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Intercomparison of a ^{134}Cs solution (July-September 1974)

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In their answers to the Questionnaire (1974-03-26), the members of Section II of the Comité Consultatif pour les Etalons de Mesure des Rayonnements Ionisants manifested much interest in the standardization of ^{139}Ce and ^{134}Cs. Therefore, the working party for advising on future intercomparisons decided to carry out small comparisons of these radionuclides. The participants in the present comparison of ^{134}Cs were:

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Each participant received a sealed glass ampoule with 5 g of a ^{134}Cs solution (approximately 1 200 s^{-1} mg^{-1}) containing 550 μg of CsCl in HCl 0.1 M. This solution was generously distributed by LMRI who carried out measurements using $4\pi\beta$(PC)-γ, $4\pi\beta$(LS)-γ counting and $4\pi\gamma$ counting with a large NaI well crystal. The two other participants did $4\pi\beta$(PC)-γ counting only.

Extensive information regarding the $4\pi\beta$-γ measurements and the sources has been collected in order to be able to compare the results and to fix the shape of the reporting form for a large scale intercomparison. The information received is summarized in the following tables. The complete information is given in the following pages, together with a graphical summary of the results.

JULY 1974		LMRI (distributor)	NPL	BIPM
Sources				
Was the original solution diluted?		no	no	yes
If yes - number of dilutions prepared		-	-	3
- approximate dilution factors		-	-	2.8 2.6
- diluent		-	-	HCl 0.1 M
Source mount. Nature		Al	Al	stainless steel
Outer diameter	mm	38	38	40
Inner diameter	mm	22	25	16
Thickness	mm	3	0.46	0.1
Backing. Nature		Cellulose	VYNS	VYNS
Mass per cm^2	$\mu g cm^{-2}$	≈10	10	≈10
Number of metallized faces		2	2	1 (sandwich)
Total mass of metal per cm^2	$\mu g cm^{-2}$	80	40	40
Source on metallized face?		yes	yes	no
Wetting agent		Insuline	0.03% in water	Ludox SM, 10^{-4}
Range of source mass	mg	15 - 25	15 - 26	27 - 70
Number of sources prepared		24	65	30
Number of sources used in final result		17	43	11
Counting equipment				
4π proportional counter				
wall material		perspex	top and bottom: Cu sides: perspex	brass, gold plated
height of each half	mm	22	22.5	20
Anode nature		W	Phosphor bronze	stainless steel
wire diameter	μm	20	75	50
wire length	mm	80	75	55
distance source/wire	mm	10	14	11.5
max. path length of β-particles in gas	mm		40	55
anode voltage	kV	2.75	2.32	3.4
Gas nature		CH_4	Ar/CH_4 (9:1)	CH_4
purity	%	99.9		technically pure
pressure		atmospheric	atm.	atm.
gas amplif. factor			10 000	240 000
plateau length	V	400	150	200
plateau slope	%/100V	0.07	0.13	0.66
discrim. level (energy)	eV	100	300	≈ 300
Scintillation counter				
Number of crystals		2	2	1
Nature		NaI (Tl)	NaI	NaI (Tl)
Diameter	mm	76	75	76
Height	mm	76	75	50
Full width of half max of the ^{54}Mn γ-line	keV	50 (662 keV, ^{137}Cs)	85	100
Dead times and their uncertainties				
τ_β	μs	7.5 ± 0.1	1.54 ± 0.01	3.18 ± 0.05
τ_γ	μs	7.5 ± 0.1	2.4 $^{+0.4}_{-0.1}$	5.42 ± 0.
Coincidence resolving time τ_r	μs	0.90 ± 0.01	0.536 ± 0.010	1.05 ± 0.05

INTERCOMPARISON OF A ^{134}Cs SOLUTION (CONTINUED)

($4\pi\beta$(PC)-γ METHOD)

Counting data

		LMRI			NPL	BIPM		
						I	II	III
γ channel setting	keV	530 / 670	730 / 860	1270 / 1470	700 / 900	500 / 690	690 / 905	1300 / 156
Background rate β	s^{-1}	2.1	2.1	2.1	1	0.84	0.86	0.87
γ	s^{-1}	1.8	0.9	0.8	0.5	1.08	0.80	0.103
c	s^{-1}	0.002	0.005	0.007	0.01	0.04	0.03	0.003
Number of sources used		1	17	1	40 + 3	11	11	5
Number of points measured						58	58	15
Range of ε_β	%	80 - 55	92 - 62	78 - 50	92 - 65	92 - 72	93 - 76	80 - 46
Procedure used for variation of ε_β		addition of foils						
Slope / intercept	% s mg	+14	- 1	+26	3	18.3	2.4	63.7
Intercept ($\varepsilon_\beta \to 1$)	$s^{-1} mg^{-1}$	1167.8	1167.3	1168	1166.2	1164.9	1162.4	1162.9
1974-07-01, 0H UT								
Random uncertainty (1σ)	$s^{-1} mg^{-1}$	0.3	0.06	1	0.17	2.9	3.8	3.0
Mean measuring time for one point	s	1 200	1 200	1 200	500	7 × 600	7 × 600	10 × 500
Epoch of measurement		Sept.	Sept.	Sept.	July 9 – July 24	June 24 — August 1		
Half-life adopted		($18\,040 \pm 105$) h						

	LMRI	NPL	BIPM
Final result (in $s^{-1} mg^{-1}$) Radioactive concentration	1 167.3	1 166.2	1 163.6
	Reference date: 1974-07-01 0H UT		
Random uncertainty	0.005 3 %	0.015 %	I 0.027 % II 0.015 % (III 0.15 %)
How was it obtained?	$\frac{t\, s_{\bar{x}}}{\bar{x}}$ (P = 68.3%)	standard error of the mean of measurements on 43 sources corrected for decay scheme using parameter obtained from measurements on 3 sources	s.e.o.m. of 11 results extrapolated, using parameter ("slope") determined from 58 points

Systematic uncertainty

	LMRI	NPL	BIPM
due to dead times	0.14 %	< 0.01 %	0.003 %
resolving time	0,068	0,06	0.11
background	–	0,01	0.002
extrapolation	0,025	0,1	0.11
weighing	0,1	0,05	0.04
others	0.053	–	–
total (linear sum)	0.26 %	0.23 %	0.27 %

Formulae used

LMRI

$$N_0 = \frac{N'_\beta N'_\gamma}{N'_c - 2\tau_r N'_\beta N'_\gamma}\left[1 + \frac{2\tau N'_c - 2\tau_r (N'_\beta + N'_\gamma)}{2 - \tau (N'_\beta + N'_\gamma)}\right] \quad \text{(Bryant)} \qquad \tau_\beta = \tau_\gamma = \tau,\ \tau_r < \tau/2$$

NPL

$$N_0 = \frac{N_\beta N_\gamma [1 - \tau_r (N'_\beta + N'_\gamma)][1 - \tau_\beta N'_\beta - \tau_\gamma N'_\gamma + (\tau_\beta + \tau_\gamma - \tau_c) N'_c]}{(1 - \tau_\beta N'_\beta)(1 - \tau_\gamma N'_\gamma)(N'_c - 2\tau_r N_\beta N_\gamma)}$$

N_0 and ε_β were measured on 43 sources; N was obtained using $N_0 = N\left(1 - \frac{1 - \varepsilon_\beta}{\varepsilon_\beta} \times 0.030\right)$

BIPM

$$N_0 = \frac{N_\beta N_\gamma [1 - \tau_r (N'_\beta + N'_\gamma)]}{(N_c - 2\tau_r N'_\beta N'_\gamma)(1 - \tau N'_c)}$$

τ is the shorter of τ_β and τ_γ, $\tau_c < \tau$

N'_β, N'_γ, N'_c are observed count rates (uncorrected)

N_β, N_γ, N_c are count rates corrected for background

ADDITIONAL MEASUREMENTS BY L.M.R.I.

4πβ(LS)-γ

Sources

Number of dilutions	2
Approximate dilution factors	550; 700
Diluent	Toluene
Scintillators	butyl PBD 10 g/dm³
	BIBUQ 12 g/dm³
Complexing agent	DBP 10 %
Volume of vessel	2.8 cm³

Counting equipment

β detector: 2 photomultipliers RCA 8850
γ detector: 2 NaI(Tl) crystals
(d = 150 mm, h = 75 mm)
dead times $\tau_\beta = (5.0 \pm 0.1)$ μs
$\tau_\gamma = (5.0 \pm 0.1)$ μs
Resolution time $\tau_r = (1.005 \pm 0.010)$ μs

Counting data

		I	II	III
γ-channel setting	keV	550 / 660	720 / 880	1270 / 1460
Background rate β	s^{-1}	15	15	15
γ	s^{-1}	19	13	9
c	s^{-1}	0.2	0.1	0.02
Number of sources measured		1	11	1
Range of ε_β	%	95 - 84	95 - 84	93 - 79
Procedure used for varying ε_β		Shift of discrimination level		
Slope/intercept	% s mg	+ 3.6 · 10⁻⁴	− 0.0025	+ 0.0192
Intercept ($\varepsilon_\beta \to 1$)	$s^{-1} mg^{-1}$	1167	1165	1171
1974-07-01, 0H UT				
Random uncertainty (1σ)	$s^{-1} mg^{-1}$	0.69	0.84	0.73
Mean measuring time for one point	s	≈ 10⁴	≈ 10⁴	≈ 10⁴
Epoch of measurement		1974-08-26 to 1974-09-05		

Formula used for calculating the activity: the same as with 4πβ(PC)-γ method

Result: Radioactive concentration = 1 168 $s^{-1} mg^{-1}$ (1974-07-01, 0H UT)
Random unertainty (1σ) $100 \frac{t s_{\bar{x}}}{\bar{x}}$ = 0.07 %
Systematic uncertainties: total 0.33 %

dead times	0.01 %
resolving time	0.01
background	0.05
extrapolation	0.20
weighing	0.06

4π γ (well crystal)

Sources

1 dilution, factor ≈ 12
Diluent: HCl 0.1 M
Carrier: CsCl 10 μg per g of solution
Source backing: Mylar
Diameter: 10 mm
(the source is plastified)
Number of sources measured: 19

Counting equipment

1 well crystal, NaI(Tl)

Diameter:	125 mm
Height:	102 mm
Well diameter:	12 mm
depth:	50 mm
Thickness of lining	1 mm (Be)

Dead time $\tau = (8.0 \pm 0.1)$ μs
Calculated efficiency for ^{134}Cs γ-spectrum: 0.953
Counting time for each source: 600 s
Counting epoch Sept. 12/13, 1974

Result

Radioactive concentration = 1165 $s^{-1} mg^{-1}$
(1974-07-01, 0H UT)
Random uncertainty (1σ) 0.022 %
Total systematic uncertainty: 0.7 %
Systematic uncertainties:

Dead time	0.05 %
Background	0.10
Weighing	0.15
Efficiency calculation	0.4

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(JULY 1974)

SUMMARY OF RESULTS