French National Atomic Energy Agency (CEA)

French National Metrology Office (LNE)

Laboratoire National Henri Becquerel

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Tasks of a National Metrology Institute (NMI)

Provide users with the metrological standards they need through a strictly established traceability

R & D

International traceability

Transfer to users

Maintenance and upgrading of standards

Coherence and excellence of the national metrology chain

Teaching

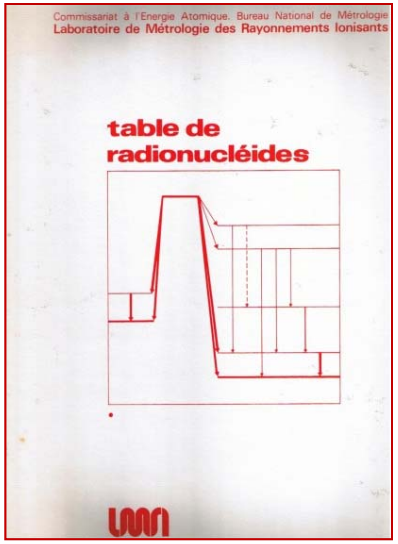
Provide recommended decay data

Good knowledge of decay scheme data is required at each part of the metrology chain.

1) Which data?
   The data describing the radioactive disintegration: **half-life, emission energy and intensity of the various radiations, etc.**

2) For which needs?
   Metrology: **detector calibration, simulation calculations, etc.**
   Medical uses**: diagnostic (Tc-99m, Tl-201, F-18, …), therapy (Ir-192, I-131, Y-90, …)**
   Nuclear fuel cycle**: residual power in the reactor, waste management, control of the nuclear matter (safeguards), etc.**

We have been undertaking decay data evaluations for many years…



- The evaluation of data is time consuming
- An international working group was formed in 1995 (DDEP):

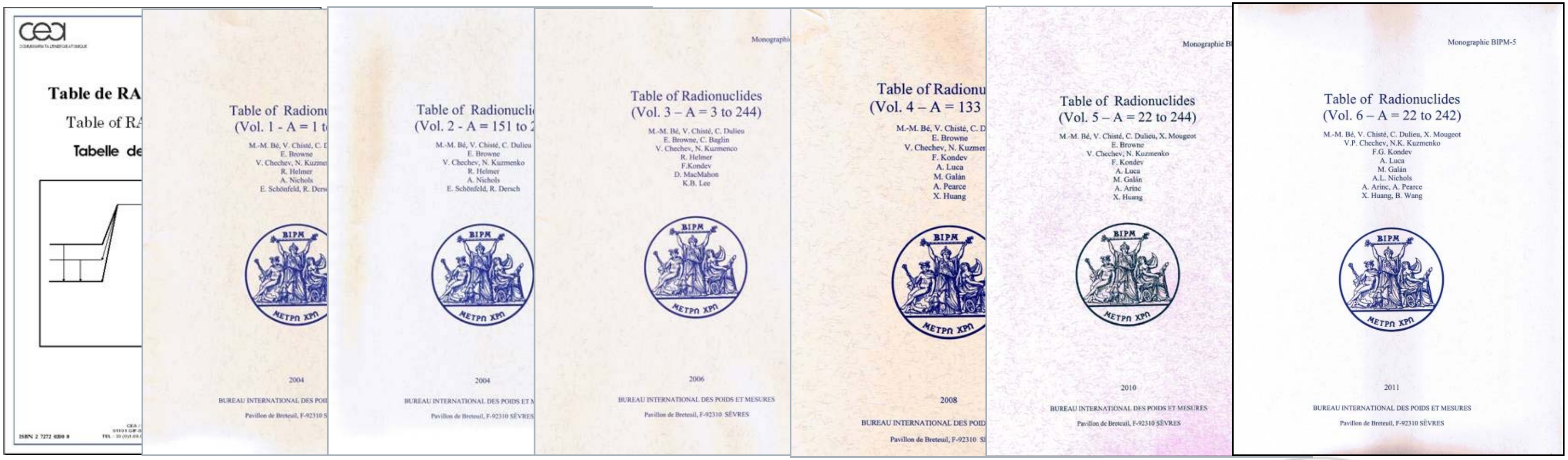
↓

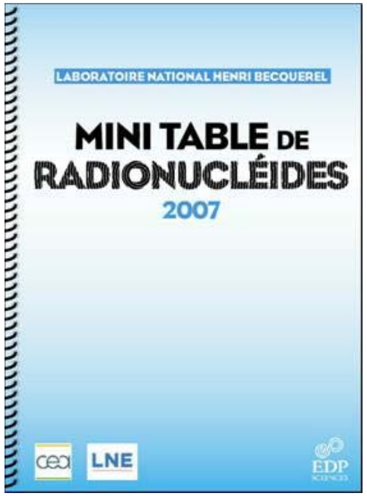
LNHB (France), PTB (Germany), INEEL and LBNL (USA), KRI (Russia)

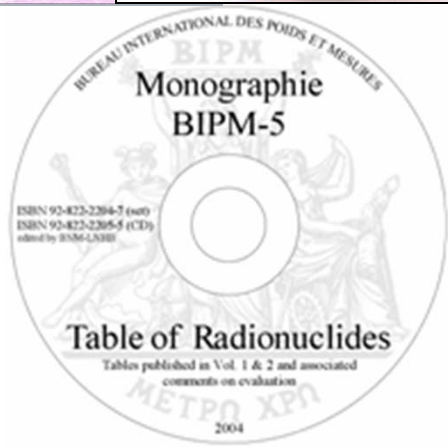
The current members of DDEP are :

Marie-Martine Bé (LNHB, France); *Coordinator, Editor-In-Chief*
Filip G. Kondev (ANL, United States)
Valery P. Chechev (KRI, Russia)
Christophe Dulieu, Mark A. Kellett, Xavier Mougeot (LNHB, France)
Alan L. Nichols (Surrey University, UK)
Tibor Kibédi (ANU, Australia)
Aurelian Luca (IFIN, Romania)
Andy Pearce, Arzu Arinc (NPL, UK)
Huang Xiaolong (CIAE, China)

Publications







LNHB Websites (1)

www.nucleide.org

3000 requests/day

Fr, Ru, It, USA, etc.

Explanation on recommended data and their evaluation (in various languages):

Tables of evaluated data and comments on evaluation
Pages updated by the Laboratoire National Henri Becquerel
All questions about the data must be sent to the authors. See chapter Addresses.

updated: 22th **November 2012 - Emission file in ASCII format added**
latest entry: **Ar-37**
latest updates: **C-14, Ga-67, Ga-68, Ge-68, Cs-134**
ASCII files updated on: **19/11/2012**
(**198** nuclides in table, sorted by **alphabetical order** / atomic number / mass number / edition date)

(**History of older evaluations**, sorted by **alphabetical order**)

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(Type of updates since last revision: **1** - update in comments only ; **2** - minor update in table ; **3** - major update in table)

Nuclide		Tables	Comments	ENSDF	ASCII	In	UpDate	Type
Ac-225	^{225}Ac	table	comments	ensdf	txt	5	26/08/2009	3
Ac-227	^{227}Ac	table	comments	ensdf	txt	4	16/02/2009	2
Ac-228	^{228}Ac	table	comments	ensdf	txt	6	22/01/2010	3
Ag-108	^{108}Ag	table	comments	ensdf	txt	3	04/09/2006	2
Ag-108m	^{108m}Ag	table	comments	ensdf	txt	3	17/01/2012	2
Ag-110	^{110}Ag	table	comments	ensdf	txt	1	12/03/2004	1
Ag-110m	^{110m}Ag	table	comments	ensdf	txt	1	24/03/2004	1
Al-26	^{26}Al	table	comments	ensdf	txt	99	24/07/2003	1
Am-241	^{241}Am	table	comments	ensdf	txt	5	20/08/2010	2

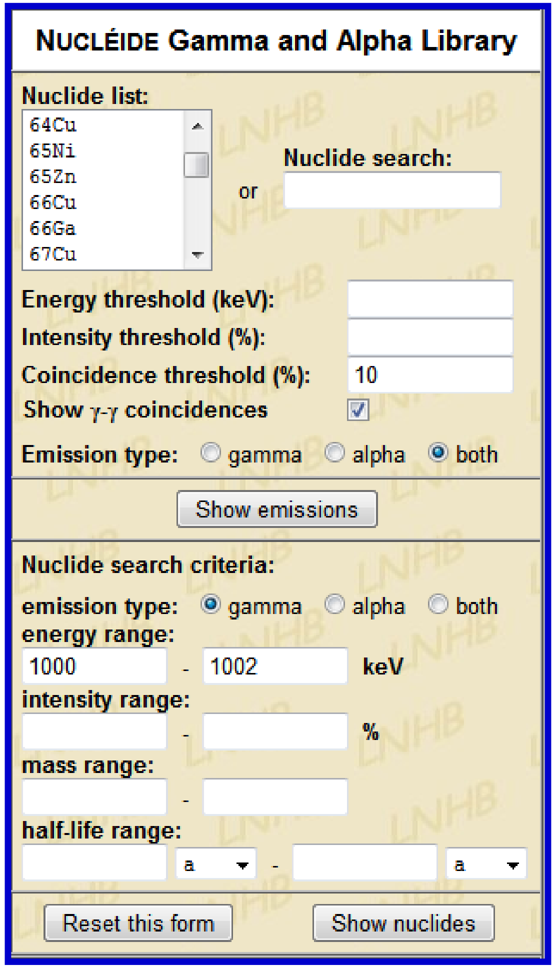
Nuclide		Tables	Comments	ENSDF	ASCII	In	UpDate	Type
Np-236	^{236}Np	table	comments	ensdf	txt	6	22/01/2012	2
Np-236m	^{236m}Np	table	comments	ensdf	txt	3	22/01/2012	2
Np-237	^{237}Np	table	comments	ensdf	txt	6	07/01/2010	2
Np-238	^{238}Np	table	comments	ensdf	txt	4	16/02/2009	2
Np-239	^{239}Np	table	comments	ensdf	txt	4	16/02/2009	2
O-15	^{15}O	table	comments	ensdf	txt	1	01/06/2004	1
P-32	^{32}P	table	comments	ensdf	txt	1	08/04/2004	1
P-33	^{33}P	table	comments	ensdf	txt	1	08/04/2004	1
Pa-231	^{231}Pa	table	comments	ensdf	txt	6	23/02/2011	3

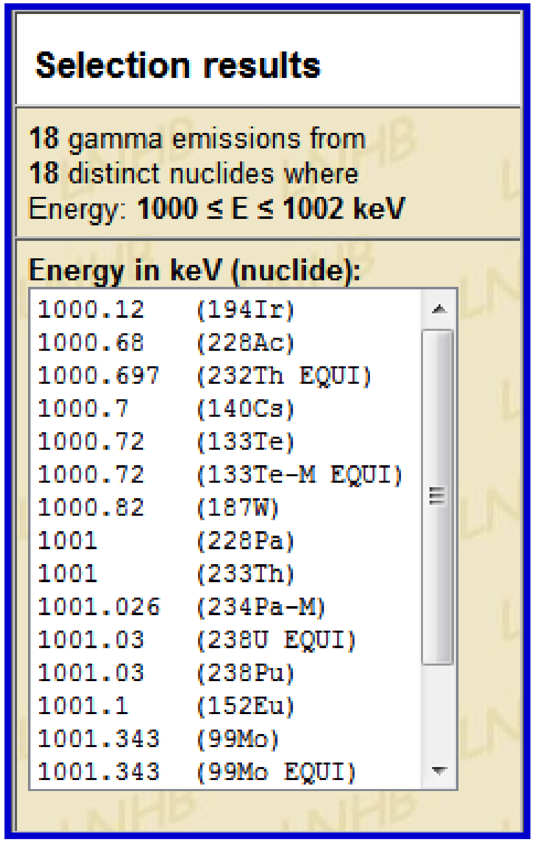
LNHB Websites (2)

Laraweb.free.fr

2750 users, 300 requests/day

59 countries, ^{241}Am, ^{137}Cs, ^{152}Eu, ^{60}Co, ^{235}U, etc.





Half-life

Reference	$T_{1/2}$ (min)	Remarks
M. L. Perlman	68,0	omitted
G. L. Gleason (1960Gl04)	67,7(3)	
L. A. Rayburn (1961Ra06)	69,2(14)	outlier
T. G. Ebrey (1965Eb01)	68,33(9)	Coin. Count. NaI(Tl), statistical uncertainty only
M. Borman (1965Bo42)	68,2(1)	
J. M. Ootukalam (1971Oo01)	68,5(5)	NaI, brief note, statistical uncertainty only
Smith and Williams (1971Sm02)	67,80(8)	IC
Iwata et al. (1983Iw02)	67,629(24)	Ge(Li)
Luca et al. (2012Lu*)	67,87 (10)	IC
Adopted	**67,83 (20)**	χ^2 crit = 2,8 ; χ^2 = 11

The set of 7 values used in the averaging process is not consistent with a reduced χ^2 of 11. The limitation of relative statistical weight procedure has then increased the Iwata's uncertainty to 0,05 in order to reduce the relative weight of this value to 50%.

Therefore, the resulting (and adopted) weighted mean is 67,83 min with an expanded uncertainty of 0,20 to cover the most precise value.

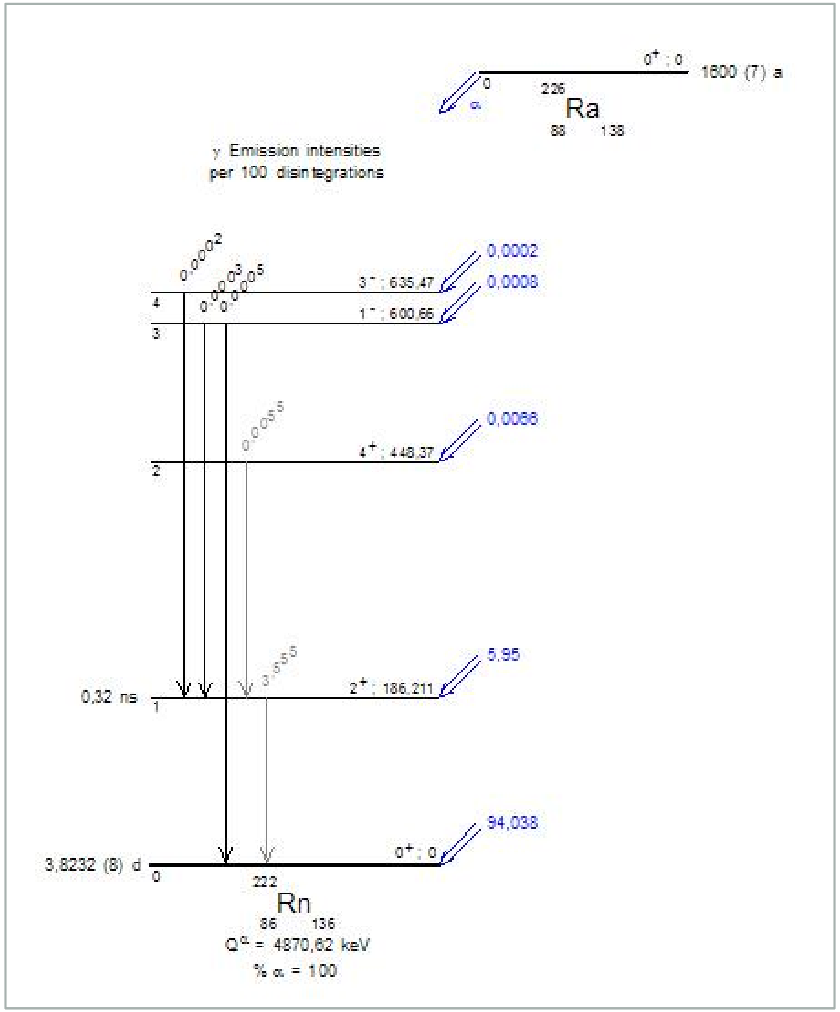
Similarly, all the physical parameters are studied.

Relative gamma-ray emission intensities:

	Vaughan 1969Va16	Carter 1968Ca15	Lange 1973La01	Vo 1994Vo15	Schönfeld 1994Sc44	Luca 2012Lu*	χ^2 /n-1	Adopted
227	-	-	-	0,0037(15)				0,0037(15)
483	-	-	-	0,0082(9)				0,0082(9)
579	0,7(1) *	1,1(2)	1,00(12)	1,05(15)	1,14(15)	1,35(30) *	0,2	1,06 (7)
683	-	-	-	0,0097(6)		-		0,0097(6)
806	2,2(2) *	2,8(2)	2,95(12)	2,81(14)	2,90(31)	2,68(34)	0,3	2,87(8)
939	-	-	-	0,0055(5)		-		0,0055(5)
1077	100	100	100	100	100	100		
1166	-	-	-	0,0005(3)		-		0,0005(3)
1261	3,1(2)	2,9(2)	3,00(7)	2,75(14)	3,06(31)	2,60(28)	1	2,95(6)
1744	0,5(1)	0,28(4)	0,30(4)	0,295(15)		-	1,4	0,297(16)
1883	4,8(3)	4,1(4)	4,33(12)	4,6(2)	3,86(59)	3,94(42)	1,1	4,39(10)
2338	<0,1	0,04(2)	0,050(6)	0,031(3)		-	4	0,035(5)
2821	-	-	0,015(2)	0,0139(11)				0,0144(11)

* Omitted from statistical processing

The overall consistency of the decay scheme must be checked



1) Parent :

$\Sigma\ \beta^- + \varepsilon + \beta^+ + \alpha + \gamma = 100\ \%$

Ground state level of the daughter(s)

$\Sigma\ \beta^- + \varepsilon + \beta^+ + \alpha + \gamma = 100\ \%$

2) Level

$\Sigma\ T_{feeding} = \Sigma\ T_{starting}$

3) Total energy conservation

4) If possible, comparison between the I_X calculated and measured

Needs for Comprehensive Evaluations

In the DDEP Tables we already have carefully evaluated decay data for:

^{11}C, ^{13}N, ^{15}O, ^{18}F, ^{32}P, ^{22}Na, ^{24}Na, ^{60}Co, ^{64}Cu, ^{66}Ga, ^{67}Ga, $^{68}Ge/Ga$, ^{89}Sr, ^{90}Y,

^{99m}Tc, ^{111}In, ^{123}I, ^{125}I, ^{131}I, ^{137}Cs, ^{153}Sm, ^{159}Gd, ^{166}Ho, ^{169}Yb, ^{177}Lu, ^{186}Re, ^{188}Re, ^{192}Ir,

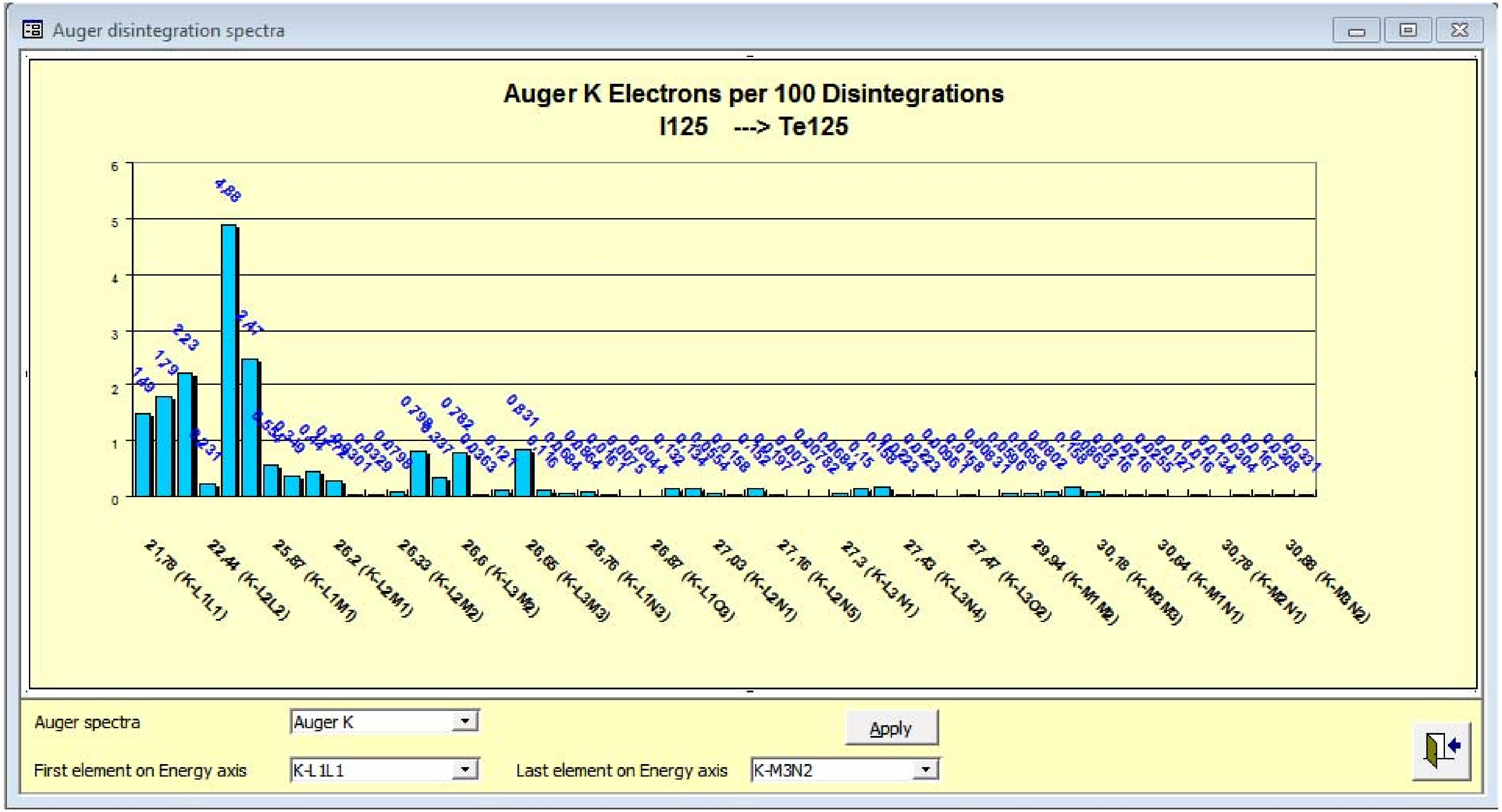
^{201}Tl, ^{203}Pb, $^{211}At/Po$, ^{213}Bi, ^{223}Ra, ^{225}Ac.

Some of these have been evaluated in the context of two previous CRPs (gamma standards and Actinides) because they are also useful for other applications.

For these applications we need a complete decay scheme, also including the weak emissions.

For example: we need to know all data in detail for the calculation of X-rays and Auger electrons.

Auger Electrons Emitted in the decay of ^{125}I



Our program (SAISINUC) can calculate the energies and emission intensities of the Auger electrons and X-rays, but for this we need to know:

- All the nuclear decay parameters (ICCs, sub shell capture probabilities, etc.)
- All the atomic parameters (fluorescence yields, relative emission probabilities, etc.)

Impurities

The production of a radionuclide often involves the production of other radionuclides which are considered as impurities.

These impurities can be important for the medical purposes themselves, but also when the activity measurement is carried out.

Example:

Tl-201 is generally produced with a more or less important quantity of Tl-200 and Tl-202.

$$T_{1/2}\ (\text{Tl-201}) = 3\ \text{d}$$
$$T_{1/2}\ (\text{Tl-200}) = 1\ \text{d}$$
$$T_{1/2}\ (\text{Tl-202}) = 12\ \text{d}$$

It is then difficult to correctly measure the specific activity in Tl-201 of a solution and therefore the calibration of the ionization chambers used in hospitals can not be achieved accurately.

Good decay scheme data are also requested for these nuclides in order to correct the activity result.

Concluding Remarks

Proposals:

- ✓ Determination of the nuclides of interest and also of any possible associated impurities,
- ✓ Evaluations of all decay data following the DDEP methodology,
- ✓ Establish a list of nuclides with their producers.

LNHB can evaluate the decay data of:

^{47}Sc, ^{44}Ti/^{44}Sc, ^{58}Co, ^{61}Cu, ^{72}Se, ^{82}Sr/^{82}Rb, ^{103}Pd, ^{131}Cs, ^{200}Tl, ^{202}Tl, ^{230}U, ^{226}Th