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RADIOISOTOPE ASSAY METHODS AT OAK RIDGE NATIONAL LABORATORY*

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The accompanying table presents the methods used at Oak Ridge for the calibration and routine measurement of radioisotope shipments. Estimates of the accuracy of disintegration rate determinations, and the precision of routine measurements are furnished. The latter quantity indicates the reproducibility to be expected among several shipments of a given material. The modes of decay and "best" values of half-lives (in the authors' opinion) are included.

Essentially all radioisotope shipments are in solution form. ("Irradiated Units" are not analyzed.) Volumetric techniques are employed to secure the sample on which activity measurements are made. When beta activity is to be determined, the sample is dried on a suitable film and mounted in such a way that it can be inserted in a counter. Samples for gamma(1) and x-ray(2) spectrometry are dried on one-inch watch glasses, while measurements of total gamma activity are made on liquid samples.

The fundamental method of standardization of beta-gamma emitting nuclides is 4π coincidence counting, employing an instrument in which the beta detector is a 4π counter, and the gamma detector is a NaI(Tl) scintillation spectrometer, equipped with a differential and integral analyzer circuit(3). The general method of coincidence counting has been described before(4); 4π coincidence counting introduces refinements which increase the accuracy of the assay. The method involves placing the 4π counter (containing the active sample deposited on a thin conducting film) next to the scintillation detector. The pulse height of the scintillation spectrometer is set so as to accept only pulses from a particular gamma

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ray. Usually the photoelectron peak resulting from the most energetic gamma ray present is used. The assembly includes amplifiers, a delay circuit to match delays within the system, the discriminator for the gamma counter, and beta, gamma and coincidence scalers. Beta emitters (little or no gamma) are measured by 4π counting(5), or "absolute beta counting" with end-window Geiger-Mueller counters(6). X-rays, emitted by electron-capturers or nuclides which decay essentially by conversion-electron emission, are measured by means of a proportional counter spectrometer(2), filled with argon or krypton. This instrument is calibrated with sources whose disintegration rates can be determined by other methods, e.g., coincidence counting or measurement with a calibrated gamma ionization chamber(7,8).

Instruments employed routinely for assay of shipments, which include ionization chambers(8), well-type scintillation counters, and GM counters, are calibrated for measurement of a particular radioisotope by taking readings on a sample of that material which has been standardized by one of the absolute techniques described above. The standardization of a scintillation spectrometer was discussed by Kahn and Lyon(1).

Comparison of Oak Ridge results on radioisotope materials with those obtained by other establishments, especially the National Bureau of Standards, has shown adequate agreement(9,10).

METHODS FOR ASSAY OF RADIOISOTOPES

Element	Isotope	Half-Life	Decay	Decay Ref.	Assay Instrument[a] Calibration	Routine	Estimated L.E., %[b]	Precision, %[c]	Remarks
Be	7	52.9d[d]	EC,γ	11	IC	IC,SC	5 (?)	2	11% gamma assumed. IC efficiency calculated.
C	14	5400y(?)	β	11	Gas IC	Gas IC	5 (?)	5	NBS C-14 standards employed; these determine accuracy.
Na	22	2.6y	β^+,γ,EC	12	4πC	IC,SC	5	2	Total disintegration rate reported.
Na	24	15.1h[d]	β,γ	11	4πC	IC,SC	3	2	Agreement with NBS noted.
Al	26	10^6y (?)[d]	β^+,γ	13	IC	IC,SC	10	2	IC efficiency calculated.
P	32	14.3d	β	11	4π	GM	3	2	Agreement with NBS noted.
S	35	87d	β	11	GM	GM	20	5	AβC[e].
Cl	36	~3x10^5y[d]	β	11	GM	GM	10	3	AβC.
K	42	12.5h[d]	β,γ	14	4πC	IC,SC	5	3	
Ca	45	163d	β	11	GM	GM	20	5	AβC.
Ca	47	4.5d[d]	β,γ	15	4πC	IC,SC	10	2	Sc-47 daughter.
Sc	46	85d	β,γ	11	4πC	IC,SC	3	2	
V	49	~334d[d]	EC	16	X	X	30	10	
Cr	51	27.8d[d]	EC,γ	17	X-γ C	IC,SC	10	5	9% gamma.
Mn	54	291d[d]	EC,γ	11	X-γ C	IC,SC	3	2	Correction for Mn-52 (if present) by β^+ counting.
Fe	55	3.0y	EC	11	X	X	30	10	
Fe	59	45d[d]	β,γ	11	4πC	IC,SC	5	2	Fe-55 content by x-ray spectrometry.
Co	56	78d	EC,β^+,γ	11	X,γS	IC,SC	30	10	
Co	57	270d	EC,γ	18	X	IC,SC	30	3	

Element	Isotope	Half-Life	Decay	Ref.	Calib.	Routine	L.E.	Precision	Remarks
Co	58	72d	EC,β^+,γ	11	X	IC,SC	10	2	
Co	60	5.2y	β,γ	11	4πC	IC,SC	3	2	Agreement with NBS noted.
Ni	63	85y (?)	β	11	PC	PC	30 (?)	10	Electrodeposited Ni; empirical correction for self-absorption.
Cu	64	12.8h^d	EC,β^+,β^-,γ	11	GM,X	IC,SC	20	2	
Zn	65	250d	EC,γ(β^+)	11	X-γ C	IC,SC	10	2	
As	73,74	76d,17.5d	EC,γ; EC,β^-,β^+,γ	11	X,γS	X,γS	30	10	As-74 content (low when shipped) calculated after calibration with pure As-73.
Se	75	127d	EC,γ	11	γS	γS	30	10	Intensity of 0.28 Mev γ assumed 80%.
Rb	86	~19.1d^d	β,γ	19	4πC	IC,SC	10	3	9% gamma.
Sr	85	64d^d	EC,γ	11	IC	IC,SC	10	2	Rb-85m daughter (~0.9 μs). IC efficiency calculated.
Sr	89	54d	β	11	4π	GM	10	3	Correction for Sr-Y-90 (if present) by Al absorption data on separated Sr.
Sr	90	20y	β	11	4π	GM	10	5	Y-90 daughter. Correction for Sr-89 (if present) by Al absorption data on separated Sr.
Y	88	104d	EC,γ(β^+)	11	X	IC,SC	30	2	
Y	91	61d	β (γ)	11	4π	GM	10	3	
Zr	95	65d	β,γ	11	4πC	IC,SC	5	5	Nb-95 daughter.
Nb	95	35d^d	β,γ	11	4πC	IC,SC	5	2	
Ru	106	1.0y	β	11	4πC	GM	10	3	Rh-106 daughter. 4π source covered with thin Al foil to exclude 40-kev Ru β.
Ag	110m-110	270d	β,γ	11	GM	IC,SC	20	2	Intensity of 0.53 Mev β assumed 35%.
Cd	109	470d	EC,γ	11	γS	γS	30	5	X-ray measurement.
Cd	115m	43d	β,γ	11	4π	GM	10	3	

Element	Isotope	Half-Life	Decay	Ref.	Calib.	Routine	L.E.	Precision	Remarks
In	114m-114	49d	IT;β,EC,γ	11	4π	GM	10	4	β disintegration rate reported.
Sn-In	113	112d;104m	EC;IT	11	IC	IC,SC	10	2	In-113m daughter γ measured. IC efficiency calculated.
Sb	124	60d	β,γ	11	4πC	IC,SC	10	2	
Sb	125	2.7y	β,γ	11	4πC	IC,SC	20 (?)	2	
Te	125m	58d	IT	11	γS	γS	30	5	Disintegration rate = ~ No. of x-rays/2.
I	129	1.7×10^7y	β,γ	11	CC	γS	10	5	
I	131	8.08d	β,γ	11	4πC	IC,SC	3	2	Agreement with NBS noted.
Cs	134	~2y	β,γ	11	γS	IC,SC	10 (?)	2	0.79 Mev γ measured.
Cs-Ba	137	~30y	β;IT	11	IC	IC,SC	5	2	Ba-137m daughter. IC efficiency calculated.
Ba	140	12.8d[d]	β,γ	11	4πC	GM	10	5	
Ce	144	282d	β,γ	11	GM	GM	10	4	Pr-144 daughter counted (AβC.)
Pr	143	13.8d[d]	β	11	4π	GM	10	4	
Nd	147	11.3d[d]	β,γ	11	4πC	IC,SC	10	3	Pm-147 daughter.
Pm	147	2.6y	β	11	GM	GM	20	5	AβC.
Hf	181	45d[d]	β,γ	11	IC	IC,SC	10	2	Ta-181m daughter (18 μs). IC efficiency calculated.
Ta	182	115d[d]	β,γ	11	4π	IC,SC	10 (?)	3	
W	185	73d	β	11	GM	GM	20	3	AβC.
Ir	192	74d	EC,β,γ	11	4π	IC,SC	20 (?)	2	β disintegration rate reported.
Au	198	2.70d[d]	β,γ	11	4πC	IC,SC	3	2	Agreement with NBS noted.
Hg	203	46.5d[d]	β,γ	11	4πC	IC,SC	10	2	
Tl	204	4y (?)	β (EC)	11	4π	GM	10	4	

NOTES:

[a] IC = ionization chamber; SC = well-type scintillation counter; $4\pi C$ = 4π coincidence counter; GM = end-window Geiger-Mueller counter; X = x-ray proportional counter spectrometer; X-γC = x-ray-gamma coincidence counter; γS = gamma spectrometer; CC = coincidence counter (External sample); PC = windowless proportional counter.

[b] Estimated limit of error in disintegration rate.

[c] Estimated precision of measurement (95% C.L.); indicates reproducibility.

[d] Determined or confirmed at ORNL.

[e] "Absolute beta counting."

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