Status of the Decay Data Evaluation Project (DDEP)

Mark A. Kellett

NSDD 2017, Copenhagen, 22 – 26 May 2017

Outline

The Decay Data Evaluation Project (DDEP)

- Membership,
- Data availability

Improvements to Beta Spectra: The MetroBeta Project

Conclusions

Decay Data Evaluation Project (DDEP) Members

A small number of decay data evaluation specialists, mainly from the metrology community:

Mark A. Kellett (Coordinator)

Xavier Mougeot

LNHB, France

Christophe Dulieu (IT support)

Alan L. Nichols

Surrey University, UK

Aurelian Luca

IFIN, Romania

Huang Xiaolong

CIAE, China

Valery P. Chechev & Nikolai Kuzmenko

KRI, Russia

Andy Pearce & Arzu Arinc

NPL, UK

Members who joined in 2016:

Brian Zimmerman

NIST, USA

Herbert Janssen

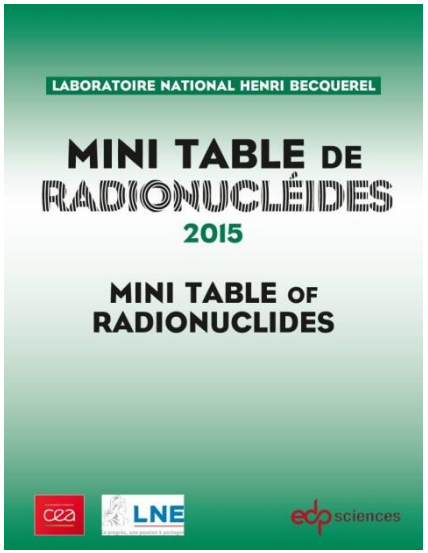
PTB, Germany

Haoran Liu

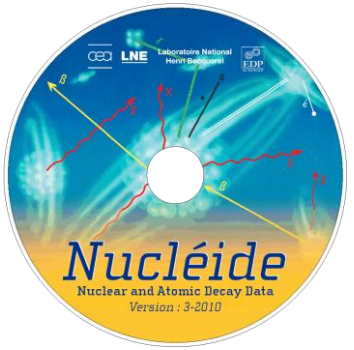
Metrology Institute, China

Additional support: Tibor Kibédi (**ANU, Australia**) – *BrIcc & BrIccMixing codes* and others from the wider community who help in the review process.

Publications of decay scheme data (1)



EDP Sciences



http://www.bipm.org/fr/publications/monographie-ri-5.html

Publications of decay scheme data (2)

Volume 7 of the Monographie BIPM 5 was published in February 2013 (29 radionuclides):

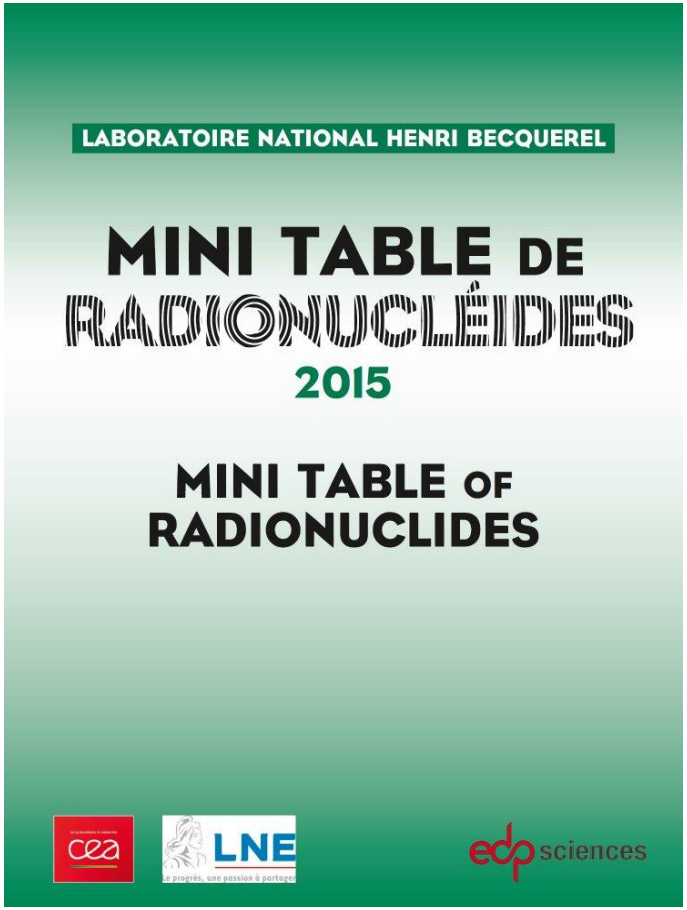
^{14}C, ^{35}S, ^{36}Cl, ^{37}Ar, ^{45}Ca, ^{67}Ga, ^{68}Ga, ^{68}Ge, ^{127}Sb, ^{127}Te, ^{127m}Te, ^{134}Cs, ^{141}Ce, ^{147}Nd, ^{147}Pm, ^{195}Au, ^{206}Hg, ^{207}Tl, ^{208}Tl, ^{209}Tl, ^{211}Pb, ^{211}At, ^{213}Bi, ^{215}Bi, ^{228}Th, ^{242}Cm, ^{243}Cm, ^{244}Cm, ^{245}Cm

Volume 8 of the Monographie BIPM-5 published December 2016 (32 radionuclides):

^{41}Ca, ^{47}Sc, ^{52}Fe, ^{58}Co, ^{61}Cu, ^{63}Zn, ^{73}Se, ^{82}Rb, ^{82}Sr, ^{88}Y, ^{89}Zr, ^{93}Zr, ^{93m}Nb, ^{94m}Tc, ^{106}Ru, ^{106}Rh, ^{109}Cd, ^{131}I, ^{127}Xe, ^{131m}Xe, ^{133}Ba, ^{140}Ba, ^{138}La, ^{140}La, ^{144}Ce, ^{144}Pr, ^{144m}Pr, ^{148}Pm, ^{148m}Pm, ^{151}Sm, ^{169}Er, ^{198}Au

Mini table of radionuclides 2015

New edition of the Mini Table of Radionuclides was published in March 2015, and is sold and distributed by EDP Sciences (25 €). ~1 300 copies sold to date



$^{61}_{29}$Cu — $T_{½}$: 3,366 (33) h — Copper / Cuivre

Descendant(s): (β^+, ε, 100 %) **Ni-61**
Q^+: 2237,5 keV

Electrons (10 lines) - $\Sigma(I_{e^-})$ omitted: 0,6 %

Energy (keV)	Intensity (%)	Type	Origin
0,6 – 1	51,2	Auger L	Ni-61
6,3 – 8,3	20,0	Auger K	Ni-61

Beta + (6 lines) - $\Sigma(I_{\beta^+})$ omitted: 0,035 %

E max. (keV)	*E* avg. (keV)	Intensity (%)
559,5	238,5	2,52
932,5	398,9	5,4
1 148,1	493,8	2,1
1 215,5	523,8	51,6

X (4 lines) - $\Sigma(I_X)$ omitted: 0,44 %

Energy (keV)	Intensity (%)	Type	Origin
7,46	4,33	$X_{Kα2}$	Ni-61
7,48	8,4	$X_{Kα1}$	Ni-61
8,3	1,76	$X_{K'β1}$	Ni-61

Gamma (34 lines) - $\Sigma(I_\gamma)$ omitted: 1,9 %

Energy (keV)	Intensity (%)	Type	Origin
67,41	4,0	γ	Ni-61
282,96	12,0	γ	Ni-61
373,05	2,09	γ	Ni-61
511	123	γ ±	
588,61	1,15	γ	Ni-61
656,01	10,4	γ	Ni-61
908,63	1,12	γ	Ni-61
1 185,23	3,6	γ	Ni-61

Production mode	Possible impurities
Ni-61 (p, n) Cu-61	-
Zn-64 (p, α) Cu-61	-
Cu-63 (γ, 2n) Cu-61	-

Reference: CEA/LNE-LNHB - 2013

$^{241}_{95}$Am — $T_{½}$: 432,6 (6) a — Americium / Américium

Descendant(s): (α, 100 %) **Np-237** (2,144 x 10^6 a)
$Q^α$: 5637,82 keV

Alpha (23 lines) - $\Sigma(I_α)$ omitted: 0,7 %

Energy (keV)	Intensity (%)	Type	Origin
5 388,25	1,66	α	Am-241
5 442,86	13,23	α	Am-241
5 485,56	84,45	α	Am-241

Electrons (48 lines) - $\Sigma(I_{e^-})$ omitted: 2,6 %

Energy (keV)	Intensity (%)	Type	Origin
6,3	14	ec L	Np-237
6 – 13,5	33,4	Auger L	Np-237
13,2	15,9	ec L	Np-237
21,6	3,7	ec M	Np-237
23,4	8,8	ec L	Np-237
28,5	4,0	ec M	Np-237
32,2	1,08	ec N	Np-237
38,7	2,3	ec M	Np-237
39,5	30,2	ec L	Np-237
54,8	8,12	ec M	Np-237

X (9 lines) - $\Sigma(I_X)$ omitted < 0,01 %

Energy (keV)	Intensity (%)	Type	Origin
11,89	0,844	$X_{Lℓ}$	Np-237
13,85	13,02	$X_{Lα}$	Np-237
15,88	0,384	$X_{Lη}$	Np-237
16,96	18,58	$X_{Lβ}$	Np-237
21,16	4,83	$X_{Lγ}$	Np-237

Gamma (179 lines) - $\Sigma(I_\gamma)$ omitted: 0,29 %

Energy (keV)	Intensity (%)	Type	Origin
26,34	2,31	γ	Np-237
59,54	35,92	γ	Np-237

Production mode	Possible impurities
Pu-241 (β^-) Am-241	T½ = 14,33 a

Reference: KRI - 2009

Access to decay scheme data (1)

Accueil LNHB | Remonter | Sommaire LNHB | Dosimétrie | Radioactivité

www.nucleide.org

This introduction presents a brief description of the radioactivity physical processes, the enumeration of the evaluation rules leading to the recommended values, and a summary of the symbols and terms used in all the publications.

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: **3rd March 2017**
newly added: **Pr-142**
recently updated: **Co-57, Xe-133m**
ASCII files updated on: **24/06/2016**
(**221** nuclides in table, sorted by **alphabetical order** / atomic number / mass number / edition date)

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

Subscribe to DDEP RSS feed

Please cite our evaluations using the following references:

Vol.	Publication	Year	ISBN	NSR	BibTeX
99	CEA Report - Table de Radionucléides	1999	2-7272-0200-8	1999BeZQ	TabRad_v0.bib
1	Monographie BIPM-5 - Table of Radionuclides, vol. 1	2004	92-822-2206-3	2004BeZR	TabRad_v1.bib
2	Monographie BIPM-5 - Table of Radionuclides, vol. 2	2004	92-822-2207-1	2004BeZQ	TabRad_v2.bib
3	Monographie BIPM-5 - Table of Radionuclides, vol. 3	2006	92-822-2218-7	2006BeZL	TabRad_v3.bib
4	Monographie BIPM-5 - Table of Radionuclides, vol. 4	2008	92-822-2231-4	2008BeZV	TabRad_v4.bib
5	Monographie BIPM-5 - Table of Radionuclides, vol. 5	2010	978-92-822-2234-8	2010BeZQ	TabRad_v5.bib
6	Monographie BIPM-5 - Table of Radionuclides, vol. 6	2011	978-92-822-2242-3	2011BeZW	TabRad_v6.bib
7	Monographie BIPM-5 - Table of Radionuclides, vol. 7	2013	978-92-822-2248-5	2013BeZP	TabRad_v7.bib
8	Monographie BIPM-5 - Table of Radionuclides, vol. 8	2016	978-92-822-2264-5	2016BeZX	TabRad_v8.bib

(*Type of updates: **N** - new evaluation; **1** - update in comments only; **2** - minor update in table; **3** - major update in table)

Nuclide		Tables	Comments	ASCII files			Vol.	UpDate	Type*
				ENSDF	PenNuc	Lara			
Ac-225	^{225}Ac	table	comments	ensdf	pennuc	txt	5	26/08/2009	3
Ac-227	^{227}Ac	table	comments	ensdf	pennuc	txt	4	16/02/2009	2
Ac-228	^{228}Ac	table	comments	ensdf	pennuc	txt	6	22/01/2010	3
Ag-108	^{108}Ag	table	comments	ensdf	pennuc	txt	3	4/09/2006	2
Ag-108m	^{108m}Ag	table	comments	ensdf	pennuc	txt	3	17/01/2012	2

Nuclide		Tables	Comments	ASCII files			Vol.	UpDate	Type*
				ENSDF	PenNuc	Lara			
O-15	^{15}O	table	comments	ensdf	pennuc	txt	1	1/06/2004	1
P-32	^{32}P	table	comments	ensdf	pennuc	txt	1	8/04/2004	1
P-33	^{33}P	table	comments	ensdf	pennuc	txt	1	8/04/2004	1
Pa-231	^{231}Pa	table	comments	ensdf	pennuc	txt	6	23/02/2011	3
Pa-233	^{233}Pa	table	comments	ensdf	pennuc	txt	5	11/01/2010	2

Access via http://www.nucleide.org/Laraweb

^{60}Co - Emissions and decay scheme

Element: **Cobalt** (Z=**27**)
Daughter(s): **Ni-60** (β^-, 100 %)
Q: **2823.07 keV**
Possible parent(s): Co-60m (I.T., 99.75 %)
Half-life (T½): **5.2711 (8) a** ≡ **166.340 (25) 10^6 s**
Decay constant (λ): **4.1671 (6) 10^{-9} s^{-1}**
Specific activity (Am): **41.824 (6) 10^{12} $Bq.g^{-1}$**
Reference: **INEEL - 2006**
Associated data files: Table - Comments

Results file (ASCII text format): Co-60.txt

Mass ⇄ Activity conversion: 1.255E+8

Decay calculation:
A(t_0)= 1000 Bq t_1= 1.697E+0 a

Coincidence threshold: **10 %**
Emissions (**10** lines) sorted by increasing

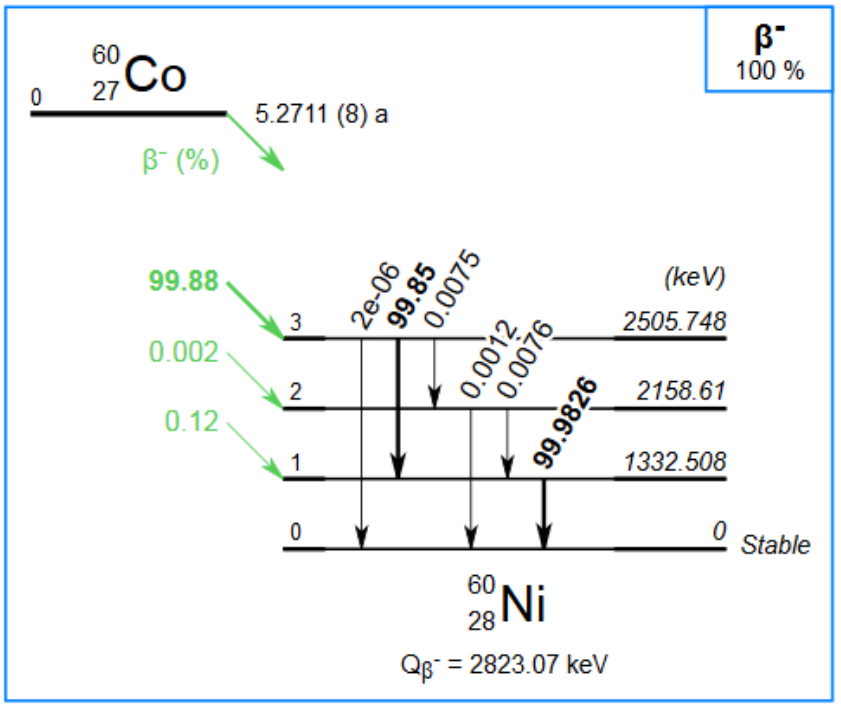
Energy (keV)	Intensity (%)
0.84 (-)	0.0002 (-)
7.46097 (-)	0.00334 (12)
7.47824 (-)	0.0065 (3)
8.2967 (-)	0.00136 (5)
347.14 (7)	0.0075 (4)
826.10 (3)	0.0076 (8)
1 173.228 (3)	99.85 (3)
1 332.492 (4)	99.9826 (6)
2 158.57 (3)	0.0012 (2)
2 505.692 (5)	0.0000020 (4)

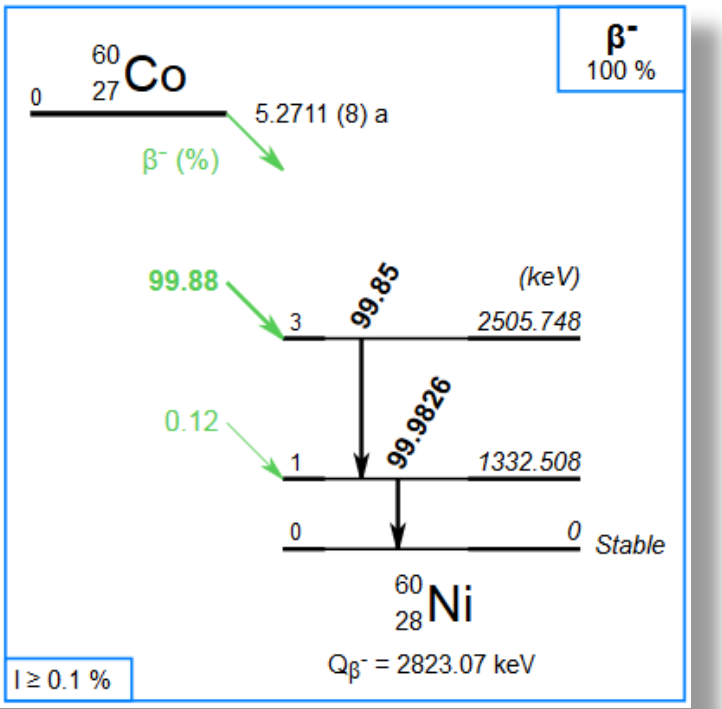
Nucléide - Lara
Library for gamma and alpha emissions

Nuclide list:
59Fe
59Ni
60Co
60Co-M
61Cu
63Ni
63Zn
64Cu

or Nuclide search:
(e.g.: 99Xx or Xx-99)

Energy threshold (keV):





New website under development

http://www.nucleide.org becomes http://www.lnhb.fr/

The MetroBeta Project

EMPIR

EURAMET

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

http://metrobeta-empir.eu/

Short Name	Organisation legal full name	Country
CEA	Commissariat à l'énergie atomique et aux énergies alternatives	France
CMI	Cesky Metrologicky Institut Brno	Czech Republic
PTB	Physikalisch-Technische Bundesanstalt	Germany
Gonitec	Gonitec BV	Netherlands
UHEI	Ruprecht-Karls-Universitaet Heidelberg	Germany
UMCS	Uniwersytet Marii Curie-Sklodowskiej	Poland
CHUV	University Hospital of Lausanne	Switzerland

The MetroBeta Project

WP No	Work Package Title	Active Partners
WP1	Theoretical calculations of beta spectra	CEA; UMCS
WP2	High-resolution beta spectrometry based on Metallic Magnetic Calorimeters (MMCs)	PTB; CEA; UHEI
WP3	Measurements of beta spectra with other methods	CHUV; CMI; Gonitec
WP4	Comparison and validation of measurements	PTB; CEA; CHUV
WP5	Creating impact	CMI; all partners
WP6	Management and coordination	CEA; all partners

Measure new high resolution beta spectra for low (< 100 keV) and intermediate (< 1 MeV) end-point energy pure beta emitters ^{151}Sm, ^{14}C, ^{99}Tc and ^{36}Cl.

http://metrobeta-empir.eu/

Conclusions

The CCRI of the BIPM endorse the use of DDEP recommended data

The DDEP has expertise in evaluating atomic and nuclear decay data

Publication of reference data in collaboration with the BIPM and provision of a database in order to disseminate these reference data

Provision of information concerning the details of each evaluation, including recommendations for new measurements

Three new evaluators from National Metrology Institutes have recently joined

Other additional data related projects, e.g. MetroBeta, are on-going

THANK YOU FOR YOUR ATTENTION

Commissariat à l'énergie atomique et aux énergies alternatives
Institut List | CEA SACLAY NANO-INNOV | BAT. 861 – PC142
91191 Gif-sur-Yvette Cedex - FRANCE
www-list.cea.fr

Établissement public à caractère industriel et commercial | RCS Paris B 775 685 019

Additional Material

A few extra slides, with additional information

Decay Data Evaluation Project (DDEP) Context

In the metrology community, in the early 1990s, there was a need for evaluated decay scheme data for absolute activity measurements, including atomic data, e.g. conversion electrons, X-rays, Auger-electrons.

During international inter-comparison exercises, differences in measured activities due to decay scheme data used.

DDEP established in 1995: common evaluation methodology and review.

The Consultative Committee on Ionising Radiation (CCRI) of the Bureau International des Poids et Mesures (BIPM), recommended the DDEP data be used by all metrology institutes.

Evaluations are compiled and edited by the LNHB and published as volumes of BIPM Monographie-5.

Decay Data Evaluation Project (DDEP) Mission

Provide recommended decay data to non-specialists, who are generally metrologists working in the field of spectrometry, or with liquid scintillation techniques.

We strive to provide all of the relevant data, meaning, half-life, energy and emission intensities for the main decay radiations; alpha, beta and gamma, but also the associated atomic data due to the internal conversion process, with the energy and emission intensities for X-rays, conversion electrons, and Auger electrons.

To provide access to these data in as convenient a way as possible.

Access to decay scheme data (2)

Nuclide		Tables	Com
Co-58	^{58}Co	table	com
Zr-93	^{93}Zr	table	com
Nb-93m	^{93m}Nb	table	com
Cu-61	^{61}Cu	table	com
Pm-148	^{148}Pm	table	com
Pm-148m	^{148m}Pm	table	com
Zn-63	^{63}Zn	table	com
Se-75	^{75}Se	table	com
Rh-106	^{106}Rh	table	com
Ru-106	^{106}Ru	table	com
Cl-36	^{36}Cl	table	com

```
Nuclide ; Co-58
Element ; Cobalt
Z ; 27
Daughter(s) ; (B+, EC) ; Fe-58
Half-life (d) ; 70.85 ; 0.03
Half-life (s) ; 6.1214E6 ; 0.0026E6
Decay constant (1/s) ; 113.233E-9 ; 0.048E-9
Mass activity (Bq/g) ; 1.17570E15 ; 0.00050E15
Reference ; CEA/LNE-LNHB - 2013
Coincidence threshold: 10 %
Emissions (8 lines)  sorted by increasing energy
-----------------------------------------------
Energy (keV) ; Ener. Unc. (keV) ; Intensity (%)
0.7312 ;  ; 0.609 ; 0.018 ; XL ; Fe-58 ;  ;  ;
6.39091 ;  ; 7.98 ; 0.11 ; XKa2 ; Fe-58 ;  ;  ;
6.40391 ;  ; 15.63 ; 0.19 ; XKa1 ; Fe-58 ;  ;  ;
7.0832 ;  ; 3.23 ; 0.05 ; XKb1 ; Fe-58 ;  ;  ;
511 ;  ; 29.88 ; 0.32 ; g511 ; Fe-58 ; -1 ; -1 ;
810.7602 ; 0.0020 ; 99.44 ; 0.02 ; g ; Fe-58 ; 1
863.958 ; 0.006 ; 0.700 ; 0.022 ; g ; Fe-58 ; 2
1674.705 ; 0.006 ; 0.528 ; 0.013 ; g ; Fe-58 ; 2
===============================================
```

```
PAR CO58
AZP 58 ; 27
NDA 1
COM ***************** Evaluation Date: 07/10/2013 ***************
COM ==================== Daughter Separator =====================
DAU FE58
DDE 1 ;  ; 2 ; 11
Q   2307.9 ; 1.1
COM ---------------------- Branch Separator ----------------------
CK  0.0109 ; 0.00031 ; 2 ; 633.169 ; 1.1 ; 0
CL1 0.001179 ; 0.000037 ; 2 ; 633.169 ; 1.1 ; 0
CL2 0.000006 ; 0.000006 ; 2 ; 633.169 ; 1.1 ; 0
CM  0.00019 ; 0.000008 ; 2 ; 633.169 ; 1.1 ; 0
CN  0.0000086 ; 0.0000025 ; 2 ; 633.169 ; 1.1 ; 0
COM ---------------------- Branch Separator ----------------------
BEP 0.1494 ; 0.0016 ; 1 ; 475.1338 ; 1.1 ; 0
CK  0.7448 ; 0.002 ; 1 ; 1497.1338 ; 1.1 ; 0
CL1 0.0796 ; 0.0011 ; 1 ; 1497.1338 ; 1.1 ; 0
CL2 0.00042 ; 0.00042 ; 1 ; 1497.1338 ; 1.1 ; 0
CM  0.01283 ; 0.00042 ; 1 ; 1497.1338 ; 1.1 ; 0
CN  0.00059 ; 0.00017 ; 1 ; 1497.1338 ; 1.1 ; 0
COM ---------------------- Branch Separator ----------------------
COM -------------- Level Separator - T1/2 in seconds -------------
LED 1674.731 ; 0.006 ; 10 ; 1.6E-12 ; 4.E-13 ; 2
GA  0.007 ; 0.00022 ; 863.958 ; 0.006 ; 1
EK  0.00000146 ; 0.00000005 ; 856.853 ; 0.006 ; 1
EL1 0.000000137 ; 0.000000005 ; 863.119 ; 0.006 ; 1
EL2 0.000000001106 ; 0.000000000045 ; 863.244 ; 0.006 ; 1
EL3 0.00000000104 ; 0.00000000005 ; 863.257 ; 0.006 ; 1
GA  0.00528 ; 0.00013 ; 1674.705 ; 0.006 ; 0
EK  0.000000305 ; 0.000000009 ; 1667.619 ; 0.006 ; 0
EL1 0.0000000286 ; 0.0000000008 ; 1673.885 ; 0.006 ; 0
EL2 0.0000000001394 ; 0.000000000004 ; 1674.01 ; 0.006 ; 0
EL3 0.000000000194 ; 0.000000000006 ; 1674.023 ; 0.006 ; 0
COM -------------- Level Separator - T1/2 in seconds -------------
```