

SIMULTANEOUS MEASUREMENT OF ALPHA AND BETA EMISSIONS ON READY CAP®

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ABSTRACT. Alpha and beta emitters are distinguished from each other on the basis of position of pulse-height spectra on Ready Cap®. This is primarily owing to the geometry of the solid scintillator, Xtalscint®, used in the Ready Cap®.

INTRODUCTION

Investigators measuring radioisotopes with scintillation techniques often desire to distinguish between disintegrations of alpha and beta emitters in the same sample. Almost 20 years ago, Thorngate, McDowell and Christian (1974) introduced the capability to discriminate between α and β emissions in liquid scintillators by pulse shape. Newer liquid scintillation (LS) counters may be equipped with pulse-discrimination electronics to measure simultaneously both α and β signals. In this paper, I report the discrimination of signals from α and β emitters, based on the different positions of the pulse-height spectral regions occupied by these decay particles, when measured using the solid scintillator, Xtalscint® (yttrium silicate), in Ready Cap®.

METHODS

Ready Cap®, a solid scintillator using Xtalscint®, and Ready-Solv™ HP, a liquid scintillator cocktail, were purchased from Beckman Instruments, Fullerton, California. The isotopes, ^{238}U and ^{241}Am , were purchased from Isotope Products Laboratories, Burbank, California. All other isotopes were purchased from New England Nuclear, a division of DuPont, Boston, Massachusetts, USA.

A Beckman LS-6000 LS counter was used for the scintillation measurements. Liquid samples were recorded using the liquid coincidence gate, and the solid scintillation samples were recorded using the "XTAL" coincidence gate. Older counters without variable coincidence gates were also used to confirm that the α and β spectral characteristics reported here were not a function of the coincidence gates.

RESULTS AND DISCUSSION

Beta Counting on Ready Cap®

Energetic β emitters count at nearly 100% efficiency using either LS or Ready Cap®. Figures 1 and 2 and the data in Table 1 show that the pulse-height spectra of energetic β emitters measured on Ready Cap® do not move to greater pulse amplitude as the energy of these isotopes increases. This is in contrast to the continuous movement to greater amplitude of the pulse-height spectra with the same energetic β emitters measured in a liquid cocktail. Resolution of the energetic β emitters, ^{90}Sr , at 546 keV, and ^{90}Y , at 2284 keV, is observed clearly in LS, but is impossible on Ready Cap®. The positional stability of the β pulse-height amplitude on Ready Cap® for β particles with decay energy >400 keV is believed to result from β particles escaping from the scintillator bed after transferring only a portion of their decay energy. A scintillation event is recorded for each decay event, but with Ready Cap®, the pulse amplitude is diminished by the energy remaining with the particle after it has left the scintillator bed. Beta spectra measured on Ready Cap® for

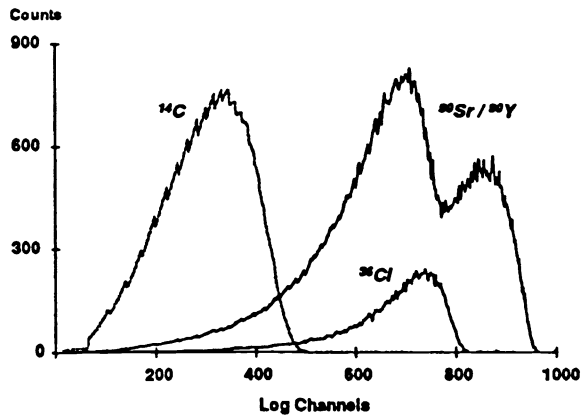


Fig. 1. Spectra of ^{14}C , ^{36}Cl and $^{90}\text{Sr}/^{90}\text{Y}$ in cocktail

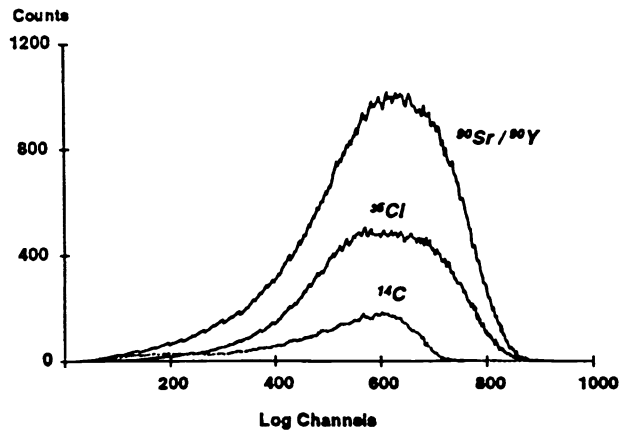


Fig. 2. Spectra of ^{14}C , ^{36}Cl and $^{90}\text{Sr}/^{90}\text{Y}$ on Ready Cap®

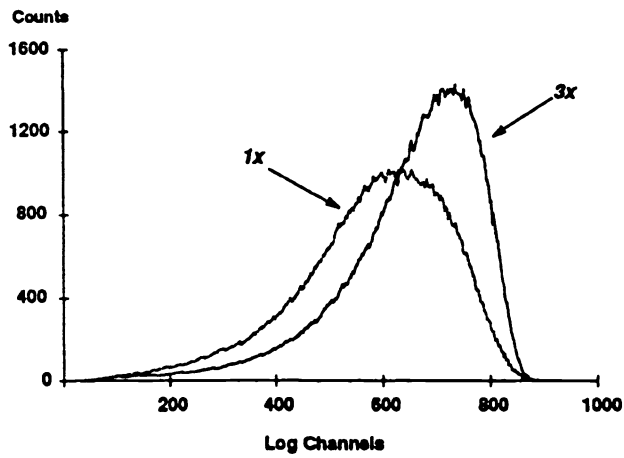


Fig. 3. Effect of yttrium silicate thickness on the spectrum of $^{90}\text{Sr}/^{90}\text{Y}$

TABLE 1. Isotope Endpoints in Cocktail and Ready Cap® in Log Channels (Log ch.) and keV

Isotope	Cocktail endpoint Log ch. (keV)	Ready Cap® endpoint Log ch. (keV)	Maximum decay energy (keV)
¹⁴ C (β)	455 (23)	705 (178)	156
³⁶ Cl (β)	801 (393)	816 (445)	712
⁹⁰ Y (β)	937 (1200)	831 (503)	2284
²⁴¹ Am (α)	782 (337)	961 (1488)	5500

TABLE 2. ⁹⁰Y Endpoint and Isotope Center of Pulse Height Spectrum Measured on Ready Cap® and Triple Scintillator Ready Cap®

Isotope	Linear channels isotope center		Log channels endpoint	
	Ready Cap®	3X Ready Cap®	Ready Cap®	3X Ready Cap®
⁹⁰ Y	156	283	831	846
³⁶ Cl	154	198	816	839

high-energy β particles would then appear to have a similar maximum amplitude, as observed in Figure 2. One expects that this fixed-energy maximum would depend on the geometry and composition of the solid scintillator bed.

Test of Hypothesis

This hypothesis can be tested by increasing the volume of the scintillator bed, measuring the pulse-height spectrum for the same isotopes on the two solid scintillator beds, and comparing whether the spectral position has changed to higher amplitude with the increased volume. Special Ready Caps® were prepared by taking the Xtalscint® from three Ready Caps® and combining it into one Ready Cap®. This provides a scintillator bed with three times the volume of a standard Ready Cap®, assuming that the deposition density was the same in both. Figure 3 displays the results from counting ⁹⁰Y and ⁹⁰Sr on these two forms of Ready Cap®. Table 2 summarizes the pertinent data for the experiment. The data show that both the isotope center- and endpoint moved to greater pulse amplitude for the triple-volume Ready Cap®. This would confirm the hypothesis that the observed constancy of the pulse-height spectrum for energetic betas on Ready Cap® is due to β particles escaping the scintillation bed without depositing all of their energy with the scintillator.

Alpha Counting on Ready Cap®

Alpha particles also count with nearly 100% efficiency on Xtalscint® solid scintillators and liquid scintillators. Keefer and Manton (1989) have reported that α emitters of differing energy cannot be distinguished from each other, nor can β emitters of differing energy be distinguished from each other when counted on Ready Cap®. Figure 4 shows the spectra of the α emitter, ²⁴¹Am, counted on both Ready Cap® and liquid scintillator. This spectrum exemplifies the general behavior of α emitters on Ready Cap®. They appear at much higher pulse amplitude than α emitters measured in LS cocktails. Wunderly (1989) reported that Xtalscint® is a more efficient scintillator than unquenched liquid scintillators, and this is believed to be the reason for the greater amplitude of pulse-height spectra for α emitters on Ready Cap®. The penetration of the scintillator is not considered to be an issue for α particles. Researchers believe that the greater mass and higher

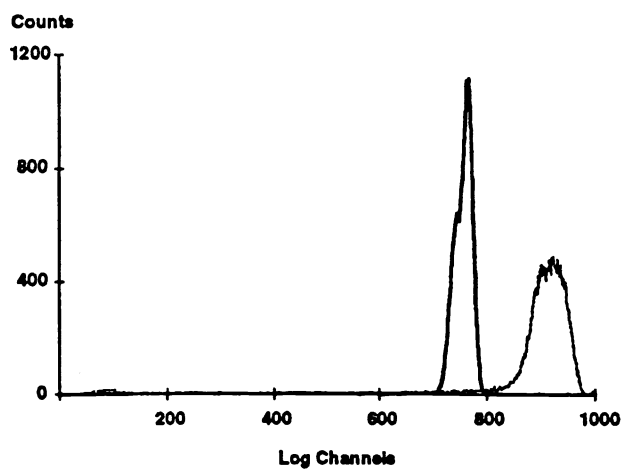


Fig. 4. Spectra of ^{241}Am in cocktail and on Ready Cap®

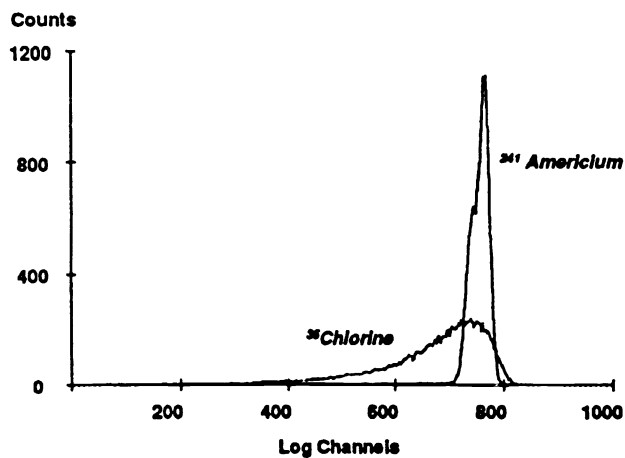


Fig. 5. Spectra of ^{241}Am and ^{36}Cl in cocktail

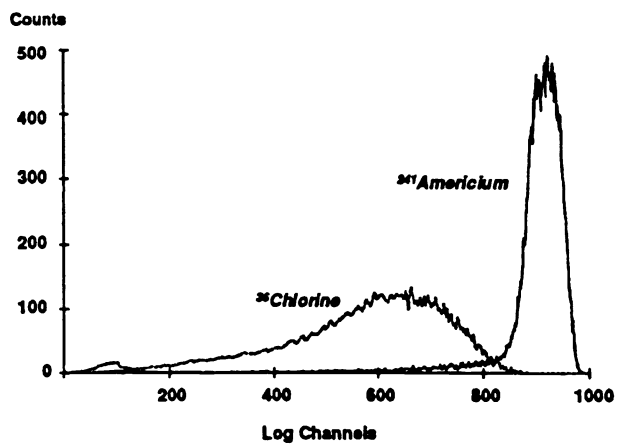


Fig. 6. Spectra of ^{241}Am and ^{36}Cl on Ready Cap® (superimposed)

TABLE 3. Dual-Label Counting of ^{241}Am and ^{36}Cl on Ready Cap®

Isotope	Activity added (cpm)	Measured cpm
^{241}Am	33,800	29,553
^{36}Cl	31,900	36,347
Total	65,700	65,900
% α	51.4%	44.8%

TABLE 4. Alpha Determination of α/β Parents and Daughters

Isotope	% α by Ready Cap®	% α by independent determination
^{238}U	58	65
^{210}Pb	32	33.3

charge density of α particles causes them to be contained within both solid and liquid scintillator boundaries, even though an α particle typically has ten times as much energy as a β particle.

An interesting feature of counting an α emitter on Ready Cap® is the small peak centered about channel 100, shown in Figure 4. This is due to air ionization by the α particle. It also appears when an α emitter is placed in an empty glass or plastic vial (spectrum not shown). Some of the α particles near the surface of the scintillator bed escape into the air and ionize the air, causing low-amplitude scintillations. This small peak represents about 6% of the total counts for this ^{241}Am sample, and will lead to a small error in quantization of α emitters in the presence of β emitters.

Simultaneous Measurement of Alpha and Beta Particles Counted on Ready Cap®

Figure 5 shows the superposition of spectra for ^{36}Cl , a β emitter, and ^{241}Am , an α emitter, measured in cocktail. It is clear that the pulse-height spectra of the two isotopes overlap, making discrimination between the two isotopes impossible, on the basis of spectral position. Figure 6 shows the superposition of ^{36}Cl and ^{241}Am spectra, each measured on Ready Cap®. The overlap of the two spectra is minimal, and discrimination between the two should be possible. Figure 7 shows a spectrum from a sample containing both ^{36}Cl isotope, at 31,900 dpm, and ^{241}Am isotope, at 33,800 dpm. Summing counts between channels 0 and 851 (the valley minimum between the α and β regions), and assigning these to ^{36}Cl , one obtains 36,347 cpm. Summing counts between channels 852 and 1000, and assigning these to ^{241}Am , one obtains 29,553 cpm (data summarized in Table 3). This agrees well with the actual activity added (α percentage added is 51.4% and α percentage found is 44.8%). (Please note that compensation for the 6% air ionization activity of α particles from ^{241}Am , but assigned to the β range, would make the agreement between added and found very close.) Therefore, it is possible to distinguish α and β emitters on Ready Cap® merely from the position of the spectra. In general, the spectral pulse-height region of α particles is above channel 850 if no color quench occurs.

^{210}Pb is a β emitter with two short-lived daughters. One daughter, ^{210}Bi , is a β emitter, and the other daughter, ^{210}Po , is an α emitter. ^{210}Pb (spectra not shown) was counted on Ready Cap® and the spectrum integrated. The counts above channel 850 are 32% of the total recorded counts (data summarized in Table 4), concurring with the theoretical prediction that 33.3% of the counts would be due to α emissions.

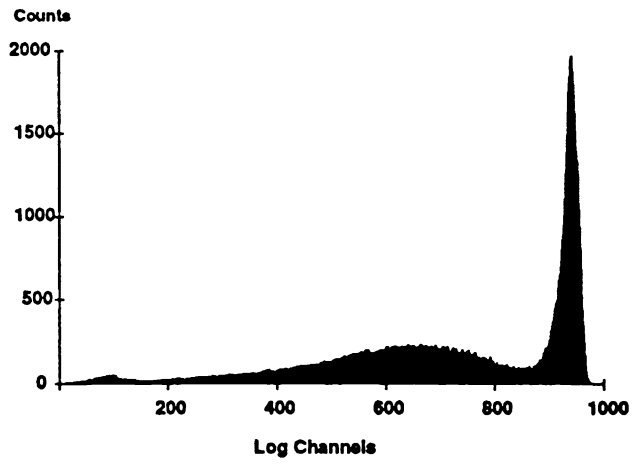


Fig. 7. Spectra of ^{241}Am and ^{36}Cl on Ready Cap[®] (counted together)

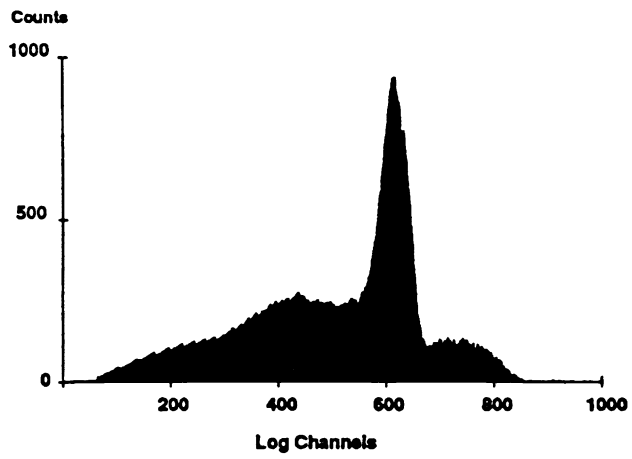


Fig. 8. Spectrum of ^{238}U in cocktail

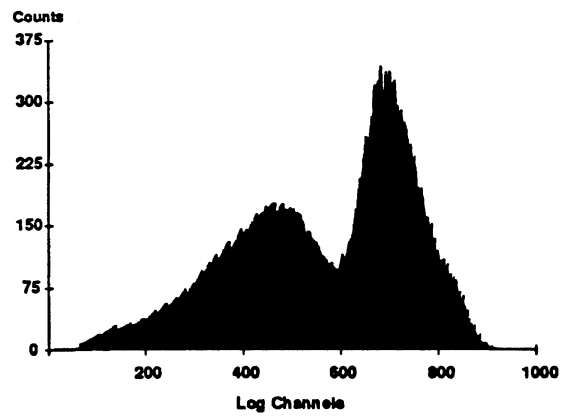


Fig. 9. Spectrum of ^{238}U on Ready Cap[®]

Finally, ^{238}U appears with numerous daughters, depending on the age and purification scheme. One daughter, ^{234}Pa , is a very high-energy β with a decay energy of 2207 keV. I counted ^{238}U , as uranyl nitrate, in cocktail on a Beckman LS-6000 using α - β discrimination, and determined the sample to have 64.7% α decays. Figure 8 shows this spectrum for ^{238}U measured in cocktail. The tall α peak is surrounded by peaks due to the β s. The peak area to the right of the α is due to the ^{234}Pa , 2207 keV β . When ^{238}U is counted on Ready Cap® (Fig. 9), all of the β peaks are found to the left of the α peak. Uranyl nitrate is a yellow solid. Because of ^{238}U 's long half-life, 10^9 yr, it takes a large sample to produce sufficient activity to measure. As a result, the Ready Cap® with uranyl nitrate was visibly stained yellow and suffered from color quench; thus, the whole spectrum in Figure 9 appears to be shifted to the left. However, it is still possible to determine the contribution from the α and β decays. Integrating from channel 0 to channel 595, the valley minimum between the two pulse-height maxima, one can determine that the counts due to the β particles are 42.3% of the total counts. Integrating from channels 596 to 1000, one determines that 57.7% of the total cps result from α decays. Again, even in the presence of color quench, it is possible to resolve α and β emissions by pulse-height position on Ready Cap®.

CONCLUSION

I have shown, using the pulse-height parameter, that solid scintillator systems that use Xtalscint® are capable of discriminating between gross α and gross β in the same sample. This convenient feature is a result of scintillator-system geometry and is not a product of electronic manipulation by the instrument. It can be obtained with all instruments having pulse-height discrimination, although it is particularly convenient with instruments having multichannel analyzers. Counting on Ready Cap® or Ready Filter™ would be particularly suitable for screening large numbers of environmental samples associated with industrial waste containment, such as in mining or nuclear power plants.

REFERENCES

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