S. Department of Commerce
Malcolm Baldrige
Secretary

National Bureau of Standards
Ernest Ambler, Director

National Bureau of Standards

Certificate

Standard Reference Material 4310

Mixed Gaseous Radioactivity Standard

Radionuclides	Xenon-133, Xenon-127, Krypton-85
Source identification	4310-
Source description	Gas in a sealed spherical borosilicate-glass ampoule (1)
Gas composition	Xenon-133, Xenon-127, Krypton-85, inactive xenon, inactive krypton, inactive CO_2 (2)
Reference time	1200 EST April 15, 1982

Radionuclide	Activity at reference time Bq (s^{-1})	Total uncertainty (Random plus systematic)	
Xenon-133		1.55 percent	See xenon-133 data sheet
Xenon-127		1.71 percent	See xenon-127 data sheets
Krypton-85		2.51 percent	See krypton-85 data sheet

Photon-emitting impurity (Activity ratio at reference time)	$^{131m}Xe/^{133}Xe$: 0.103 ± 5% (3)
Half lives	^{133}Xe: 5.245 ± 0.006 days (4) ^{127}Xe: 36.41 ± 0.02 days (5) ^{85}Kr: 10.72 ± 0.01 years (6)
Measuring instrument	NBS pressurized "4π"γ ionization chamber A calibrated by internal gas-proportional counting

This Standard Reference Material was prepared in the Center for Radiation Research, Nuclear Radiation Division, Radioactivity Group, Dale D. Hoppes, Group Leader.

Washington, D.C. 20234
March, 1982

George A. Uriano, Chief
Office of Standard Reference Materials

Notes on back

FOOTNOTES

(1) Approximate ampoule specifications:

volume	30 cm^3
outside diameter	4.24 cm
wall thickness	0.19 cm

(2) Pressure - 101 kPa (760 Torr) ± 20%.

(3) Limits of detection as a percentage of the gamma-ray-emission rate of the 81-keV gamma rays emitted in the decay of xenon-133 are

0.1 percent between 37 keV and 76 keV
0.01 percent between 86 keV and 1900 keV,

provided that impurity photons are separated in energy by 5 keV or more from the prominent photons emitted in the decays of xenon-133, xenon-127, and krypton-85.

(4) NCRP Report No. 58, 1978, p. 387.

(5) NCRP Report No. 58, 1978, p. 376.

(6) NCRP Report No. 58, 1978, p. 348.

Krypton-85
Data Sheet

1) Random uncertainty 0.23 percent

Half the 99-percent confidence interval of the mean (2.861 times the standard error computed from 20 ionization-chamber measurements).

2) Systematic uncertainty 2.28 percent

Linear sum of estimated uncertainty limits due to:

a) calibration of the pressurized "4π"γ ionization chamber A, which is the linear sum of the estimated uncertainties due to:

1)	half the 99-percent confidence interval of the mean for 6 gas-counting measurements	0.42 percent
2)	gram-mole measurements	0.22 percent
3)	extrapolation of the gas-counting data	0.2 percent
4)	dilution of sources for gas counting	0.4 percent
5)	half the 99-percent confidence interval of the mean for 30 ionization-chamber measurements	0.24 percent
6)	uncertainty in half life	0.1 percent
7)	gas-transfer losses	0.1 percent
8)	attenuation in glass	0.2 percent

b) attenuation in glass walls of ampoule 0.2 percent

c) gas-transfer losses 0.2 percent

3) When this source is used to measure the efficiency as a function of energy of a photon-spectrometer system, the attenuation in the glass walls of the 30.0-cm^3 ampoule must be considered. The attenuation of 5.7 percent for the 0.514-MeV gamma ray was determined using a Ge(Li)-spectrometer system with a resolution of 1.28-keV full width at half maximum at 514 keV. For a germanium-spectrometer system of poorer resolution, or a NaI(Tl)-spectrometer system, the attenuation would be less than 5.7 percent.

over

(4) DECAY SCHEME: NCRP REPORT NO. 58, p. 348, 1978

85KR B- DECAY (10.72 Y 1) I(MIN) = 0.10%

Radiation Type	Energy (keV)	Intensity (%)	Δ (g-rad/ μCi-h)
β- 1 max	173.0 20		
avg	47.5 6	0.430 10	0.0004
β- 2 max	687.0 20		
avg	251.4 8	99.570 10	0.533
total β-			
avg	250.5 8	100.000 15	0.534
γ 1	513.990 10	0.430 10	0.0047

Xenon-133
Data Sheet

1) Random uncertainty 0.10 percent

Half the 99-percent confidence interval of the mean (2.861 times the standard error computed from 20 ionization chamber measurements).

2) Systematic uncertainty 1.45 percent

Linear sum of estimated uncertainty limits due to:

a) calibration of pressurized "4π" γ ionization chamber A, which is the linear sum of the estimated uncertainty limits due to:

1) half the 99-percent confidence interval of the weighted mean of three series of gas-counting measurements 0.66 percent

2) extrapolation of the gas-counting data 0.22 percent

3) half the 99-percent confidence interval of the mean of three series of ionization-chamber measurements 0.01 percent

4) radium-226 reference sources ratios 0.36 percent

b) Half life 0.20 percent

3) When this source is used to measure the efficiency as a function of energy of a photon-spectrometer system, the attenuation in the glass walls of the 30.0-cm^3 ampoule must be considered. The attenuation, 11.3 percent, for the 0.081-MeV gamma ray was determined using a Ge(Li)-spectrometer system with a resolution of 1.00-keV full width at half maximum at 81 keV. For a germanium-spectrometer system of poorer resolution, or a NaI(Tl)-spectrometer system, the attenuation would be less than 11.3 percent.

over

(4) DECAY SCHEME: NCRP REPORT NO. 58, p. 387, 1978

133XE B- DECAY (5.245 D 6) I(MIN) = 0.10%

Radiation Type	Energy (keV)	Intensity (%)	Δ (g-rad/ μCi-h)
Auger-L	3.55	49.0 20	0.0037
Auger-K	25.5	5.5 7	0.0030
ce-K- 1	43.636 11	0.30 6	0.0003
ce-K- 2	45.0124 4	52.0 3	0.0498
ce-L- 2	75.2827 4	8.49 20	0.0136
ce-MNO- 2	79.7799 4	2.3 3	0.0039
β- 1 max	266 3		
avg	75.0 10	0.66 10	0.0011
β- 2 max	346 3		
avg	100.5 10	99.34 10	0.213
total β-			
avg	100.3 10	100.01 15	0.214
X-ray L	4.29	6.1 17	0.0006
X-ray $K\alpha_2$	30.6251 3	13.3 3	0.0087
X-ray $K\alpha_1$	30.9728 3	24.6 5	0.0163
X-ray Kβ	35	8.84 20	0.0066
γ 1	79.621 11	0.22 6	0.0004
γ 2	81	37.1 4	0.0640

4 weak γ's omitted ($\Sigma I\gamma$ = 0.07%)

Xenon-127
Data Sheet

1) Random uncertainty 0.22 percent

Half the 99-percent confidence interval of the mean (2.861 times the standard error computed from 20 ionization-chamber measurements).

2) Systematic uncertainty 1.49 percent

Linear sum of estimated uncertainty limits due to:

a) calibration of the pressurized "4 " ionization chamber A, which is the linear sum of the estimated uncertainties due to:

1)	half the 99-percent confidence interval of the mean for 51 gas-counting measurements	0.40 percent
2)	gram-mole measurements	0.1 percent
3)	extrapolation of the gas-counting data	0.2 percent
4)	dilution of sources for gas counting	0.4 percent
5)	half the 99-percent confidence interval of the mean for 40 ionization-chamber measurements	0.19 percent
6)	radium-226 reference ratios	0.2 percent

3) When this source and the data given in section 4 are used to measure the efficiency as a function of energy of a photon spectrometer system, the attenuation in the glass walls of the 30.0 cm^3 ampoule should be considered. The attenuation corrections given in the table were determined with a Ge(Li)-spectrometer system with resolutions indicated in the table below and a source to detector distance of 25 cm. For a germanium-spectrometer system of appreciably poorer resolution, or a NaI(Tl)-spectrometer system, the tabulated attenuations would be maximum values.

Energy (keV)	Resolution (FWHM) (keV)	glass attenuation (%)
202.84	1.06	8.0
172.10	1.03	8.2
374.96	1.20	6.2
145.22	1.03	8.7
57.60	1.01	14.0

over

(4) DECAY SCHEME: NCRP REPORT NO. 58, p. 376-377, 1978

127XE EC DECAY (36.41 D 2) I(MIN) = 0.10%

Radiation Type	Energy (keV)	Intensity (%)	Δ (g-rad/ μCi-h)
Auger-L	3.3	96 6	0.0068
Auger-K	23.6	12 3	0.0059
ce-K- 1	24.431 20	4.28 18	0.0022
ce-L- 1	52.412 20	0.61 3	0.0007
ce-M- 1	56.528 20	0.123 6	0.0001
ce-K- 2	112.05 3	1.54 6	0.0037
ce-K- 3	138.93 3	3.65 13	0.0108
ce-L- 2	140.03 3	0.391 14	0.0012
ce-L- 3	166.91 3	0.475 15	0.0017
ce-K- 4	169.67 3	6.63 8	0.0240
ce-L- 4	197.65 3	0.98 3	0.0041
ce-M- 4	201.77 3	0.198 3	0.0009
ce-K- 5	341.79 5	0.289 11	0.0021
X-ray L	4	10 4	0.0008
X-ray $K\alpha_2$	28.3172 4	25.1 10	0.0151
X-ray $K\alpha_1$	28.6120 3	46.7 17	0.0285
X-ray Kβ	32.3	16.4 7	0.0113
γ 1	57.600 20	1.33 6	0.0016
γ 2	145.22 3	4.29 14	0.0133
γ 3	172.10 3	25.5 8	0.0936
γ 4	202.84 3	68.3 5	0.295
γ 5	374.96 5	17.2 6	0.137

1 weak γ's omitted (ΣIγ = 0.01%)

(5) CORRELATED SUMMING CORRECTIONS FOR THE 127XE ACTIVITY. NOTE; THE PEAK EFFICIENCY IS DENOTED BY "{ GAMMA RAY ENERGY }", THE TOTAL DETECTION EFFICIENCY IS DENOTED BY "(GAMMA RAY ENERGY)", AND "*" INDICATES MULTIPLICATION. "NO" REPRESENTS THE ACTIVITY AT THE MEASUREMENT TIME. IN MOST SYSTEMS, ONLY FIRST-ORDER EFFICIENCY TERMS NEED TO BE EVALUATED, AND THESE ARE GIVEN BELOW. IF THESE CORRECTIONS ARE LARGE(GREATER THAN 8%), THEN THE HIGHER ORDER TERMS MAY BE NEEDED. THESE ARE AVAILABLE UPON REQUEST.

FOR THE 202.84 KEV GAMMA RAY, THE PEAK AREA RATE IS EQUAL TO .6830*{ 202.84 }*NO*C1*C2

FACTOR FOR SUMMING IN EFFECTS

C1=[1.000 + .013*{ 57.6 }{ 145.24 }/{ 202.84 }]

FACTOR FOR SUMMING OUT EFFECTS

C2=[1.000 - .778*(KX) - .311*(172.12)]

FOR THE 172.12 KEV GAMMA RAY, THE PEAK AREA RATE IS EQUAL TO .2550*{ 172.12 }*NO*C2

FACTOR FOR SUMMING OUT EFFECTS

C2=[1.000 - .853*(KX) - .016*(57.6) - .826*(202.84) - .051*(145.24)]

FOR THE 374.96 KEV GAMMA RAY, THE PEAK AREA RATE IS EQUAL TO .1720*{ 374.96 }*NO*C1*C2

FACTOR FOR SUMMING IN EFFECTS

C1=[1.000 + 1.169*{ 202.84 }{ 172.12 }/{ 374.96 }]

FACTOR FOR SUMMING OUT EFFECTS

C2=[1.000 - .719*(KX)]

FOR THE 145.24 KEV GAMMA RAY, THE PEAK AREA RATE IS EQUAL TO .0429*{ 145.24 }*NO*C2

FACTOR FOR SUMMING OUT EFFECTS

C2=[1.000 - 1.366*(KX) - .209*(57.6) - .311*(172.12)]

FOR THE 57.6 KEV GAMMA RAY, THE PEAK AREA RATE IS EQUAL TO 0.0133*{ 57.6 }*NO*C2

FACTOR FOR SUMMING OUT EFFECTS

C2=[1.000 - .990*(KX) - .676*(145.24) - .311*(172.12)]