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Nuclide Guide and International Chart of the Nuclides - 2009

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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 - 2009 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-2009 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-2009. The presented decay data can be used not only in nuclear physics and associated fields but also in medicine, agriculture and space studies.

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I. 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.

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II. CONTENTS OF THE NUCLIDE GUIDE AND CHART

The new Nuclide Guide and Chart-2009 have been developed as a revised and updated versions of the NG and CN-2006 produced in the issue of Russian-Chinese collaboration.

1. Nuclide Guide-2009

As before, in the Nuclide Guide-2009 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	<α> 4490 (250)
	<e> 8.8
	<γX> 1.2 (3)
92-U-237	<β^-> 68 (6)
	<e > 110
	<X> 61
	<γ> 75.5 (8)
92-U-238	<α> 4187 (30)
	<e> 8.8
	<γX > 1.2 (1)
93-Np-234	<β^+> 0.17 (4)
	<e> 35
	<X> 70
	<γ> 1030 (30)
93-Np-237	<α> 4842 (1)
	<e>
	<γX> 30
93-Np-238	<β^-> 210 (10)
	<e> 35
	<X> 6.3
	<γ> 582 (9)
93-Np-239	<β^-> 118 (4)
	<e> 85
	<X> 57
	<γ> 118.2 (7)
94-Pu-236	<α> 5760 (25)
	<e> 9.6
	<γX> 1.58 (7)
94-Pu-237	<e> 9.1 (4)
	<γX> 52.5 (10)
	<α> 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

2. Chart of Nuclides-2009

The International Chart of Nuclides was developed taking into account information from Nuclide Guide-2009.

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

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)
		$<\beta^->$ 405 (7)
$<\gamma>$ 132.52 (7)		$<\gamma>$ 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)
$<\beta^->$ 390 (25)		α 5387.5 5343.7
$<\gamma>$ 50.3 (20)		$<\gamma>$ 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.

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.

III. 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 in the nuclear science and engineering. 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-2009 completely meet this goal.

REFERENCES

[1] T. Golashvili, S. Badikov, V. Chechev, H. Xiaolong, G. Zhigang and W. Zhendong, in *Proceedings of Inter. Conf. on Nucl. Data for Sci. and Techn.* (Nice, france, 2007), p. 85.
[2] Nucl. Data Sheets **107 - 110** (2006 - 2009).
[3] M. M. Be, V. Chiste, C. Dulieu, E. Browne, V. Chechev, N. Kuzmenko, R. Helmer, F. Kondev, D. MacMahon and K.B. Lee. *Table of Radionuclides (Vol.3 – A = 3 to 244)* (Sevres, Bureau International des Poids et Mesures, 2006).
[4] M. M. Be, V. Chiste, C. Dulieu, E. Browne, V. Chechev, N. Kuzmenko, F. Kondev, A. Luca, M. Galan, A. Pearce and X. Huang. *Table of Radionuclides (Vol. 4 – A = 133 to 252)* (Sevres, Bureau International des Poids et Mesures, 2008).
[5] Evaluated Nuclear Structure Data File (ENSDF)-2009, NNDC, Brookhaven National Laboratory, USA; http://www.nndc.bnl.gov.
[6] G. Audi, O. Bersillon, J. Blachot and A. H. Wapstra, Nucl. Phys. A **729**, 3 (2003).
[7] E. Browne, R. B. Firestone and V. S. Shirley, *Table of Radioactive Isotopes* (John Wiley and Sons, Inc., New York, 1986).