Russian National Standard Reference Data System and Nuclide Guide, International Chart of Nuclides - 2012

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Abstract

Russian National Standard Reference Data System (RNSRDS) involves the evaluation, systematization, measurement, standardization of physical constants and data on properties of substances and materials in different fields of science, technique and technology. An appropriate NSRDS functional structure is presented. This structure includes the fields of power engineering, industry in which the data bases are developed.

New versions of Nuclide Guide (NG) and Chart of the Nuclides (CN) were developed as a result of Russian-Chinese collaboration. Compared to the previous versions of the NG and CN - 2006 new evaluated information has been included to the NG and CN -2010 from the following publications: 1) Nuclear Data Sheets, volumes 107 – 110, 2) Monographie BIPM-5, Table of Radionuclides, 2006, 3) Monographie BIPM-5, Table of Radionuclides, 2008. In addition, for the Nuclide Guide-2010 the authors re-calculated the average energies of radiations of the 500 radionuclides with half-lives about and more than 1 hour. The International Chart of Nuclides was developed taking into account information added and revised in Nuclide Guide-2011. The presented decay data can be used not only in nuclear physics and associated fields but also in medicine, agriculture and space studies.

KEYWORDS: radionuclides, chart of nuclides, decay data, atomic mass, gamma-ray energy, Russian National Standard Reference Data System

1. INTRODUCTION

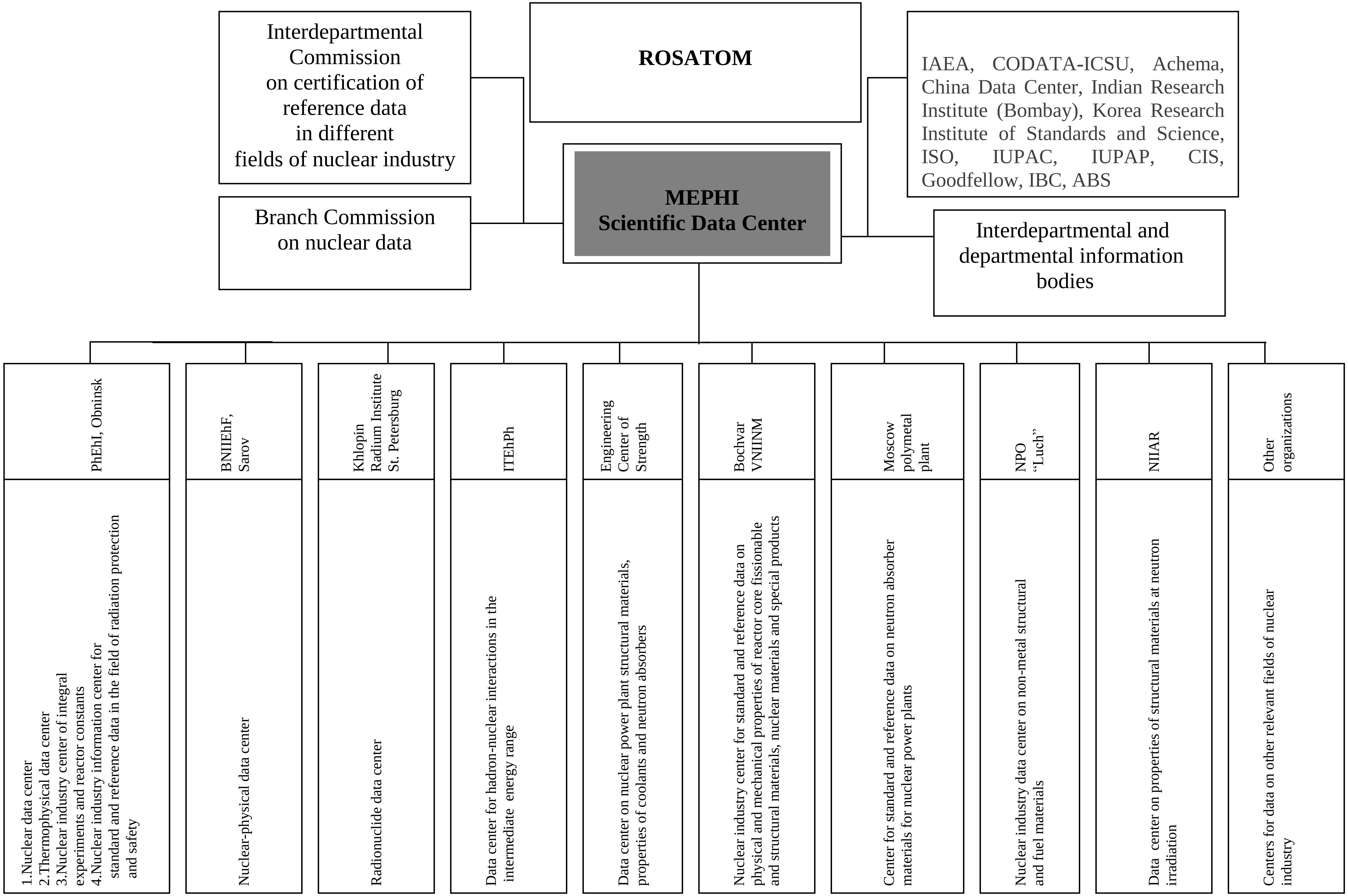
The nuclear data directories and wall charts of the nuclides are widely used by wide circle of experts of different level (students, graduate students, engineers, scientific researchers), who would like to have primary true information on stable and radioactive nuclides. In all such publications it is important to deal with high-quality and critical evaluated decay data for radionuclides. Therefore a periodic revision of nuclide guides and charts is highly desirable as the quality of measurements and evaluations is improved permanently.

The information presented in the Nuclide Guide (NG) and Chart of the Nuclides (CN) in 2006 [1] was compiled from *ENSDF-2006*, atomic mass evaluation-2003 by Audi and Wapstra and interactive data bases at web-sites www.nndc.bnl.gov, www.nucleide.org. From that time new important decay data evaluations for many radionuclides have been published, in particular, such as *Nuclear Data Sheets*, volumes 107 – 110 [2] and Monographie BIPM-5, *Table of Radionuclides*, 2006 [3], 2008 [4]. Also data in the above databases have been updated. In addition, for the Nuclide Guide the authors re-calculated the average radiation energies for 500 radionuclides with half-lives about and more than 1 hour. Therefore a revision of NG and CN is proved to be beneficial.

2. RUSSIAN NATIONAL STANDARD REFERENCE DATA SYSTEM

Below is a functional structure of the Russian National Standard Reference Data System in the field of nuclear science, technique and technology.

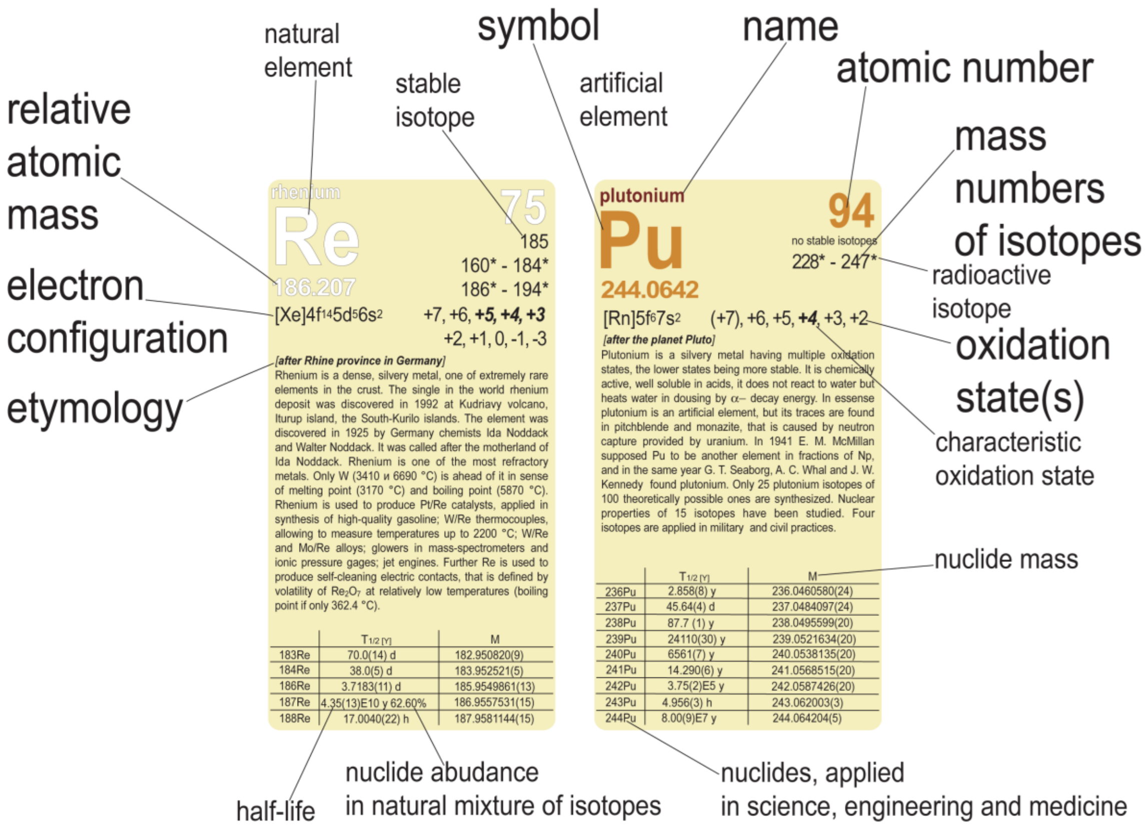
Functional structure of the Russian National Reference Data System in the field of nuclear science, technique and technology



I would like to inform you about Russian-Chinese cooperation in the field of principal nuclide data acquisition and evaluation for the purpose of development of wall-type charts of the nuclides. Any chart comprises 9 nuclear characteristics for about 3880 nuclides recommended by international and national organizations (data evaluated using ENSDF and standard reference data from IAEA, Russia, Japan and China). We published two nuclide guides in Russia in English and Russian (1995 and 2012) and one in China in English, Russian and Chinese (2011). The wall-type nuclide charts were prepared and issued in 1995, 2002, 2004, 2006, 2008, 2010, 2011, 2012. The next edition of the charts will be issued in 2010.

We would like you to consider the chance of cooperation and invite all the countries to join our project taking into account the experience gained by many countries in development of wall-type charts of the nuclides. We hope that the forthcoming issue of the wall-type chart of the nuclides prepared by specialists from various countries will be considered as a good exemplar of international cooperation in the field of peaceful utilization of nuclear data not only in nuclear science, technique and technology, but in the field of space, environment, medicine, agriculture and so on. Nuclear engineering in medicine provides unique possibilities for diagnostics.

The Scientific Data Center issued also Periodic Table of Elements (2008) involving physical characteristics and properties of chemical elements (Golashvili T.V. and Demidov A.P. are the authors). The Table includes such characteristics as atomic number, mass number, relative atomic mass, oxidation state, electron configuration, nuclide abundance, half-life for stable and natural isotopes of 112 elements. Below are presented boxes from the Table for Ca, Rb, Zr and Xe.



CALCIUM

Ca

20

40.078

40, 42 - 44, 46, 48
34* - 39*, 41*, 45*,
47*, 49* - 57*

[Ar]4s^2 **+2**

[Lat. calx, calcis - lime ("soft stone")]

Calcium is a medium hard, silvery, typical alkaline earth metal. English chemist H. Davy in 1808 isolated metallic calcium from hydrate of lime with electrolysis. Pure metallic Ca is used in the metallothermic process to produce rare-earth metals. ^{48}Ca is used to produce super-heavy elements in accelerators. Lead of accumulator battery plates is doped with calcium. Ca is used in calcium-base babbites; in chemical current sources. Monocrystals of calcium fluoride (fluorite) are used in optics (astronomical lenses, prisms), and as a laser material. Monocrystals of calcium tungstate (scheelite) are used in laser equipment. Calcium carbide is widely used to produce acetylene. Calcium oxide being both free and as part of ceramic mixtures is used to produce refractory materials. Calcium compounds are widely used as antihistaminic preparations. Calcium ions play a significant role in animal organizms (calcium channels). Calcium is an important element to form skeleton. Loss of calcium ions results in osteoporosis.

	$T_{1/2}$ [Y]	M
^{45}Ca	162.67(25) d	44.9561866(4)
^{47}Ca	4.536(3) d	46.9545460(24)

RUBIDIUM

Rb

37

85.4678

85, 87
71* - 84*, 86*
88* - 102*

[Kr]5s^1 **+1**

[Lat. – rubidius - due to red color in spectrum]

Rubidium is a soft, silvery, chemically active alkali metal, extremely unstable in air (it ignites when reacts with air in presence of trace water). It forms all kinds of salts. It was discovered by R.W. Bunsen and G.R. Kirchhoff (Heidelberg, Germany) in 1861. Metallic rubidium was produced by R.W. Bunsen in 1863. ^{86}Rb is used in γ-flaw detection, measuring equipment. Rb and its alloys are used in photoconverters, as coolant and working fluid of high-temperature turbosets; as catalyst to treat oil, to synthesize methanol and higher alcohols, in-situ coal gasification and to produce artificial liquid fuel; as lubricant in vacuum. Rubidium chloride is used to measure high temperatures (up to 400 °C). Rb plasma is used to drive laser emission. Rubidium chloride and rubidium hydroxide are used in fuel cells as electrolyte.

	$T_{1/2}$ [Y]	M
^{81}Rb	4.570(4) h	80.918996(6)
^{82}Rb	1.273(2) min	81.9182086(30)
^{83}Rb	86.2(1) d	82.915110(6)
^{84}Rb	33.1(1) d	83.914385(3)
^{86}Rb	18.642(18) d	85.91116742(21)
^{89}Rb	15.15(12) min	88.912278(6)

ZIRCONIUM

Zr 40

91.224

90 - 92, 94, 96
78* - 89*, 93*, 95*
97* - 110*

[Kr]$4d^2 5s^2$ **+4**, +3, +2, 0, -2

[Arabic - zarkun (cinnabar) or Persian - zargun (gold-like)]

Zirconium is a grayish-white, lustrous, stable to corrosion metal. Zirconium as dioxide was first isolated in 1789 by Germany chemist M.H. Klaproth as a result of zircon analysis. Zr is used as a structural material in nuclear and chemical reactors, as a smokeless agent in signal lights of pyrotechnics and primers; as superconducting alloy (Nb/Zr); as a refractory material for refractory facing in glass-melting and iron-and-steel furnaces; in structural ceramics, enamels and glazes; in prosthetics; zirconium carbide is used as a structural material in solid-core nuclear jet engines; zirconium beryllide is used in aerospace engineering (engines, effusers, reactors, radioisotope electric generators); zirconium hydride is used as neutron moderator in nuclear reactors. Fianites (cubic zirconia), produced by modifying zirconium dioxide, are used as optical materials, in medicine (surgical instrument), as synthesized jewellery (colour dispersion, index of refraction and irisation are higher than those of diamond), in producing man-made fibers.

	$T_{1/2}$ [Y]	M
^{95}Zr	64.032(6) d	94.9080426(26)

XENON

Xe 54

131.293

124, 126, 128 - 132, 134
136, 110* - 123*, 125*
127*, 135*, 137* - 147*

[Kr]$4d^{10} 5s^2 5p^6$ +8, +6, +4, +2, 0

[Greek - χενοζ - stranger (discovered as an impurity)]

Xenon is a monoatomic, odorless, colourless gas. It was discovered by English scientists W. Ramsay and M.W. Travers in 1898. The first chemical xenon compound ($XePtF_6$) stable at room temperature was reported by Neil Bartlett in 1962 in Canada. Xenon is used in filament lamps, powerful gas-discharge and flashing light sources; as a preparation for general narcosis; as high-efficiency working fluid for electroreactive (ion and plasma) spacecraft engines; radioactive xenon isotopes are used as radiation sources in radiography and diagnostics in medicine, l eak d etection i n v acuum e quipment; x enon fluorides are used for matal passivation; liquid xenon is a working fluid for high-power lasers; xenon fluorides and oxides are used as oxidizing agents for rocket propellant, as w ell a s c omponents o f g as m ixtures f or b oth h igh power laser weapon of earth-based antiaircraft defense, and space-based lasers. Xenon fluorides are toxic.

	$T_{1/2}$ [Y]	M
^{131m}Xe	11.934(21) d	
^{133}Xe	5.243(1) d	132.9059107(26)
^{133m}Xe	2.19(1) d	
^{135m}Xe	9.14(2) h	

3. CONTENTS OF THE NUCLIDE GUIDE AND CHART

The new Nuclide Guide and Chart – 2011, 2012 have been developed as a revised and updated versions of the NG and CN - 2006 produced in the issue of Russian-Chinese collaboration.

3.1 Nuclide Guide-2011, 2012

As before, in the Nuclide Guide-2011, 2012 the nine nuclear and decay characteristics are given for each nuclide. In particular, spin, parity, mass of nuclide, magnetic moment (if available), mass excess, half-life or abundance, decay modes, branching ratios, emitted particles, energies of most intense gamma-rays and their intensities, decay energies and mean values of radiation energy per decay are presented. For stable and natural long-lived nuclides cross-sections of thermal neutron induced activation are indicated. Almost all the characteristics are presented with uncertainties which were calculated by authors or extracted from databases *ENSDF-2009* [5] and *NUBASE* [6].

In the Nuclide Guide-2006 the average radiation energies were taken from Table of Radioactive Isotopes, 1986 [7]. In the new version the re-calculated values of these characteristics are given. In Table 1 the data sample for a number of heavy applied nuclides is presented.

Table 1 The average radiation energies per decay (in keV)

92-U-236	$\langle\alpha\rangle$ 4490(250) $\langle e\rangle$ 8.8 $\langle\gamma X\rangle$ 1.2(3)
92-U-237	$\langle\beta^-\rangle$ 68(6) $\langle e\rangle$ 110 $\langle X\rangle$ 61 $\langle\gamma\rangle$ 75.5(8)
92-U-238	$\langle\alpha\rangle$ 4187(30) $\langle e\rangle$ 8.8 $\langle\gamma X\rangle$ 1.2(1)
93-Np-234	$\langle\beta^+\rangle$ 0.17(4) $\langle e\rangle$ 35 $\langle X\rangle$ 70 $\langle\gamma\rangle$ 1030(30)
93-Np-237	$\langle\alpha\rangle$ 4842(1) $\langle e\rangle$ $\langle\gamma X\rangle$ 30
93-Np-238	$\langle\beta^-\rangle$ 210(10) $\langle e\rangle$ 35 $\langle X\rangle$ 6.3 $\langle\gamma\rangle$ 582(9)
93-Np-239	$\langle\beta^-\rangle$ 118(4) $\langle e\rangle$ 85 $\langle X\rangle$ 57 $\langle\gamma\rangle$ 118.2(7)
94-Pu-236	$\langle\alpha\rangle$ 5760(25) $\langle e\rangle$ 9.6 $\langle\gamma X\rangle$ 1.58(7)
94-Pu-237	$\langle e\rangle$ 9.1(4) $\langle\gamma X\rangle$ 52.5(10) $\langle\alpha\rangle$ 0.23

94-Pu-238	<α> 5486(5) <e> 9 <γX> 1.4
94-Pu-239	<α> 5146(6) <e> 4.8
94-Pu-240	<α> 5155(8) <e> 11 <γX> 1.3
94-Pu-241	<α> 0.114(2) <β^{-}> 5.8(1) <γX> 0.0017
94-Pu-242	<α> 4892(12) <e> 7 <γX> 1.1
94-Pu-243	<β^{-}> 159(20) <e> 6.4 <γX> 27(4)
94-Pu-244	<α> 4576.1(5) <e> 4.3 <γX> 0.78
95-Am-240	<α> 0.01 <e> 59(4) <X> 77(2) <γ> 950(40)
95-Am-241	<α> 5477(11) <e> 29.2(5) <γX> 28.4(5)
95-Am-242m	<α> 23.9(6) <γ> 0.2
95-Am-243	<α> 5271(4) <e> 19.7(5) <γX> 56.7(9)
96-Cm-242	<α> 6104 <e> 7.7 <γX> 0.01
96-Cm-243	<α> 5666(140) <e> 120(40) <X> 53 <γ> 73(1)
96-Cm-244	<α> 5796 <e> 6.7 <γX> 1.51
96-Cm-245	<α> 5380(30) <e> 71 <X> 73 <γ> 21.7(2)
96-Cm-246	<α> 5377.82(17) <e> 6.8 <X> 1.3 <γ> 0.0138(4)

97-Bk-249	<β-> 32.4(4) <γX> 0.0006 <α> 0.08
98-Cf-248	<α> 6249.4(9) <e> 5.0 <γX> 1.23(8)
98-Cf-249	<α> 5787(30) <e> 66 <X> 15 <γ> 312(4)
98-Cf-250	<α> 6017.0(4) <e> 3.68(4) <γX> 0.89(5)
98-Cf-252	<α> 5929.6(3) <e> 3.95(20) <X> 0.9

3.2 Chart of Nuclides-2012

The International Chart of Nuclides was developed taking into account information from Nuclide Guide-2012.

As is known, the term "nuclide" has been instituted in the nuclear science to distinguish between the isotopes of different chemical elements according their nuclear properties. The nuclide is an atom having the given number of protons in nucleus Z which defines the charge of the nucleus, and number of neutrons N. The sum $A = Z+N$ represents mass number of the nuclides. These three numbers define the nuclide place (its "box") in the chart of nuclides to be discussed. The structure of the box in the Chart of Nuclides with the indicated principal nuclide characteristics was described in [1].

The symbol of a chemical element and mass number is specified in the first line inside the box for any nuclide. The value of mass excess Δ (in MeV) is presented in the second line. The quantum characteristics of nucleus in the ground state - its spin and parity, are given in the third line. Radionuclide half-life is presented in the fourth line as one of the most important nuclear decay characteristics of radioactive nuclides. In case of stable isotopes this line contains the nuclide percentage in natural mixture of the chemical element under consideration. The fifth line contains the modes of nuclear transformations (decays) (α, β^-, ε, $\varepsilon\beta^+$, β, n, etc.) of the radioactive nuclides. Radiation capture cross section of thermal neutrons (activation cross section) in barns is presented in this line for the stable and natural long-lived nuclides.

As in the CN-2006 [1], the remaining 4 lines of boxes contain the additional nuclear decay characteristics of the radioactive nuclides as follows (in keV): total decay energy Q, average energy of radiation in the same units (bracketed), and the energy of the most intensive alpha- and gamma-radiation. The uncertainties of the recommended values are parenthetical and provided with the number of units of the last significant digit of the value.

Below the examples of the updated boxes for ^{139}Ce, ^{233}Th, ^{239}U and ^{246}Cm from CN-2009 are presented in Fig.1.

Ce 139	**Th 233**
-86952 (7)	38733.2 (20)
$3/2^+$	$1/2^+$
137.64 (2) d	22.15 (8) min
ε	β^-
Q^+ 270 (3)	Q^- 1243.1 (14)
	<β^-> 405 (7)
<γ> 132.52 (7)	<γ> 33.2
γ 165.858	γ 29.37 86.48 459.22

U 239	**Cm 246**
50573.9 (19)	62618.4 (21)
$5/2^+$	0^+
23.46 (4) min	4723 (27) y
β^-	α, SF
Q^- 1261.5 (16)	$Q(\alpha)$ 5476.7 (9)
$\langle\beta^-\rangle$ 390 (25)	α 5387.5 5343.7
$\langle\gamma\rangle$ 50.3 (20)	$\langle\gamma\rangle$ 0.0138 (4)
γ 43.533 74.664	γ 44.55 102.8

Fig. 1. Information boxes for ^{139}Ce, ^{233}Th, ^{239}U and ^{246}Cm.

4. THE INNOVATIVE ACTIVITY

- First of all in medicine for beam therapy and diagnostics.

- In light and food-processing industry for disinfection and sterilization of the manufacturable products.

- In housing services or in harmful manufacturing for a filtration, purification and separation of substances (development of track membranes in Joint Institute for Nuclear Research, Dubna).

- And also, devices for detection of nuclear and radioactive materials, for example, for customs and check points.

Besides it is necessary to pay attention to utilization of achievements of nuclear instrument making and mechanical engineering in other sectors of the industry, for example, in a fuel and energy complex, heavy mechanical engineering, electronic industry.

4.1 Materials and products on their basis

RADIONUCLIDE SOURCES AND PREPARATIONS
  THE TECHNICAL INFORMATION
  RADIONUCLIDE SOURCES
  RADIONUCLIDE PREPARATIONS
  TOOLS AND THE EQUIPMENT
  PACKING AND TRANSPORTATION
STABLE ISOTOPES
XENON DIFLUORIDE
CALCIUM METAL
PRODUCTS FROM ZIRCONIUM
  INGOTS
  PIPES
  RODS
  THE WIRE COLD-DRAWN FROM ALLOYS OF ZIRCONIUM
  SHEETS COLD-ROLLED FROM ALLOYS OF ZIRCONIUM
  ZIRCONIUM DIOXIDE
  TRANSITIVE WELDED CONNECTIONS ZIRCONIUM - STEEL
PRODUCTS FROM THE NATURAL AND IMPOVERISHED URANIUM
REAR EARTH PRODUCTION
  CARBONATES OF REAR EARTH METALS
  CONCENTRATE OF REAR EARTH METAL OXIDES OF CERIC GROUP
  POLISHING POWDERS ON BASIS OXIDES OF REAR EARTH METALS
POWDER WIRE FOR OUT-OF-KILN PROCESSINGS OF PIG-IRON AND STEEL
LONGITUDINAL ELECTROWELDED PIPES
PRODUCTS FROM STAINLESS-STEEL CHROMIUM-NICKEL ALLOYS
THE EQUIPMENT

THERMAL CONVERTERS
THE GENERAL DATA
INDEPENDENT DIGITAL TEMPERATURE MEASURING INSTRUMENT "NIKA"
SUBMERGED RIGID THERMAL CONVERTER FOR THE HIGH PRESSURE
FLEXIBLE SURFACE THERMAL CONVERTER UNDER THE SCREW
MANUAL SUPERFICIAL PROBE
FLEXIBLE SUPERFICIAL THERMAL CONVERTER WITH THE COLLAR
TRIBE-DEVICES

5. CONCLUSION

Charts and guides of nuclides present the evident primary information on the basic characteristics of stable nuclides and decay properties of the radioactive nucleus. The further, more detailed information on nuclide characteristics is contained in various specialized nuclear data collections and bases. Computers are used now most often to retrieve the data. However just as electronic carriers have not cancelled the traditional form of the literature as printed books, the nuclide directories and charts of nuclides are still in proper value not only in the nuclear science and engineering but also in space, medicine, agriculture and enviromental protection. Due to them each interested person can quickly orient himself in huge quantity of the nuclides (exceeding 3000), nuclear isomers, nuclear masses, half-lives and other characteristics. The authors hope that the Nuclide Guide and International Chart of Nuclides - 2012 completely meet this goal.

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