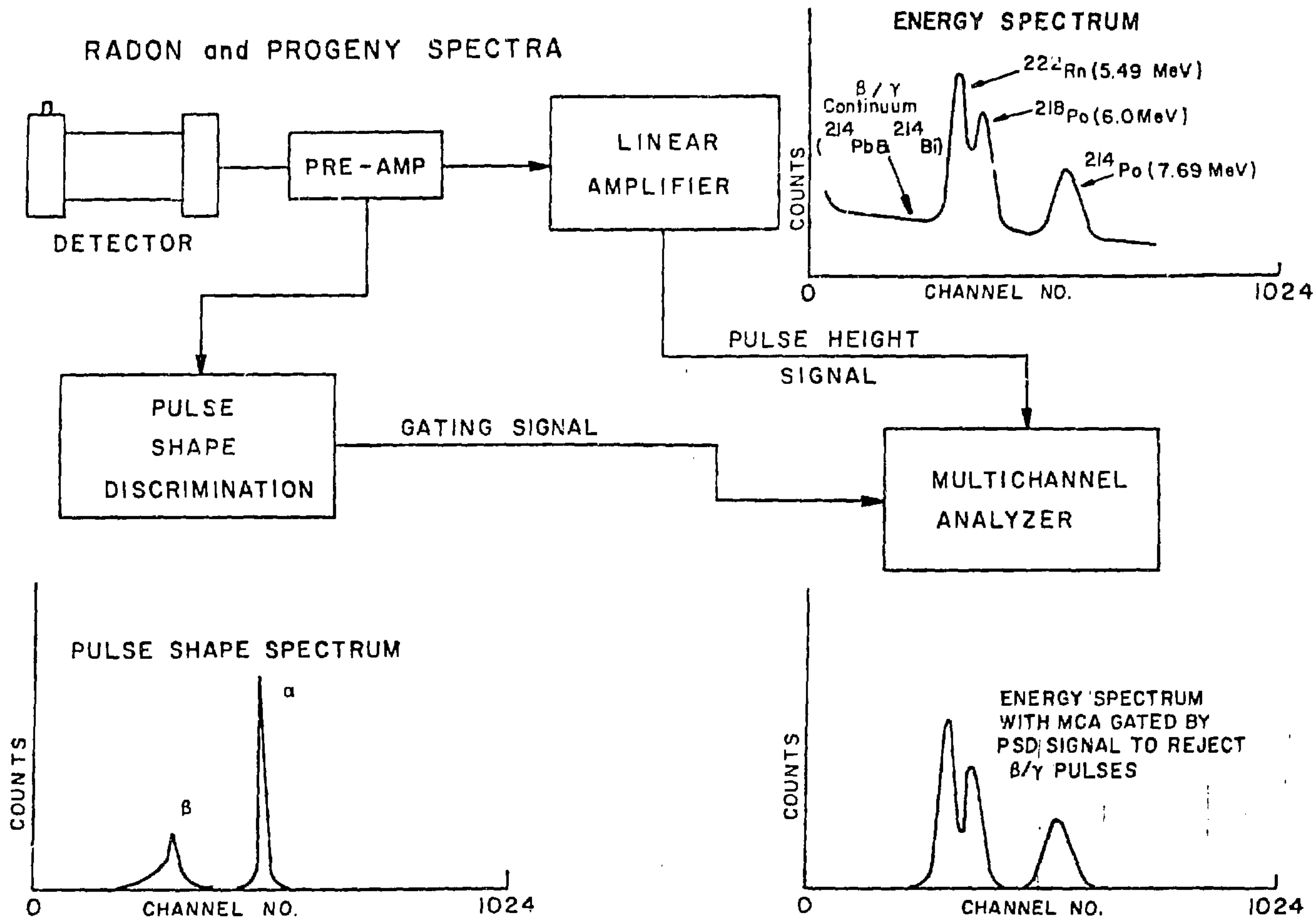
RADON and PROGENY SPECTRA
DETECTOR
PRE-AMP
LINEAR AMPLIFIER
ENERGY SPECTRUM
222Rn (5.49 MeV)
218Po (6.0 MeV)
214Po (7.69 MeV)
β / γ Continuum
(214Pb & 214Bi)
COUNTS
0
CHANNEL NO.
1024
PULSE HEIGHT SIGNAL
PULSE SHAPE DISCRIMINATION
GATING SIGNAL
MULTICHANNEL ANALYZER
PULSE SHAPE SPECTRUM
α
β
COUNTS
0
CHANNEL NO.
1024
ENERGY SPECTRUM WITH MCA GATED BY PSD SIGNAL TO REJECT β/γ PULSES
COUNTS
0
CHANNEL NO.
1024

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