

International comparison of a solution of ^{134}Cs (October 1978)

Preliminary report

by A. Rytz

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BUREAU INTERNATIONAL DES POIDS ET MESURES

F-92310 SEVRES

List of the laboratories having submitted their results by 1979-02-28

1. AAEC Australian Atomic Energy Commission, Lucas Heights, Australia
2. AECL Atomic Energy of Canada Limited, Chalk River, Canada
3. AIEA Agence Internationale de l'Energie Atomique, Vienna, Austria
4. ASMW Amt für Standardisierung, Messwesen und Warenprüfung, Berlin, German Democratic Republic
5. BCMN Bureau Central de Mesures Nucléaires d'Euratom, Geel, Belgium
6. BIPM Bureau International des Poids et Mesures, Sèvres, France
7. ETL Electrotechnical Laboratory, Tokyo, Japan
8. IBJ Instytut Badán Jadrowych, Świerk, Poland
9. IEA Instituto de Energia Atômica, Pinheiros-São Paulo, Brazil
10. IMM Institut de Métrologie D.I. Mendéléev, Leningrad, USSR
11. IRK Institut für Radiumforschung und Kernphysik, Vienna, Austria
12. LMRI Laboratoire de Métrologie des Rayonnements Ionisants, Saclay, France
13. NAC National Accelerator Centre, Pretoria, South Africa
14. NBS National Bureau of Standards, Washington, D.C., USA
15. NIM National Institute of Metrology, Peking, People's Republic of China
16. NPL National Physical Laboratory, Teddington, United Kingdom
17. NRC National Research Council of Canada, Ottawa, Canada
18. OMH Országos Mérésügyi Hivatal, Budapest, Hungary
19. PTB Physikalisch-Technische Bundesanstalt, Braunschweig, Federal Republic of Germany
20. SCK Studiecentrum voor Kernenergie, Mol, Belgium
21. UVVVR Ústav pro výzkum, výrobu a využití radioisotopů, Prague, ČSSR

Table 1

2

Laboratory	Method used	Sources		4 π Proportional counter			Gamma-ray counter			Dead times				Resolving time		
		Range of mass** (mg)	Total backing mass ($\mu\text{g}/\text{cm}^2$)	Gas	Pressure (kPa)	Discr. level (keV)	Number	Diam. (mm)	Height (mm)	τ_β^*	(μs)		τ_γ^*	τ_r^*	(μs)	
AAEC	4 π β (PC)- γ	20-60 d	25-1 060	CH ₄	atm	0.3	1	75	75	9.10	(3)	20.0	(2)	1.202	(5)	
AECL	4 π β (PC)- γ	14-53	28	CH ₄	atm	≈ 0.1	2	76	76	2.199	(5)	2.212	(5)	0.621 2	(6)	
AIEA	4 π β (PC)- γ	10-21	38	CH ₄	atm	0.18	1	76	76	4.16	(1)	3.95	(1)	0.991	(4)	
ASMW BARC	4 π β (PC)- γ	9-88 d	35	C ₃ H ₈	atm	I, II 0.8 III 0.2	1	102	76	4.001	(18)	4.000	(18)	1.036	(3)	
BCMNI	4 π β (PC)- γ	9-15 14-15	VYNS 50 Carbon 19	CH ₄	atm	1	2	76	76	4.05	(4)	4.00	(4)	1.00	(2)	
BIPM	4 π β (PC)- γ	8-51	130	CH ₄	atm	0.06	1	76	76	4.20	(1)	4.20	(1)	1.07	(1)	
ETL	4 π β (PC)- γ	7-16	30	CH ₄	atm	0.2	2	76	76	4.35	(5)	2.11	(5)	0.688 7	(28)	
IBJ	4 π β (LS)- γ	5-10	-	-	-	-	1	45	50	7.90	}	(5)	8.20	(10)	0.35	(1)
	4 π β (PC)- γ	5-10	80	CH ₄	atm	0.4	2	45	50	7.40						
IEA	4 π β (PC)- γ	30-55 d	30	Ar/CH ₄	atm	0.7	2	76	76	3.02	(2)	3.01	(2)	0.967	(7)	
										3.05	(2)	3.03	(4)	0.97	(1)	
IER																
IMM	4 π β (PC)- γ	10-25	40	Ar/CH ₄	atm	0.1	1	40	40	3.2	(1)	3.2	(1)	2.12	(4)	
	4 π β (PC)- γ	11-12	40	CH ₄	atm	0.2	1	40	40	6.0	(1)	6.0	(1)	0.99	(2)	

* The uncertainty in units of the last digit is given in parentheses

** d indicates that the original solution was diluted

Table 1 (cont'd)

Laboratory	Method used	Sources		4 π Proportional counter			Gamma-ray counter			Dead times		Resolving time
		Range of mass** (mg)	Total backing mass ($\mu\text{g}/\text{cm}^2$)	Gas	Pressure (kPa)	Discr. level (keV)	Nal(Tl) crystals Number	Diam. (mm)	Height (mm)	τ_β^* (μs)	τ_γ^* (μs)	
IPA												
IRK	4 π (NaI) γ	7-26 d	-	-	-	-	1 well	127	127	-	8.0 (2)	-
LMRI	4 π β (PC)- γ	15-120	45	CH ₄	atm	0.1	1 Ge(Li)	True coaxial	10 cm ³	$\geq 6^{***}$	$\geq 6^{***}$	1.13 (1)
	4 π β (LS)- γ	2.3-2.5 g d	-	-	-	-	-	-	-	4.997 (25)	4.991 (25)	1.020 (2)
	4 π (NaI)- γ	d	-	-	-	-	1 well	125	100	-	-	-
NAC	4 π β (LS)- γ	22-27	-	(LS)	-	-	1	76	76	1.061 (3) to 1.141(6)	1.35 (3)	0.514 0.506 0.503 (1)
	4 π β (PPC)- γ AC	14-49 d	25	Ar/CH ₄	1.43	2-100	2	76	76	20.1 (2)	20.1 (2)	1.00 (5)
NIM	4 π β (PC)- γ	25-60 d	10	CH ₄	atm	0.45	2	50	50	5.8 (2)	2.0 (1)	1.24 1.40 (4)
	4 π β (LS)	25-45 d	-	-	-	-	-	-	-	28.2 (4)	-	-
	4 π β (PC)- γ	11-41 d	20	CH ₄	atm	-	2	75	75	5.10 (51)	1.40 (24)	1.064 (16)
NPL	4 π β (PC)- γ	27-32	60	Ar/CH ₄	atm	0.2	1	75	75	1.507 (10)	2.5 ($\begin{smallmatrix} -1 \\ +4 \end{smallmatrix}$)	0.547 (10)

* The uncertainty in units of the last digit is given in parentheses

** d indicates that the original solution was diluted

*** Different values used; $\tau_\beta = \tau_\gamma$

Table 1 (cont'd)

Laboratory	Method used	Sources		4 π Proportional counter			Gamma-ray counter			Dead times		Resolving time	
		Range of mass** (mg)	Total backing mass. ($\mu\text{g}/\text{cm}^2$)	Gas	Pressure (kPa)	Discr. level (keV)	Number	Diam. (mm)	Height (mm)	τ_β^*	τ_γ^*	τ_r^*	(μs)
NRC	4 π β (PPC)- γ AC	16-24	40	Ar/CH ₄	0.81	1-40	2	76	76	2.080 (15)	2.050 (15)	0.972 (10)	
OMH	4 π β (PC)- γ	10-33	30	CH ₄	atm	0.22	1	76	76	3.024 (5)	2.988 (5)	1.005 (10)	
PTB	4 π β (PC)- γ	10-12	45	CH ₄	atm	0.5	1	76	76	2.96 (3)	2.99 (3)	1.69 (3)	
	"	"	"	Ar/CH ₄	atm	0.5				4.99 (3)	4.96 (3)	2.96 (3)	
	4 π β (PPC)- γ	"	"	"	1	≥ 0.5	1	76	76	5.12 (3)	5.11 (3)	1.02 (2)	
	"	"	"	"	1.1	0.5-50	2	76.2	76.2	2.00 (6)	2.00 (6)	0.988 (30)	
	4 π (NaI) γ	8-13	-	-	-	15	2 well	150	100		5		
SCK	4 π β (PC)- γ	6-21	50-1 000	CH ₄	atm	0.3	1	102	102	2.82 (1)	2.85 (2)	1.002 7 (1)	
	4 π (NaI) γ	2.5-9		-	-	-	1 well	127	127	-	4.189 (2)	-	
UVVVR	4 π β (PC)- γ	15-50 d	40	CH ₄	atm	0.3	2	76	51	6.520 (15)	6.520 (15)	1.09 (1)	
												0.980 (15)	

* The uncertainty in units of the last digit is given in parentheses

** d indicates that the original solution was diluted

Table 2

Laboratory Method	γ -channel setting (keV)	Numbers of sources data measured points		Range of N_c/N_γ (%)	Mean time for one data point (s)	Slope to intercept ratio*		Radioactivity concentration 1978-10-15 (Bq·mg ⁻¹)	Standard deviation (1 σ) (Bq·mg ⁻¹)	Total syst. uncertainty of the final result** (Bq·mg ⁻¹)	Coincidence formula used***	
AAEC	PC	530-650	15	17	94-73	4 000	0.172	(10)	830.94	1.01	3.33	C
			11	12	94-82		0.206	(5)	831.15	0.50		
		710-880	15	20	95-78	4 000	-0.014	-	829.79	0.63		
			11	15	95-86		-0.005	-	829.91	0.46		
		1 210-1 630	15	19	91-63	12 000	0.399	(22)	832.98	2.42		
			11	14	91-74		0.432	(7)	833.43	1.13		
							<u>831.59</u>	<u>0.56</u>				
AECL	PC	500-685	15	68	92-68	500	0.155 0	(14)	830.42	0.44	1.08	B
		685-915	17	176	93-73	500	-0.002 0	(11)	830.11	0.17		
		730-1 520	15	64	92-67	500	0.119 2	(8)	831.32	0.46		
		1 280-1 535	15	109	89-55	1 000	0.357 0	(24)	832.80	0.40		
									<u>830.11</u>	<u>0.15</u>		
AIEA	PC	>483	11	38	94-65	1 000	0.163	(5)	830.53	0.38	2.07	O
		483-700	11	37	94-64	1 000	0.185	(6)	830.42	0.49		
		>700	11	37	95-67	1 000	0.133	(6)	828.27	0.45		
		700-900	11	37	95-70	1 000	0.015 7	(20)	827.75	0.27		
									<u>829.24</u>	<u>0.20</u>		
ASMW	PC	I 300-1 300	9	15	91-57	6 000	0.132	(3)	829.2	0.6	1.7	C
		II 500-700	3	4	86-57	6 000	0.145	(9)	829.0	2.0		
		III 300-1 300	10	21	94-57	6 000	0.146	(3)	830.1	0.5		
									<u>829.5</u>	<u>0.2</u>		

Table 2 (cont'd)

Laboratory Method	γ -channel setting (keV)	Numbers of sources data measured points		Range of N_c/N_γ (%)	Mean time for one data point (s)	Slope to intercept ratio*	Radioactivity concentration 1978-10-15 (Bq·mg ⁻¹)	Standard deviation (1 σ) (Bq·mg ⁻¹)	Total syst. uncertainty of the final result** (Bq·mg ⁻¹)	Coincidence formula used***
BARC										
BCMNI PC	560-700	5	40	86-70	1 000	0.165 (6)	829.9	0.6	1.2	C-I
	700-875	9	81	90-70	1 000	-0.019 (5)	827.9	0.4		
	700-1 750	4	44	88-60	1 000	0.129 (2)	827.9	0.6		
							<u>828.4</u>	<u>0.3</u>		
BIPM PC	500-700	15	59	90-55	5 000	0.149 1 (15)	831.05	0.51	1.1	C-I
	700-900	15	60	92-62	5 000	0.000 8 (10)	830.32	0.23		
	1 260-1 490	14	25	88-50	54 000	0.297 2 (37)	833.3	2.4		
							<u>830.46</u>	<u>0.21</u>		
ETL PC	500-700	32	40	92-65	1 800	0.176 6 (112)	832.51	1.09	3.0	C
	700-900	32	40	94-70	1 800	0.014 7 (34)	831.12	0.60		
	1 200-1 500	31	38	90-60	1 800	0.344 7 (139)	830.88	1.61		
							<u>831.39</u>	<u>0.50</u>		
IBJ LS	324-1 400	7	7	88-76	300	0.126 0 (33)	828.4	0.7	0.58	C
	135-1 400	7	7	89-77	300	0.083 4 (22)	826.8	0.8		
							<u>827.56</u>	<u>0.64</u>		
PC	315-1 400	7	6	88-75	300	0.132 2 (28)	827.8	2.6	3.2	
	460-1 400	7	6	88-75	300	0.131 3 (46)	827.5	1.3		
							<u>827.65</u>	<u>2.6</u>		
IEA PC	498-695	37 (3)	10	94-75	3 600	0.183 (5)	831.7	0.3	1.1	B
	710-890	46 (2)	20	96-72	3 600	0.009 7 (11)	830.6	0.3		
							<u>831.1</u>	<u>0.3</u>		

Table 2 (cont'd)

Laboratory Method	γ -channel setting (keV)	Numbers of		Range of N_c/N_γ (%)	Mean time for one data point (s)	Slope to intercept ratio*	Radioactivity concentration 1978-10-15 (Bq·mg ⁻¹)	Standard deviation (1 σ) (Bq·mg ⁻¹)	Total syst. uncertainty of the final result** (Bq·mg ⁻¹)	Coincidence formula used***	
		sources measured	data points								
IER											
IMM	PC	550-820	10	15	86-50	2 000	0.063	842.6	0.8	3.7	C
		≥ 80	5	3	85-65	7 000	0	849.8	1.4	5.3	C
IPA											
IRK	NaI	>22.1	10	-	-	-	-	828.3	0.8	1.0	-
LMRI	PC	****	21	28	88-45	5 000	-	829.6	0.80	0.83	O
				for each γ sett.							
		550-650	8	13	83-60	240	0.097 0 (15)	834.2	1.7		
		750-850	8	13	84-60	240	-0.017 0 (34)	834.8	1.4		
	1 350-1 450	8	13	78-51	240	0.242 4 (100)	831.2 833.2	2.1 1.0	1.3	B	
	NaI		12				830.0	0.2	4.6	-	
NAC	LS	>500	10	15	92-78	800	0.126 1 (19)	831.16	0.50		O
		500-700	4	15	91-76	800	0.182 8 (21)	831.16	0.90		
		700-900	4	15	93-80	800	0.055 7 (28)	829.44	0.80		
		1 000-1 500	3	15	88-67	1 600	0.392 7 (26)	833.9 831.16	1.0 0.50	1.92	
NBS	PPC	700-900	5	≈ 35	92-58	200	0.012 3 (8)	830.33	0.46	1.85	B
	AC						831.83	0.29	1.11		

Table 2 (cont'd)

Laboratory		γ -channel setting	Numbers of sources data measured. points		Range of N_c/N_γ	Mean time for one data point	Slope to intercept ratio*	Radioactivity concentration 1978-10-15	Standard deviation (1σ)	Total syst. uncertainty of the final result**	Coincidence formula used***	
Method		(keV)			(%)	(s)		(Bq·mg ⁻¹)	(Bq·mg ⁻¹)	(Bq·mg ⁻¹)		
NIM	PC	520-680	22	220	95-79	1 200	0.197 0 (5)	830.5	0.3		C	
		720-880	24	240	96-82	1 200	0.01	832.1	0.2			
								two-dimen- sional	830.7 <u>831.0</u>	0.3 <u>0.2</u>	5.2	-
	LS	-	9	-	-	-	-	832	1	11		
	PC	473-700	20	7	94-76	300	0.176 (19)	830.00	0.51	4.2	C	
NPL	PC	A	715-1 500	15	37+12	93-58	1 200	0.126 5 (22)	829.58	0.25		C-1
			715-873	15	33+12	94-63	1 200	-0.025 69(57)	828.89	0.16		
		B	715-1 500	11	36+7	93-63	1 200	0.141 9 (23)	828.63	0.22		
			715-873	11	37+7	94-67	1 200	-0.014 31(94)	829.27 <u>828.93</u>	0.16 <u>0.20</u>	{ + 3.3 - 1.4	
NRC	PPC	520-700	10	14	92-79	500	0.189 (2)	832.04	0.17		B	
		710-910	10	14	93-81	500	-0.005 (1)	830.34	0.29			
		1 850-2 060	10	14	83-56	2 000	0.614 (2)	832.70	0.64			
		790-804	10	14	93-85	500	-0.045 (5)	831.48 <u>831.7</u>	0.44 <u>0.4</u>	2.5		
	AC PC	520-700 } 710-910 }	10	14	93-82			831.42	0.56		O	
			520-700 } 710-910 }	10	14	93-63			831.29	0.32		
		1 850-2 060	10	14	93-82			832.11	0.60			
2Ge(Li)	790-804	10	14	93-82			831.48 <u>831.69</u>	0.44 <u>0.21</u>	1.5			

Table 2 (cont'd)

Laboratory Method	γ -channel setting (keV)	Numbers of		Range of N_c/N_γ (%)	Mean time for one data point (s)	Slope to intercept ratio*	Radioactivity concentration 1978-10-15 (Bq·mg ⁻¹)	Standard deviation (1 σ) (Bq·mg ⁻¹)	Total syst. uncertainty of the final result** (Bq·mg ⁻¹)	Coincidence formula used***			
		sources measured	data points										
OMH	PC	500-700	15	30	94-70	1 250	0.141 (3)	833.02	0.25	1.8	C		
		700-930	15	15		1 250	0.010 (1)	829.57	0.42				
		500-1 540	14	14		1 250	0.119 (6)	832.29	0.26				
		750-1 540	14	14		1 250	0.124 (3)	832.01	0.27				
							<u>832.15</u>	<u>0.37</u>					
PTB	PC ₁	>500	16	44	93-70	2 400	0.154 (5)	829.3	0.3	0.39	C		
		730-860	10	10	93-70	2 400	-0.006 (1)	829.1	0.3				
	PC ₂	>500	16	44	93-70	2 400	0.162 4 (24)	829.0	0.2				
		730-860	10	11	93-70	2 400	-0.000 (3)	828.7	0.5				
								<u>829.06</u>	<u>0.14</u>				
	PPC	>500	4	206	92-65	3 600	+0.12-0.17	829.18	0.22			0.33	C
		730-860	3	155	92-40	3 600	+0.005 4 (1)	829.02	0.02				
								<u>829.10</u>	<u>0.22</u>				
	PPC (2 param.)	{ 720-880 } { >1 400 }	12	117	95-75 80 45	2 000	-0.739 (13) -0.260 (12)	829.03	0.11	0.25	C-I		
	4 π (NaI) γ	>15	3		96.9±0.4			828.3	1.2	1.3	-		
SCK	PC	510-690	9	14	90-63	1 000	0.134 (40)	827.72	1.72	1.5	C		
		700-900	9	14	92-69	1 000	-0.008 8 (22)	827.98	0.41				
		510-690	9	12	90-71	1 000	0.157 1 (55)	829.37	0.95				
							<u>828.19</u>	<u>0.38</u>					
	NaI	> 22	2			1 000		829.10	0.97	4.4	-		

Table 2 (cont'd)

Labo- ratory Method	γ -channel setting (keV)	Numbers of sources measured	data points	Range of N_c/N_γ (%)	Mean time for one data point (s)	Slope to intercept ratio*	Radioactivity concentration 1978-10-15 (Bq·mg ⁻¹)	Standard deviation (1 σ) (Bq·mg ⁻¹)	Total syst. uncertainty of the final result** (Bq·mg ⁻¹)	Coincidence formula used***	
UVVVR PC	Dilution 1	>500	11	17	93-55	320	0.191 (4)	830.04	0.66	C-I	
		>182	11	17	93-55	320	0.146 (25)	829.94	0.41		
	2	>500	50	46	93-70	500	0.176 (4)	830.72	0.41		
		>182	50	46	93-70	500	0.144 (4)	829.73	0.33		
	3	>500	37	33	94-70	800	0.181 (5)	829.60	0.41		
		>500	35	30	93-66	800	0.176 (7)	829.38	0.66		
		>182	35	30	93-66	800	0.144 (6)	828.76	0.58		
							<u>829.70</u>	<u>0.27</u>	1.25		

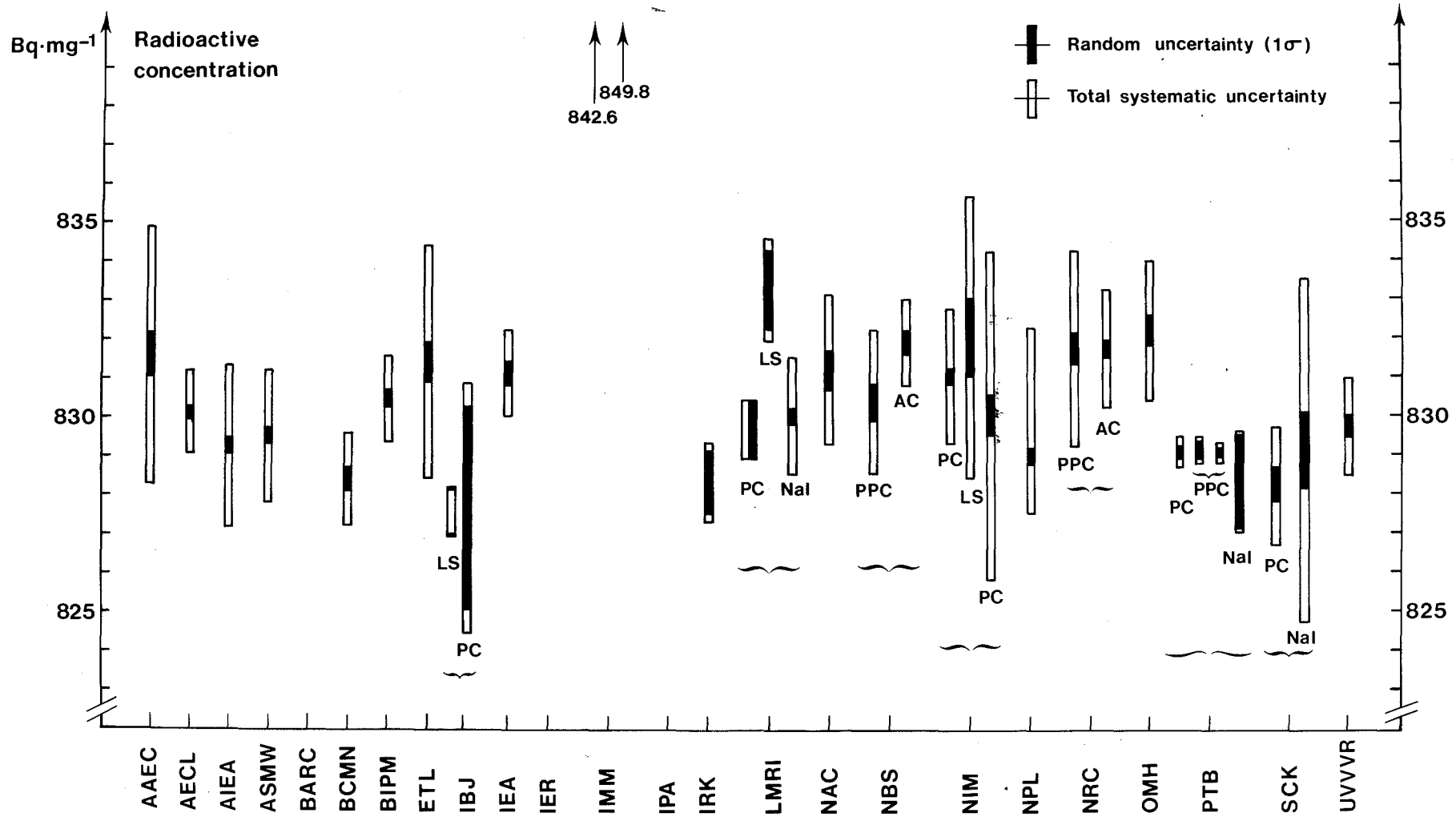
* The uncertainty in units of the last digit is given in parentheses

** Corresponding to the confidence level of 1 σ (where indicated)

*** Coincidence formulae: B = Bryant, C = Campion, C-I = Cox-Isham, O = other

**** Multiparametric linear adjustment with five different γ -channel settings was used:

I	II	III	IV	V
610-698	787-808	565-573	448-478	557-565
		799-808	1 032-1 047	1 164-1 175
		1 360-1 373		



Graphical representation of the results

Supplementary results from the ^{134}Cs comparison
(Rapport BIPM-79/5)

Table 1

Laboratory	Method used	Sources		4 π Proportional counter			Gamma-ray counter			Dead times (μs)		Resolving time τ_r^* (μs)
		Range of mass (mg)	Total backing mass ($\mu\text{g}/\text{cm}^2$)	Gas	Pressure (kPa)	Discr. level (keV)	Number	Diam. (mm)	Height (mm)	τ_β^*	τ_γ^*	
IER	4 π β (PC)- γ	10-86	50	CH ₄	atm	1	1	76	76	3.201 (1)	3.196 (1)	1.075 (2)
IPA	4 π β (PC)- γ	9-18	50-150	CH ₄	atm	1	1	76	76	10.0 (5)	10.0 (5)	1.095 (5)
BARC	4 π β (PC)- γ	18-21	70	LPG	atm	0.2	1	76	76	6.35 (20)	6.35 (20)	2.295 (100)

Table 2

Laboratory	Method	γ -channel setting (keV)	Numbers of sources measured	Numbers of data points	Range of N_c/N_γ (%)	Mean time for one data point (s)	Slope to intercept ratio*	Radioactivity concentration 1978-10-15 ($\text{Bq}\cdot\text{mg}^{-1}$)	Standard deviation (1σ) ($\text{Bq}\cdot\text{mg}^{-1}$)	Total syst. uncertainty of the final result** ($\text{Bq}\cdot\text{mg}^{-1}$)	Coincidence formula used***
IER	PC	700-900	18	960	93-80	16-20	0	829.30	0.18	} + 1.5 - 2.3	C-1
		700-1 600	17	800	93-77	22-100	0.114 2 (21)	828.41	0.30		
		520-700	17	900	93-71	25-90	0.185 7 (16)	829.14	0.28		
								<u>829.09</u>	<u>0.14</u>		
IPA	PC	700-900	8	6	91-65	500	0.013 9 (24)	827.93	1.91	3.2	O
		700-1 000	8	6	90-66	500	0.037 3 (20)	829.47	1.53		
		500-1 500	8	6	89-65	400	0.135 3 (49)	830.84	2.33		
		100-900	8	6	89-66	400	0.097 5 (39)	832.03	1.58		
								<u>828.87</u>	<u>1.19</u>		
BARC	PC	480-700	7	44	90-45	1 200	0.103 3 (29)	831.67	0.94	2.1	C
		700-960	7	44	92-50	1 200	0.011 5 (11)	832.23	0.49		
		> 480	7	44	91-46	1 200	0.085 5 (26)	832.49	1.29		
								<u>832.13</u>	<u>0.41</u>		