Laboratory of Radioactivity Standards

POLATOM

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GENERAL INFORMATION

Laboratory of Radioactivity Standards

Laboratory of Radioactivity Standards in National Centre for Nuclear Research Radioisotope Centre POLATOM in Otwock, Poland, continues work of Radioactive Materials Metrology Laboratory, where for last few tens years measuring methods of the radioactivity of radionuclides were developed. It is the only laboratory in Poland performing radioactivity measurements of α-, β and γ-emitters by absolute methods and performing calibration of standard solutions and radioactive sources.

Orders

Key steps in the procedure for ordering products and services of LRS are as follows:

- Choice of product or service by the customer
- Reviewing order or question to determine all the relevant requirements of the customer
- Pricing offer
- Placing an order by the customer
- Confirmation of order receipt by the LRS

Orders should be addressed to:

National Centre for Nuclear Research
Radioisotope Centre POLATOM
Andrzeja Sołtana 7, 05-400 Otwock,
POLAND
Phone: +48 22 718 07 53
Fax: +48 22 779 73 81
E-mail: polatom@polatom.pl

or directly to Laboratory:

National Centre for Nuclear Research
Radioisotope Centre POLATOM
Laboratory of Radioactivity Standards
Andrzeja Sołtana 7, 05-400 Otwock,
POLAND
Phone: +48 22 718 07 18
Fax: +48 22 718 03 50
E-mail: metrologia@polatom.pl

Delivery time

For most orders delivery time is 6 weeks since order receipt. This time may be changed depending on the availability of certain isotopes.

Quality assurance of radioactivity standards

Properties of radioactive standards can deteriorate over time due to a number of physico-chemical phenomena. When using the source as intended and not exposing it to mechanical damages laboratory ensures usefulness of the source for period two times longer than the half-life for short-lived radionuclides ($T_{1/2}$ <1 year) and within 2 years for all other radionuclides.

NOTE: The above statement does not deny, in many cases, much longer period of source usefulness.

Calibration certificates

Standards are delivered with calibration certificate that contains information about calibration method, radionuclidic impurities (if necessary) and measurement uncertainty. On certificate you may find:

- Radionuclide symbol
- Principal radionuclide half-life
- Activity (or particle emission rate) with uncertainty on reference date
- Nuclear data

NOTE: Original calibration certificate is necessary in case of standard's recalibration.

Accreditation

The LRS has implemented and maintained quality management system compliant with the international standard ISO / IEC 17025:2005. Confirmation of technical competence as a calibration laboratory is accreditation certificate awarded by the Polish Centre for Accreditation in December 2008.

Laboratory of Radioactivity Standards as accredited calibration laboratory (accreditation no. AP 120) offers following services:

- Calibration of dose calibrators with ionization chambers
- Calibration of radioactive solutions with primary and secondary methods
- Calibration of radioactive point sources of γ-emitters
- Calibration of radioactive control sources for use with dose calibrators
- Calibration of radioactive area sources
- Calibration of radioactive multigamma solutions and sources

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Outside accreditation scope LRS offers following services:

- Analysis of radionuclidic composition and determination of radionuclides activity in different materials
- Dose rate measurements for ophthalmic applicators

RADIOACTIVE STANDARD SOLUTIONS

Handling precautions

It is strongly advisable to wear overalls and protective gloves.

When diluting a solution is necessary, the diluents used must have the same chemical composition and the same concentration of non-radioactive material as the standard solution.

When preparing a source, it must be ensured that volatile components are not lost during handling. Working surfaces should be subject to radiation protection checks after use.

Volume

Volume of solution in vials is determined with assumption that density is equal to 1 g × cm^{-3}.

The standardized volumes are not larger than 10 mL. Request of larger volumes are subject to individual reviews.

Available packaging

Radioactive standard solutions are usually supplied in sealed glass ampoules.

High-activity solutions are supplied in capped vials for ease of handling and better protection.

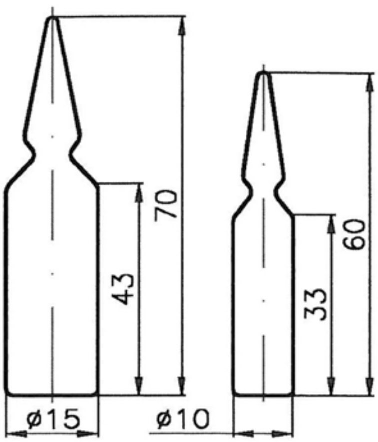
Carrier solution

Carrier solution for particular radionuclide is shown in the table. It is indicative value only and is subject to change without notice. The chemical composition shown on the calibration certificate must be complied with in case of dilution by the end-user.

Measured values

Standard solutions are characterized in terms of activity per 1 g of solution. The stated activity applies to the main radionuclide and excludes decay products and identified impurities.

Vials with radioactive solution.



5 mL and 1 mL glass ampoules for radioactive standard solutions.

Radioactive standard solutions

Radionuclide *Half-life*	Carrier solution	Code	Total activity [kBq]	Expanded uncertainty (for $k = 2$)
^{3}H *12.3 years*	distilled water	H3SR	1 - 400	2.0 %
^{14}C *5700 years*	60 μg sodium acetate in 1mL distilled water	C14SR	1 - 400	1.0 %
^{22}Na *2.6 years*	25 μg Na as NaCl in 1mL 1 M HCl	NA22SR	1 - 400	1.5 %
^{32}P *14.3 days*	25 μg P as Na_2HPO_4 in 1mL H_2O + 1% HCHO	P32SR	1 - 400	0.8 %
^{35}S *87.3 days*	100 μg S as Li_2SO_4 in 1 mL 0.1 M HCl	S35SR	1 - 400	1.0 %
^{36}Cl *3.01 x 10^5 years*	1 M HCl	CL36SR	1 - 400	1.0 %
^{45}Ca *163 days*	100 μg Ca as $CaCl_2$ in 1 mL 0.1 M HCl	CA45SR	1 - 400	0.8 %
^{46}Sc *83.79 days*	50 μg Sc as $ScCl_3$ in 1 mL 0.1 M HCl	SC46SR	1 - 400	0.8 %
^{51}Cr *27.7 days*	25 μg Cr as Na_2CrO_4 in 1 mL 0.1 M HCl	CR51SR	1 - 400	1.5 %
^{54}Mn *312.1 days*	25 μg Mn as $MnCl_2$ in 1 mL 0.1 M HCl	MN54SR	1 - 400	1.5 %
^{55}Fe *2.75 years*	25 μg Fe as $FeCl_2$ in 1 mL 1 M HCl	FE55SR	1 - 400	2.0 %
^{57}Co *271.8 days*	25 μg Co as $CoCl_2$ in 1 mL 0.1 M HCl	CO57SR	1 - 400	0.8 %
^{59}Fe *44.5 days*	25 μg Fe as $FeCl_2$ in 1 mL 1 M HCl	FE59SR	1 - 400	1.0 %
^{60}Co *5.27 years*	25 μg Co as $CoCl_2$ in 1 mL 0.1 M HCl	CO60SR	1 - 400	0.8 %
^{63}Ni *98.7 years*	25 μg Ni as $NiCl_2$ in 1 mL 1 M HCl	NI63SR	1 - 400	1.5 %
^{65}Zn *244.0 days*	25 μg Zn as $ZnCl_2$ in 1 mL 0.1 M HCl	ZN65SR	1 - 400	1.2 %
^{75}Se *119.8 days*	25 μg Se as Na_2SeO_3 in 1 mL H_2O + NaOH (pH = 9)	SE75SR	1 - 400	1.2 %
^{85}Sr *64.85 days*	25 μg Sr as $SrCl_2$ in 1 mL 0.1 M HCl	SR85SR	1 - 400	1.2 %
^{88}Y *106.6 days*	25 μg Y as YCl_3 in 1 mL 1 M HCl	Y88SR	1 - 400	0.8 %
^{90}Sr+^{90}Y *28.8 years*	25 μg Sr as $Sr(NO_3)_2$ + 25 μg Y as $Y(NO_3)_3$ in 1 mL 0.1 M HNO_3	SR90SR	1 - 400	1.2 %

Radionuclide *Half-life*	Carrier solution	Code	Total activity [kBq]	Expanded uncertainty (for k = 2)
^{99}Mo+^{99m}Tc *2.75 days*	25 µg Mo as $(NH_4)_2MoO_4$ in 1 mL H_2O +1% HCHO	MO99SR	1 - 400	1.2 %
^{109}Cd *461.4 days*	25 µg Cd as $CdCl_2$ in 1 mL 0.1 M HCl	CD109SR	1 - 400	2.0 %
^{110m}Ag+^{110}Ag *249.8 days*	25 µg Ag as $Ag(CN)_2$ in 1 mL H_2O + 1% HCHO	AG110SR	1 - 400	1.2 %
^{113}Sn+^{113m}In *115.1 days*	25 µg Sn + 25 µg In in 1 mL 4 M HCl	SN113SR	1 - 400	2.0 %
^{124}Sb *60.2 days*	1 mg tartaric acid in 1 mL 1 M HCl	SB124SR	1 - 400	1.5 %
^{125}I *59.4 days*	50 µgI as NaI + 50 µg $Na_2S_2O_3$ in 1 mL H_2O + 1% HCHO	I125SR	1 - 400	1.0 %
^{131}I *8.02 days*	50 µg I as NaI + 50 µg $Na_2S_2O_3$ in 1 mL H_2O + 1% HCHO	I131SR	1 - 400	0.8 %
^{133}Ba *10.54 years*	25 µg Ba as $BaCl_2$ in 1 mL 1 M HCl	BA133SR	1 - 400	1.2 %
^{134}Cs *2.07 years*	25 µg Cs as CsCl in 1 mL 0.2 M HCl	CS134SR	1 - 400	0.8 %
^{137}Cs+^{137m}Ba *30.05 years*	25 µg Cs as CsCl in 1 mL 0.2 M HCl	CS137SR	1 - 400	1.5 %
^{139}Ce *137.6 days*	25 µg Ce as $Ce(NO)_3$ in 1 mL 0.1 M HNO_3	CE139SR	1 - 400	
^{152}Eu *13.52 years*	25 µg Eu as $EuCl_3$ in 1 mL 1 M HCl	EU152SR	1 - 400	1.5 %
^{169}Yb *32.0 days*	25 µg Yb as $YbCl_3$ in 1 mL 0.5 M HCl	YB169SR	1 - 400	1.0 %
^{170}Tm *127.8 days*	100 µg Tm as $TmCl_3$ in 1 mL 0.1 M HCl	TM170SR	1 - 400	1.5 %
^{192}Ir *73.83 days*	25 µg Ir as $(NH_4)_2IrCl_6$ in 1 mL 0.1 M HCl	IR192SR	1 - 400	0.8 %
^{198}Au *2.69 days*	25 µg Au as $HAuCl_4$ in 1 mL 1 M HCl	AU198SR	1 - 400	1.2 %
^{204}Tl *3.79 years*	100 µg Tl as $TlNO_3$ in 1 mL 0.1 M HNO_3	TL204SR	1 - 400	1.2 %
^{241}Am *432.6 years*	50 µg La as $LaCl_3$ in 1 mL 1 M HCl	AM241SR	1 - 400	1.2 %

NOTE: Activity values outside the catalogue range are subject to individual reviews.

POINT SOURCES OF SINGLE RADIONUCLIDE

Point sources of α-emitters

Standards of α-emitters are used for energy and efficiency calibration of α radiation detectors and other measuring systems. They are characterized by the activity of principal radionuclide (kBq). On special request they can be characterized by the flux of particles emitted in 2π solid angle (s^{-1}). Active part of the source is evaporated radioactive solution.

Available types of casing

The casing of the source is the Plexiglas cylinder with a diameter of 20 mm and a height of 6.5 mm with cover. Active part with diameter of 3 mm is placed centrally in the recess, and then covered with Mylar foil with a thickness of 3.5 μm (500 $\mu g \times cm^{-2}$). The foil is protected by the ring of Plexiglas. Additionally, the source has a removable lid for safety and convenience for transportation and storage.

Point sources of α-emitters

Radionuclide *Half-life*	Code	Activity [kBq]	Expanded uncertainty (for k = 2)
^{241}**Am** *432.6 years*	AM241ASP	1 - 400	1.5 %

NOTE: Activity values outside the catalogue range are subject to individual reviews.

Point source of ß-emitter

Point sources of ß-emitters

Standards of ß-emitters are used for energy and efficiency calibration of ß radiation detectors and other measuring systems. They are characterized by the activity of principal radionuclide (kBq). On special request they can be characterized by the flux of particles emitted in 2π solid angle (s^{-1}). Active part of the source is evaporated radioactive solution.

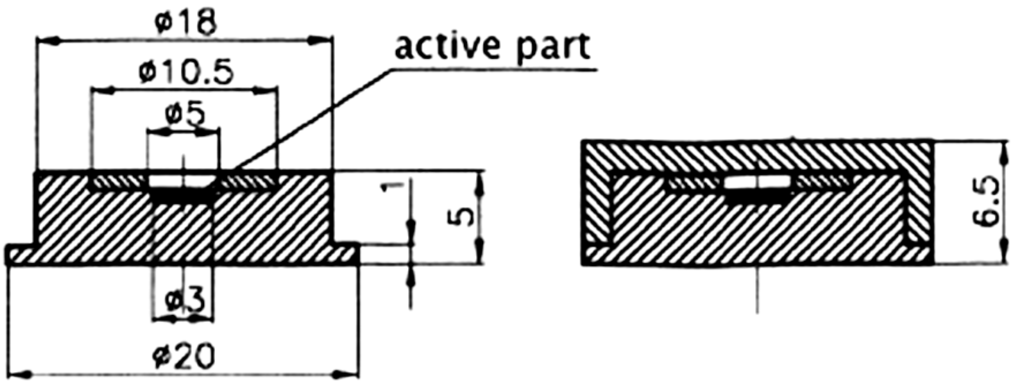
Available types of casing

The casing of the source is the Plexiglas cylinder with a diameter of 20 mm and a height of 6.5 mm with cover. Active part with diameter of 3 mm is placed centrally in the recess, and then covered with Mylar foil with a thickness of 3.5 μm (500 $\mu g \times cm^{-2}$). The foil is protected by the ring of Plexiglas. Additionally, the source has a removable lid for safety and convenience for transportation and storage.

Point sources of ß-emitters

Radionuclide *Half-life*	Code	Activity [kBq]	Expanded uncertainty (for $k = 2$)
^{14}C *5700 years*	C14BSP	1 - 400	1.5 %
^{22}Na *2.6 years*	NA22BSP	1 - 400	1.5 %
^{35}S *87.3 days*	S35BSP	1 - 400	1.5 %
^{36}Cl *3.01 x 10^5 years*	CL36BSP	1 - 400	1.5 %
^{60}Co *5.27 years*	CO60BSP	1 - 400	1.5 %
^{89}Sr *50.6 days*	SR89BSP	1 - 400	1.5 %
$^{90}Sr+^{90}Y$ *28.8 years*	SR90BSP	1 - 400	1.5 %
^{134}Cs *2.07 years*	CS134BSP	1 - 400	1.5 %
$^{137}Cs+^{137m}Ba$ *30.05 years*	CS137BSP	1 - 400	1.5 %
^{204}Tl *3.79 years*	TL204BSP	1 - 400	1.5 %

NOTE: Activity values outside the catalogue range are subject to individual reviews.



Point source α/ß.

Point sources of γ-emitters

Standards of γ-emitters are used for energy and efficiency calibration of γ radiation detectors and other measuring systems. They are characterized by the activity of principal radionuclide (kBq). Active part of the source is evaporated radioactive solution.

Available types of casing

There are available two types casing.

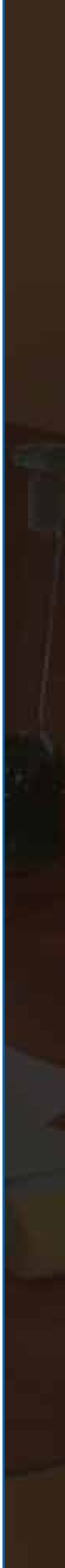
Sources in Plexiglas – Active part with 4 mm diameter is placed central between two Plexiglas discs with 12 mm diameter and 1 mm height each one. Two discs are glued together, which prevents the escape of radioactive material.

Sources in polyethylene foil - Active part with 3 mm diameter is placed central between two polyethylene foil discs with 0.3 mm thickness. Two discs are glued together and placed in aluminium ring, which prevents the escape of radioactive material. Complete source has 30 mm diameter and 2.5 mm height.

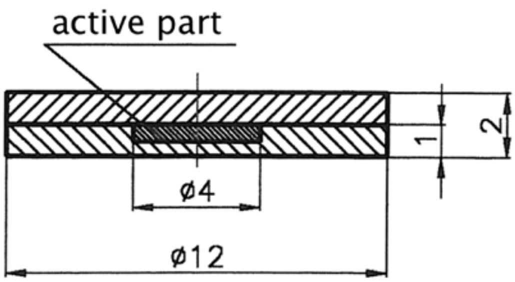
Point sources of γ-emitters – sources in Plexiglas

Radionuclide *Half-life*	Code	Activity [kBq]	Expanded uncertainty (for $k = 2$)
^{22}Na *2.60 years*	NA22GSP	1 - 400	2.0 %
^{51}Cr *27.7 days*	CR51GSP	1 - 400	2.0 %
^{54}Mn *312.1 days*	MN54GSP	1 - 400	2.0 %
^{57}Co *271.8 days*	CO57GSP	1 - 400	1.5 %
^{60}Co *5.27 years*	CO60GSP	1 - 400	1.0 %
^{65}Zn *244.0 days*	ZN65GSP	1 - 400	2.0 %
^{85}Sr *64.85 days*	SR85GSP	1 - 400	1.5 %
^{88}Y *106.6 days*	Y88GSP	1 - 400	1.0 %
^{109}Cd+^{109m}Ag *461.4 days*	CD109GSP	1 - 400	2.0 %
^{113}Sn+^{113m}In *115.1 days*	SN113GSP	1 - 400	2.0 %
^{131}I *8.02 days*	I131GSP	1 - 400	2.0 %
^{133}Ba *10.54 years*	BA133GSP	1 - 400	1.5 %
^{137}Cs+^{137m}Ba *30.05 years*	CS137GSP	1 - 400	2.0 %
^{152}Eu *13.52 years*	EU152GSP	1 - 400	2.0 %
^{241}Am *432.6 years*	AM241GSP	1 - 400	1.5 %

NOTE: Activity values outside the catalogue range are subject to individual reviews.



Point sources of γ-emitters in Plexiglas.



Point source of γ-emitter in Plexiglas.

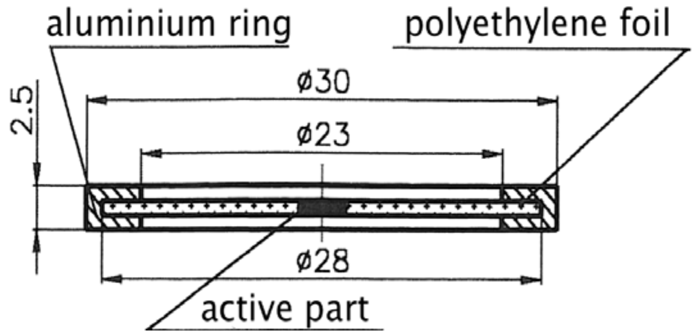
Point sources of γ-emitters – sources in polyethylene foil

Radionuclide *Half-life*	Code	Activity [kBq]	Expanded uncertainty (for $k = 2$)
^{22}Na *2.60 years*	NA22GSF	1 - 400	2.0 %
^{51}Cr *27.7 days*	CR51GSF	1 - 400	2.0 %
^{54}Mn *312.1 days*	MN54GSF	1 - 400	2.0 %
^{55}Fe *2.75 years*	FE55GSF	1 - 400	2.5 %
^{57}Co *271.8 days*	CO57GSF	1 - 400	1.5 %
^{60}Co *5.27 years*	CO60GSF	1 - 400	1.0 %
^{65}Zn *244.0 days*	ZN65GSF	1 - 400	2.0 %
^{85}Sr *64.9 days*	SR85GSF	1 - 400	1.5 %
^{88}Y *106.6 days*	Y88GSF	1 - 400	1.0 %

^{109}Cd+^{109m}Ag *461.4 days*	CD109GSF	1 - 400	2.0 %
^{113}Sn+^{113m}In *115.1 days*	SN113GSF	1 - 400	2.0 %
^{131}I *8.02 days*	I131GSF	1 - 400	2.0 %
^{133}Ba *10.54 years*	BA133GSF	1 - 400	1.5 %
^{137}Cs+^{137m}Ba *30.05 years*	CS137GSF	1 - 400	2.0 %
^{152}Eu *13.52 years*	EU152GSF	1 - 400	2.0 %
^{241}Am *432.6 years*	AM241GSF	1 - 400	1.5 %

NOTE: Activity values outside the catalogue range are subject to individual reviews.

Point sources of γ-emitters in polyethylene foil..



Point source of γ-emitter in polyethylene foil.

MULTIGAMMA SOURCES

Laboratory of Radioactivity Standards produces multigamma solutions, multigamma sources in Marinelli beakers and multigamma point sources designed for calibration of γ-spectrometers in different geometries.

Sources of ^{133}Ba and ^{152}Eu

These radionuclides have many emission lines covering wide energy range:

- 30 – 384 keV for ^{133}Ba
- 40 – 1408 keV for ^{152}Eu

These sources also have advantage in the form of long half-life:

- 10,5 years for ^{133}Ba
- 13,52 years for ^{152}Eu

Radionuclide mixture

^{241}Am, ^{109}Cd, ^{57}Co, ^{51}Cr, ^{113}Sn, ^{85}Sr, ^{137}Cs, ^{54}Mn, ^{65}Zn, ^{60}Co

Such mixture of radionuclides is prepared with proportions allowing obtaining similar counts from each emission line. Using the above mixture it is possible to obtain simpler spectrum than in the case of ^{133}Ba and ^{152}Eu standards, with fewer γ – γ coincidences, and to create a calibration curve for the γ-detector in the energy range from 60 keV to 1333 keV. Even after the decay of the short-lived radionuclides in the source, few isotopes with a long half-life remain. These radionuclides provide further verification of the curve for specific energy efficiency (59.5 keV for ^{241}Am, 88.0 keV for ^{109}Cd, 122.0 and 136.5 keV for ^{57}Co, 661.7 keV for ^{137}Cs, 834.8 keV for ^{54}Mn and 1173 and 1332.5 keV for ^{60}Co - 8 of 12 initially available emission lines).

Sources in Marinelli beakers

Standard multigamma source in Marinelli beaker is characterized by the activity of individual radionuclides components. There are used to calibrate the X- and γ-ray spectrometers.

In volume sources two types of matrix are used, in which a mixture of radioactive solutions is distributed:

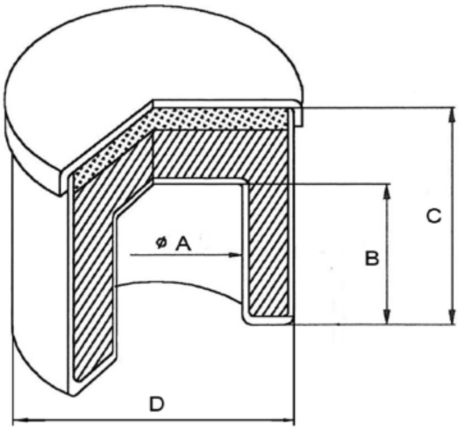
- water - density of 0.998 g × cm^{-3}
- epoxy resin - density of 1.15 g × cm^{-3}

LRS recommends performing a calibration of measurement systems using standard multigamma sources with matrix density similar to real samples. At the same time it is advisable to study the stability of the measuring systems by carrying out regular control measurements using a source with a long half-life (eg. ^{152}Eu).

Available types of containers

Container type	Dimensions [cm]				Container volume [cm³]	Active part volume [cm³]
	A	B	C	D		
125G-E	6,5	7,6	15,2	13,0	1100	1000
132G-E	8,4	7,1	13,0	17,0	1100	1000
533N-E	8,4	7,6	11,7	13,0	540	500

Multigamma sources in epoxy resin.



Marinelli beaker (for dimensions see table above)

Multigamma sources in Marinelli beaker

Radionuclide	Activity [kBq]	Matrix	Code	Container	Extended uncertainty (for $k = 2$)
^{133}Ba	1 – 40	water / resin	MGBA133SV	see table above	3 %
^{152}Eu	1 - 40	water / resin	MGEU152SV	see table above	3 %
^{241}Am **^{109}Cd** **^{57}Co** **^{51}Cr** **^{113}Sn** **^{85}Sr** **^{137}Cs** **^{54}Mn** **^{65}Zn** **^{60}Co**	5.0 20.0 0.8 20.0 3.5 3.0 4.0 5.0 10.0 5.5	water / resin	MGMIXSV	see table above	3 – 5 %

NOTE: Activity values outside the catalogue range are subject to individual reviews.

Multigamma solution

Standard multigamma solutions are characterized in terms of activity [kBq] for individual radionuclides included in the mixture. Multigamma solutions are usually supplied in sealed glass ampoules. High-activity solutions are supplied in capped vials for ease of handling and better protection.

Radionuclide	Activity [kBq]	Code	Extended uncertainty (for $k = 2$)
^{241}**Am**	5.0	MGMIXSR	3 – 5 %
^{109}**Cd**	20.0		
^{57}**Co**	0.8		
^{51}**Cr**	20.0		
^{113}**Sn**	3.5		
^{85}**Sr**	3.0		
^{137}**Cs**	4.0		
^{54}**Mn**	5.0		
^{65}**Zn**	10.0		
^{60}**Co**	5.5		

NOTE: Activity values outside the catalogue range are subject to individual reviews.

Point multigamma sources

Standard point multigamma sources are characterized in terms of activity [kBq] for individual radionuclides included in the mixture. Active part, in the form of evaporated multigamma solution, with 3 mm diameter is placed central between two polyethylene foil discs with 0.3 mm thickness. Two discs are glued together and placed in aluminium ring, which prevents the escape of radioactive material. Complete source has 30 mm diameter and 2.5 mm height.

Radionuclide	Activity [kBq]	Code	Expanded uncertainty (for $k = 2$)
^{241}**Am**	5.0	MGMIXSP	3 – 5 %
^{109}**Cd**	20.0		
^{57}**Co**	0.8		
^{51}**Cr**	20.0		
^{113}**Sn**	3.5		
^{85}**Sr**	3.0		
^{137}**Cs**	4.0		
^{54}**Mn**	5.0		
^{65}**Zn**	10.0		
^{60}**Co**	5.5		

NOTE: Activity values outside the catalogue range are subject to individual reviews.

CHECK SOURCES

Check sources for dose calibrators

Check sources, used for stability studies of dose calibrators, are characterized in terms of activity [MBq] of particular radionuclide.

Active part is standards solution of particular radionuclide distributed in epoxy resin. LRS offers 3 long-lived radionuclides (^{57}Co, ^{133}Ba, ^{137}Cs) covering a wide energy range from 80 keV to 1330 keV.

Available casing

There are two types of casing available:

- polyethylene vial with 16 mm diameter and 54 mm height
- polyethylene vial with 27 mm diameter and 61 mm height

Check sources for dose calibrators

Radionuclide *Half-life*	Code	Activity [MBq]	Expanded uncertainty (for k = 2)
^{57}Co *271.8 days*	CO57CTR	4 - 10	1.5 %
^{133}Ba *10.54 years*	BA133CTR	4 - 10	1.5 %
^{137}Cs+^{137m}Ba *30.05 years*	CS137CTR	4 - 10	2.0 %

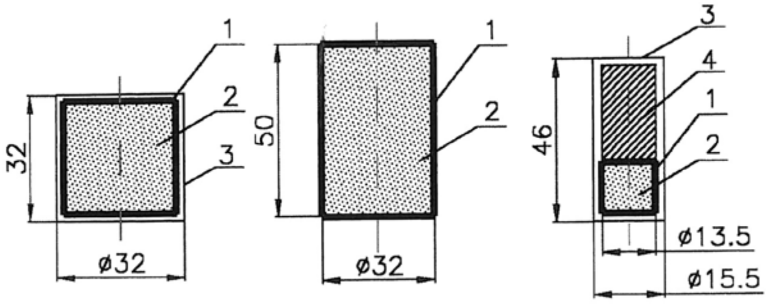
NOTE: Activity values outside the catalogue range are subject to individual reviews.

SIMULATED SOURCES

MOCK-^{131}I

These sources are mixture of ^{133}Ba and ^{137}Cs, which combined in adequate proportions, are simulating γ-spectrum of ^{131}I. Mock-^{131}I sources have much longer half-life comparing to ^{131}I.

MOCK-^{131}I sources.

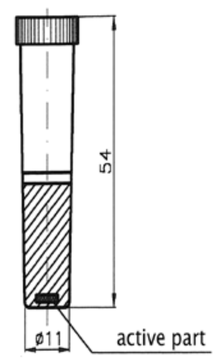


Possible geometries of MOCK-^{131}I sources (1 – cadmium casing, 2 – active part, 3 – PVC casing, 4 – non-active part).

MOCK-^{125}I

These sources are prepared from ^{129}I solution and are simulating spectra of ^{125}I. Mock-^{125}I sources have much longer half-life comparing to ^{125}I.

MOCK-^{125}I sources.



MOCK-^{125}I source.

These sources are prepared from ^{85}Sr and are simulating γ spectrm of ^{18}F or other β^{+}-emitters. Mock-^{18}F sources have much longer half-life comparing to ^{18}F.

Simulated radionuclide / Real radionuclide	Period of source's usefulness	Code	Simulated activity / Real activity	Expanded uncertainty (for k = 2)
^{18}F / ^{85}Sr	6 months	F18MOCK	5 MBq / 10 MBq	2.0 %
^{125}I / ^{129}I	2 years	I125MOCK	1000 Bq / 1075 Bq	2.0 %
^{131}I / ^{133}Ba + ^{137}Cs	12 months	I131MOCK4 I131MOCK40 I131MOCK400	from 4.00 kBq / 3.88 kBq to 400 kBq / 388 kBq	2.0 %

NOTE: Activity values outside the catalogue range are subject to individual reviews.

SERVICES

LRS has technical equipment and measuring methods, adequate to measurement of radioactivity and radionuclidic purity of different substances, the measurement of particle flux leaving the surface of the source and the absorbed dose.

Laboratory of Radioactivity Standards as accredited calibration laboratory (accreditation no. AP 120) offers following services:

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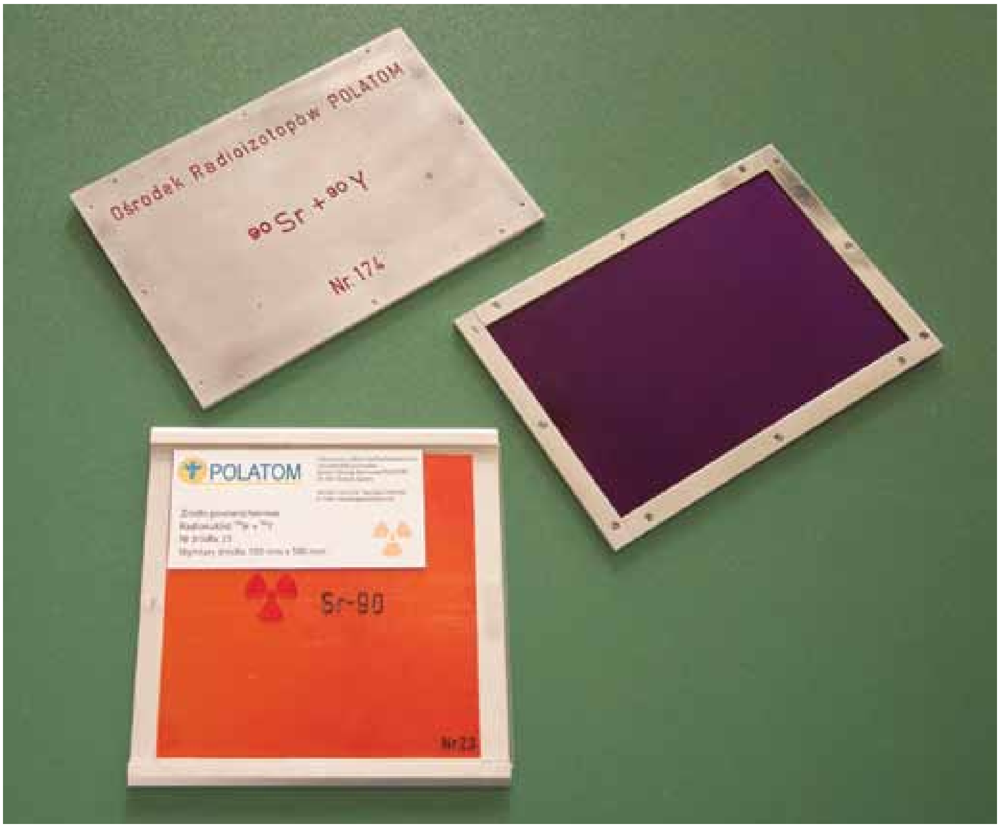
AP 120

- Calibration of dose calibrators with ionization chambers
- Calibration of radioactive solutions with primary and secondary methods
- Calibration of radioactive point sources of γ-emitters
- Calibration of radioactive control sources for use with dose calibrators
- Calibration of radioactive surface sources
- Calibration of radioactive multigamma solutions and sources

Dose calibrator with 4π ionization chamber.



Area sources for contamination detectors calibration.

Outside accreditation scope LRS offers following services:

- Analysis of radionuclidic composition and determination radionuclides activity in different materials
- Dose rate measurements for ophthalmic applicator

Traceability

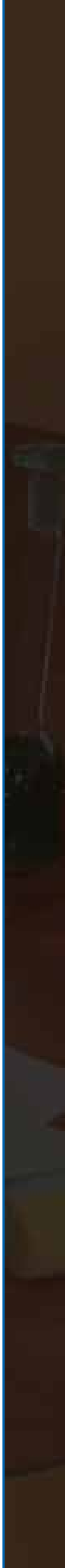
President of the Central Office of Measures in Poland (GUM) in 1999 established and with Decision No. 1 / 2004 of 21 April 2004 confirmed the establishment of the National Standard of Radionuclides Activity in Poland. The standard is stored and used in the Laboratory of Radioactivity Standards. National Standard consists of unique measuring systems of the highest metrological quality in Poland, which are used for the absolute methods of radioactivity measurements. LRS transmit the unit of radioactivity to users of radioactive sources in Poland, providing them with standard solutions and sources, and performing the calibration of dose calibrators. LRS also participates in international key comparisons of radioactivity measurements, enabling the linking to the global system of national standards. These comparisons are organized by the International Bureau of Weights and Measures BIPM and the European Association of National Metrology Institutes EURAMET. The laboratory also participates in comparisons within the framework of the International Reference System SIR.

Measurement methods

LRS has technical equipment and measurement methods, adequate to measurement of radioactivity and radionuclidic purity of different substances, the measurement of particle flux leaving the area of the source and the absorbed dose.

System No.	Name of measuring system
1	Triple-to-double coincidence ratio system
2	4π(LS)-γ coincidence and anticoincidence system
3	X-γ coincidence system
4	Liquid scintillation counter α/ß TriCarb 2910 TR
5	Liquid scintillation counter α/ß Wallac 1411
6	Gas proportional counter 2π
7	Gas proportional counter 4π
8	Set of scintillation counters with NaI(Tl) detectors
9	Set of 4π ionization chambers
10	Spectrometric systems with HPGe detectors
11	Dose rate meter MAD-2000

Systems 1, 2 and 3 with a group of absolute measurement methods, are part of the National Standard of Radionuclides Activity in Poland. Radioactivity of radionuclides determined with secondary methods is related to the National Standard in an unbroken chain of comparisons. Unique systems and measurement methods, and additional laboratory equipment such as analytical balances, enable production of standard solutions and radioactive sources of different types.



Uncertainty of measurements

Each measurement has an error, which is defined as the result of measurement minus a true value. Since true value is not known, so measurement uncertainty is determined. For all standards described in this catalogue, the uncertainty of measurements were calculated according to the document EA-4/02 "Expression of measurement uncertainty in calibration," published by the European Cooperation for Accreditation in December 1999.

a) The method of calculating the measurement uncertainty can be summarized as follows.

b) The total uncertainty is composed of many different parts (eg. the uncertainty resulting from co unting statistics, the uncertainty of the instrument, the uncertainty of the standard).

c) Each component of uncertainty is classified as a Type A or Type B uncertainty:

- Type A: the uncertainty estimated by statistical methods
- Type B: the uncertainty estimated by other methods (eg. theoretical calculation

d) Each component is then characterized by standard deviation (u_i) taking into account the prob ability of statistical distribution.

e) Estimated standard deviations are then added together to form squares to obtain the square of the total standard deviation: $U_C^2 = (\sum u_i^2)$

f) This value is then multiplied by the "coverage factor" k to obtain an expanded uncertainty $U = k \cdot u_C$. All standards in this catalogue have "coverage factor" equal to 2, which corresponds approximately to coverage probability of 95%.

ADDITIONAL INFORMATION

Nuclear data

According to BNM-LNHB/CEA – Table de Radionuclides (Monographie BIPM-5)

Radionuclide	Half life	Decay type	α decay		ß decay		Photons emitted	
			energy [keV]	intensity [%]	max energy [keV]	intensity [%]	energy [keV]	intensity [%]
^{3}H	12.312 ± 0.025 years	$ß^-$	-	-	18.59	100	-	-
^{14}C	5700 ± 30 years	$ß^-$	-	-	156.5	100	-	-
^{22}Na	2.603±0.001 years	$ß^+$ ec	-	-	546 1821	90.3 0.06	511 1275	180.7 99.94
^{32}P	14.284 ± 0.036 days	$ß^-$	-	-	1711	100	-	-
^{35}S	87.32 ± 0.16 days	$ß^-$	-	-	167.1	100	-	-
^{36}Cl	(301 ± 3) x 10^3 years	$ß^-$ ec	-	-	709 1142	98.1 1.9	-	-
^{45}Ca	163 ± 1 days	$ß^-$	-	-	256	100	-	-
^{46}Sc	83.79 ± 0.02 days	$ß^-$	-	-	357 1478	100 0.004	889 1121	100 100
^{51}Cr	27.703 ± 0.003 days	ec	-	-	-	-	X: 4.95÷5.46 γ : 320.1	22.8 9.9
^{54}Mn	312.13 ± 0.03 days	ec	-	-	-	-	X: 5.4÷5.9 γ : 834.8	25.7 99.97

^{55}**Fe**	2.747 ± 0.008 years	ec	-	-	-	-	X: 5.9÷6.5	28.4
^{57}**Co**	271.80 ± 0.05 days	ec	-	-	-	-	X: 5.9÷6.5 γ : 14.4 122.1 136.5	57.1 9.2 85.5 10.7
^{59}**Fe**	44.495 ± 0.008 days	β^-	-	-	85 132 275 467 1566	0.1 1.3 45.3 53.1 0.2	143 192 335 382 1099 1292 1482	1.0 3.1 0.3 0.02 56.5 43.2 0.1
^{60}**Co**	5.2710 ± 0.0008 years	β	-	-	317 1491	99.88 0.12	1173 1332	99.85 99.98
^{63}**Ni**	98.7 ± 2.4 years	β^-	-	-	66	100	-	-
^{65}**Zn**	244.01 ± 0.09 days	ec β^+	-	-	329.9	1.42	X: 8.0÷9.0 γ: 511 1115.5	39.49 2.84 50.22
^{75}**Se**	119.79 ± 0.04 days	ec	-	-	-	100	66 97 121 136 199 265 280 304 401	1.1 3.5 17.3 59.0 1.5 59.1 25.2 1.3 11.6
^{85}**Sr**	64.850 ± 0.007 days	ec	-	-	-	-	X: 13.3÷15.2 γ: 514.0	59.2 98.5

^{88}Y	106.63 ± 0.02 days	ec β$^-$	-	-	764.5	0.204	X: 14.1 ÷16.1 γ: 898.0 1836.1	59.8 93.9 99.3
^{89}Sr	50.57 ± 0.03 days	β$^-$	-	-	586 1495	0.01 99.99	909	0.01
^{90}Y	2.6684 ± 0.0013 days	β$^-$	-	-	519 2280	0.02 99.98	-	-
^{90}Sr **+^{90}Y** *)	28.80 ± 0.07 years 2.668 ± 0.001 days	β$^-$ β$^-$	-	-	^{90}Sr: 546 ^{90}Y: 2280 519	100 99.98 0.02	-	-
^{99m}Tc	6.0067 ± 0.0010 hours	it	-	-	-	-	X: 18.3÷21.0 γ: 140.5	7.7 88.5
^{99}Mo **+ ^{99m}Tc** *)	2.7479 ± 0.0005 days 6.0067 ± 0.0010 hours	β$^-$ it	-	-	436.6 848.1 1214.5	16.5 1.2 82.1	X: 18.3÷21.0 γ : 40.6 181.1 366.4 739.5 777.9 140.5	7.7 1.0 6.0 1.2 12.1 4.3 89.6
^{109}Cd	461.4 ± 1.2 days	ec	-	-	-	-	X: 22.0÷25.5 γ: 88.0	101.5 3.6
^{113}Sn **+^{113m}In**	115.09 ± 0.03 days 1.658 ± 0.004 godz	ec it	-	-	-	-	X: 24.0÷27.9 γ: 255.1 391.7	97.5 2.11 64.97

^{124}Sb	60.2 ± 0.03 days	ß$^{-}$	-	-	212 612 867 948 1580 1657 2303	8.8 52.0 3.6 2.0 5.4 2.5 22.6	603 646 709 714 723 791 968 1045 1326 1355 1368 1437 1691 2091	97.9 7.2 1.4 2.4 11.3 0.7 1.8 1.8 1.4 0.9 2.4 1.0 48.8 5.6
^{125}I	59.407± 0.009 days	ec	-	-	-	100	γ: 35 X: 28	6.7 140
^{131}I	8.0233 ± 0.0019 days	ß$^{-}$	-	-	247.9 303.9 333.8 606.3 806.9	2.1 0.6 7.4 89.4 0.4	X: 29.5÷34.6 γ: 80.2 284.3 364.5 637.0 722.9	5.4 2.6 6.1 81.2 7.3 1.8
^{133}Ba	10.540 ± 0.006 years	ec	-	-	-	-	X: 30.6÷36.0 γ: 53.2 79.6 81.0 160.6 223.2 276.4 302.9 356.0 383.8	119.6 2.1 2.6 32.9 0.6 0.5 7.1 18.3 62.1 8.9

^{134}**Cs**	2.066 ± 0.001 years	ß$^-$ ec	-	-	88.5 415.1 657.8	27.2 2.5 70.2	475.3 563.2 569.3 604.7 795.8 801.9 1038.6 1167.9 1365.2	1.5 8.4 15.4 97.6 85.5 8.7 1.0 1.8 3.0
^{137}**Cs** **+** ^{137m}**Ba** *)	30.05 ± 0.08 years 2.552 ± 0.001 min	ß$^-$ it	-	-	514.0 1175.6	94.4 5.6	X: 31.8÷37.4 γ: 661.7	6.9 85.0
^{139}**Ce**	137.6 ± 0.02 days	ec	-	-	-	100	X: 34 γ: 166	80 79.9
^{152}**Eu**	13.522 ± 0.016 years	ß$^-$ ß$^+$ ec	-	-	175.4 384.8 695.6 1474.5 730.5	1.8 2.4 13.8 8.2 0.02	X: 39.5÷50.2 γ: 121.8 244.7 344.3 411.1 444.0 778.9 867.4 964.1 1085.8 1112.1 1212.9 1299.1 1408.0	74.2 28.4 7.6 26.6 2.2 3.1 13.0 4.2 14.5 10.1 13.4 1.4 1.6 20.9
^{170}**Tm**	127.8 ± 0.6 days	ß$^-$	-	-	884 968	24.0 75.9	84	3.3

^{177}Lu	6.647 ± 0.004 days	$ß^-$	-	-	177.0 385.4 498.3	11.6 9.1 79.3	X: 54.6÷65.3 γ: 112.9 208.4 249.7 321.3	5.5 6.2 10.4 0.2 0.2
^{192}Ir	73.827 ± 0.013 days	$ß^-$ ec	-	-	258.7 538.8 675.1	5.6 41.4 47.9	205.8 296.0 308.5 316.5 468.1 588.6 604.4 612.5	3.3 28.7 29.7 82.8 47.8 4.5 8.2 5.3
^{204}Tl	3.788 ± 0.015 years	$ß^-$ ec	-	-	763.7	97.1	X: 68.9÷87.9	1.7
^{239}Pu	24100 ± 11 years	ß	5106 5144 5157	11.9 17.1 70.8	-	-	X: 11.6÷20.7 γ: 12.98 38.66 51.62	4.7 0.034 0.010 0.027
^{241}Am	432.6 ± 0.6 years	ß	5388.3 5442.9 5485.6	1.7 13.2 84.5	–	–	X: 11.9÷22.2 γ: 26.34 59.54	36.7 2.3 35.9

*) – in equilibrium

UNITS CONVERSION

kBq / MBq / GBq	μCi / mCi / Ci
1	0.027
2	0.054
4	0.108
5	0.135
8	0.216
10	0.270
40	1.08
50	1.35
100	2.70
400	10.8
500	13.5
800	21.6

μCi / mCi / Ci	kBq / MBq / GBq
0.1	3.70
0.25	9.25
0.5	18.50
0.75	27.75
1	37
2	74
3	111
5	185
7	259
10	370
20	740
25	925

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