A RELATIVELY FAST ASSAY OF Sr-90 BY MEASURING THE CHERENKOV EFFECT FROM THE INGROWING Y-90

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In the year 1978 alone, over 30 publications were registered dealing with the biological effects and radiation hazards due to the intake and adsorption of Sr-90 (1). Some of these publications include experimental results obtained from radioanalyses of Sr-90, which by themselves are mainly based on measurements of the short-lived, separated daughter nuclide Y-90. A delay of 10 to 15 days is often necessary prior to the radioassay, in order to insure a large enough ingrowth of Y-90 ($T_{\frac{1}{2}}$ = 64.1 h). This time interval can be considerably reduced if the assay is carried out by Cherenkov counting of the ingrowing yttrium. Cherenkov radiation is produced in aqueous solutions by high energy β- particles and has been successfully used for the determination of P-32 (2), Na-24 (3), K-40 (4) and Rb-86 (5). This work is an improvement of a procedure on the assay of Sr-89 and Sr-90 in presence of each other, in which the equilibrated Y-90 is separated from the parent before counting; this part of the procedure is superfluous if only Sr-90 is present (6).

METHOD

The Cherenkov effect induced by the 2.27 MeV β-emitter Y-90 can be measured with good efficiency using conventional liquid scintillation counters (6). The weak contribution of the soft β-s from the parent Sr-90 is eliminated by suitable adjustments of the gain setting and the base-line window opening in the counting channel. Any detectable activity in a freshly separated Sr-90 sample is thus due solely to the ingrowing Y-90. The activity of the strontium is calculated by use of the following expression :

$$\mu Ci(t_o) = \frac{\text{cpm Y-90 } (t_b) \times \exp \lambda_{Sr}(t_a - t_o)}{y_{Sr} \times \varepsilon_Y \times 2.22 \times 10^6 \{1 - \exp[-\lambda_Y(t_b - t_a)]\}} \qquad [1]$$

where : t_o = the reference time of sampling;
t_a = the final Sr/Y separation time;
t_b = the Y-90 counting time;
λ_{Sr} and λ_Y = the decay constants of the two radionuclides (0.0243 y^{-1} and 0.0108 h^{-1} respectively);
y_{Sr}= the radiochemical yield of strontium;
ε_Y = the counting efficiency of Y-90.

THEORETICAL ASPECTS (summarized from 7,8)

Cherenkov radiation is produced when charged particles (in our case β-s) pass through a transparent medium at a velocity greater than that of light in the same medium. This radiation is emitted at an angle θ with respect to the direction of the inducing particle according to (7) $\cos \theta = 1/\beta n$, where β is the velocity ratio v/c and n the refractive index of the medium. For relativistic electrons, β is related to the energy E (keV) of the particle, by (7)

$$\beta = \left\{1 - \left[\frac{1}{(E/511) + 1}\right]^2\right\}^{\frac{1}{2}}$$

. The threshold condition for Cherenkov radiation is $\beta n = 1$, so that if n for water equals 1.332 then β must be > 0.751. This lower energy threshold is 263 keV, below which no Cherenkov effect occurs. However only β-emitters above 1 MeV give sufficiently high yields to be of any practical significance (8).

Cherenkov radiation is one-directional , weak in intensity and has a continuous spectrum mainly in the ultraviolet, with only a small portion extending into the visible region (7).

RESULTS AND DISCUSSION

All the measurements were conducted with 20 ml aqueous solutions in standard polyethylene counting vials. Two optional liquid scintillation spectrometers were used, the Packard Tricarb Model 3390 and the older Model 3214; the working conditions for both instruments are summarized in table 1.

TABLE 1. Working conditions for the Cherenkov counting of Y-90

	Tricarb 3390	Tricarb 3214
Gain %	40	30
Window opening	100 - 1000	50 - 1000
Counting efficiency	$\varepsilon = 0.43$	$\varepsilon = 0.39$
Background	9 - 11	11 - 13

The data in table 2. are a measure of the feasability of assaying a sample before the Sr/Y equilibrium is reestablished. It gives the magnitude of the experimental error that can be anticipated if the Y-90 counting is carried out at various time intervals after the final separation and purification of strontium. Activities as low as 10^{-3} µCi per vial can be measured with reasonable accuracy after only 2 days following the separation. Lower activities require longer periods of time for the Y-90 ingrowth, but even for 10^{-5} µCi 5 days seem to be sufficient.

The radiochemical yield was determined with the help of the γ-emitting Sr-85. Additions of up to 2000 dpm were not detectable at our working conditions. With activities higher than .01 µCi larger aliquots of the marker Sr-85 are desirable (6).

The lower limit of detection is about 3×10^{-6} µCi at conditions of secular equilibrium ($\approx$ 18 d), which in practice amounts to 2 or 3 cpm above background. An assay of such very low activities requires long counting times (about 500 counts per sample), if the measurements are to be statistically significant. In addition, too early counting of such samples would introduce an error due to an increase in the activity of the ingrowing Y-90, during the measurement itself. Very low activities should therefore be assayed only after the Sr/Y equilibrium has been reestablished.

TABLE 2. Estimated overall errors for Sr-90 activities, measured at various time intervals after the separation from Y-90
(counting times per sample : 100 minutes or less)

Y-90 ingrowth time ($t_b - t_a$) (days)	± 95% confidence limit, in % of activity : .01 - .15 (µCi)	.003 - .009 (µCi)	8×10^{-5} - .001 (µCi)	10^{-5} (µCi)
< 1	30.	-	-	-
1 - 2	4.4	8.1	-	-
2 - 3	4.5	5.9	34.	-
3 - 5	5.6	5.7	23.	-
5 - 7	6.0	7.7	9.0	15.

RECOMMENDED PROCEDURE (short summary)

1. About 5 to 10 mg of inactive carrier and a known activity of Sr-85 tracer (10^{-3}- 10^{-4} dpm) are added to the original sample. The strontium is separated and purified by a standard radiochemical procedure.

2. The aqueous sample is transfered into a polyethylene counting vial and made up to the desired volume (20 ml). It should be ready for measurement 24 hours after the final Sr/Y separation step. The gain settings and window openings on the liquid scintillation spectrometer should be arranged in such a way as to eliminate the contribution of the parent nuclide Sr-90; only the ingrowing Y-90 is counted.

3. If necessary, the measurements are repeated on consecutive days until the desired precision is achieved. The radiochemical yield is determined by comparison with a blank Sr-85 sample.

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