

ORTEC[®]

NuclideNavigator[®]-Pro

Interactive Chart of the Nuclides and Reference Program
for
Microsoft[®] Windows[®] 10

C53-BW
Software User's Manual

Version 4.1.0

Advanced Measurement Technology, Inc.

a/k/a/ ORTEC®, a subsidiary of AMETEK®, Inc.

WARRANTY

THIS SOFTWARE IS PROVIDED "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL ORTEC, THE COPYRIGHT OWNER, OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

NuclideNavigator-Pro was developed for AMETEK by Walter King and Associates

Copyright© 2014-2020 Walter King and Associates
All Rights Reserved.

Copyright © 2021, Advanced Measurement Technology, Inc. All rights reserved.

ORTEC® is a registered trademark of Advanced Measurement Technology, Inc. All other trademarks used herein are the property of their respective owners.

NOTICE OF PROPRIETARY PROPERTY —This document and the information contained in it are the proprietary property of AMETEK Inc., ORTEC Business Unit. It may not be copied or used in any manner nor may any of the information in or upon it be used for any purpose without the express written consent of an authorized agent of AMETEK Inc., ORTEC Business Unit.

Table of Contents

1.	INTRODUCTION	4
2.	NuclideNavigator-Pro Chart of the Nuclides	5
2.1	File Menu	7
2.2	Tools Menu	7
2.3	View Menu	8
2.4	Help Menu.....	10
2.5	Elemental Properties	15
2.6	Nuclide Information	16
2.7	Spectrum Viewer.....	21
2.8	Library Search.....	24
3.	Library Lister	27
3.1	File Menu	27
3.2	About Menu	28
3.3	Reporting Controls	28
4.	Library Manager	30
4.1	Source Menu	30
4.2	Options Menu.....	31
4.3	Help Menu.....	33
4.4	Target Menu	33
4.5	Edit Menu.....	34
4.6	Source Library Controls.....	37
4.7	Target Library Controls.....	37
5.	Decay Calculator	38
5.1	File Menu	38
5.2	Plot Options Menu	39
5.3	Spectrum Menu	39
5.4	About Menu	40
5.5	Chart Right-Click menu	40
5.6	Decay Time Controls	41
5.7	Decay Types.....	41
6.	Periodic Chart of the Elements	46
6.1	File Menu	46
6.2	Help Menu.....	47
6.3	Navigation Controls	48
7.	Units Converter.....	50
7.1	Navigation	50
Appendix A	– References.....	51
A.1	Nuclide and Emissions Data	51
A.2	Decay Schemes	52
A.3	Fission Yields.....	52
A.4	Neutron Cross Sections	52
A.5	Example Spectra.....	52
A.6	Decay Calculation Methodology.....	52
A.7	Elemental Data	52

1. INTRODUCTION

NuclideNavigator-Pro is an extensive resource for nuclear decay and emissions data, elemental information, and a wide variety of standard unit conversions. It is comprised of several interactive programs and reference materials which can be accessed from the Windows Start menu or from the main NuclideNavigator-Pro application interface as follows:

- NuclideNavigator-Pro is the main application interface for the Chart of the Nuclides with a variety of ways to view, navigate, and query nuclear data provided in several databases compiled from various references described in Appendix A. Synthetic gamma-ray spectra in high (HPGe) and low (NaI) resolution detector response functions, and synthetic spectra of beta-, beta+, and alpha emissions are also available. (See Section 2.)
- The Library Lister is used to generate nuclear data reports based on a subset of nuclides selected from a master database. (See Section 3.)
- The Library Manager is used to create libraries compatible with standard ORTEC applications, such as GammaVision, or an XML format that may be used with other applications. (See Section 4.)
- The Decay Calculator provides several decay options including simple decay of a single nuclide, parent-daughter decay/build-up, full decay chains for a nuclide and its progeny, user-defined nuclide groups, and Cf-252 calculations. (See Section 5.)
- The Periodic Chart of the Elements provides an intuitive interface to view elements by physical form and chemical groups with easy access to basic physical properties. (See Section 6.)
- The Units Converter application is a simple tool to convert units for an extensive list of engineering and scientific parameters. (See Section 7.)
- Decay Schemes are provided in PDF format. (See Section A.2)
- A function for displaying synthetic spectra for an individual nuclide in the NuclideNavigator-Pro program and decay chain gammas in the Decay Calculator.

Nuclear data from several references (See Appendix A) are included as Master libraries in the SQLite database format. These files are in the directory C:\ProgramData\Ametek\Data Libraries by default. The legacy Microsoft Access libraries from the standard NuclideNavigator can also be used as Master libraries. Modifications to the Master libraries are not recommended as changes could create incompatibilities with NuclideNavigator-Pro. If changes or queries to the database are desired, then it is highly recommended to make a copy of the original databases before opening these files outside of the NuclideNavigator-Pro program. An SQLite Database Browser program is available in the application directory for use by experienced database administrators to query and customize SQLite databases if desired.

2. NuclideNavigator-Pro Chart of the Nuclides

NuclideNavigator-Pro is the main program interface for the Chart of the Nuclides. Nuclear data is provided in master libraries provided in the SQLite Database format or the legacy Microsoft Access Databases distributed with the standard NuclideNavigator program. Links to the other utility programs and reference data provided with NuclideNavigator-Pro are also available from the associated menu and toolbar shortcuts.

The screenshot displays the NuclideNavigator-Pro interface with the following data visible in the nuclide chart:

Element	Isotope	Half-life	Decay Mode	Energy (E)	Yield (σ)
Carbon (C)	C 8	1.98E-21 s	0+	E 12.142692, 8.037643	σ_a .004, .002
	C 9	126.5 ms	(3/2-)	E 16.494482, 9.031037	
Boron (B)	B 7	3.25E-22 s	(3/2-)	E 11.907551, 7.029712	
	B 8	770.0 ms	2+	E 17.979906, 8.024608	
Beryllium (Be)	Be 6	4.95E-21 s	0+	E 4.288155, 6.019726	
	Be 7	53.22 d	3/2-	E .861894, 7.016929	
Lithium (Li)	Li 5	3.04E-22 s	3/2-	E .447653, 5.012538	
	Li 6	7.590	1+	E 6.015123	σ_y .038, σ_a 941, 423

At the bottom of the interface, the status bar shows: Cell: 142px, C 12, Z = 6, n = 6, Carbon, Pu-240 Fission, Chain Yield (%), Independent Yield (%), Cumulative Yield (%).

To get started simply select a library from the associated File menu or toolbar shortcut, adjust the display from the desired View menus, navigate the chart, and access library information using the following controls:

-  To the far left on the toolbar allows a direct jump to the specified nuclide. The specified nuclide will be positioned near the bottom left in the General Electric and Karlsruhe Chart views, and near the top left in the TriLinear Chart views.
-  Shifts the displayed region of the chart diagonally along the "Ridge of Stability".

- Slider bars along the horizontal axis at the bottom of the window and vertical axis to the right of the window shifts the displayed region along the Neutron and Proton axes, respectively.
- While hovering over a nuclide in the chart the information bar at the bottom of the window displays the nuclide information and fission yields for that nuclide as a result of fission from the nuclide selected from the menu **View\Fission Yields**.

Cell: 100 px	Sr 90	Z = 38	n = 52	Strontium	U-235 Fission	Chain Yield (%)	5.87344	Independent Yield (%)	0.07370	Cumulative Yield (%)	5.78000
--------------	-------	--------	--------	-----------	---------------	-----------------	---------	-----------------------	---------	----------------------	---------

- Double-Click on an element box (to the far left of isotope boxes when the General Electric and Karlsruhe Chart formats are displayed) to access detailed information, such as as x-ray energies/intensities and elemental abundances. Note that the element fields are not available with the Trilinear chart display. (See Section 2.5.)
- Double-Click on a nuclide in the chart to access detailed information, such as gamma, beta, and alpha emissions, parents and daughters, example spectra, and more. (See Section 2.6.)

7. Tool Bar Shortcuts

-  Open Source Library (Same as **File\Open Source Library** menu)
-  Print Preview (See **File\Print Preview** menu)
-  Print Selected Region of the Chart (See **File\Print** menu)
-  Zoom In to View More Detail (See **Tools\Zoom\In** menu)
-  Zoom Out to View More Nuclides (See **Tools\Zoom\Out** menu)
-  Search the Data Library (See **Tools\Search\Gammas (or Alphas)** menu)
-  Periodic Chart of the Elements (See **Tools\ Periodic Chart** menu)
-  Units Converter (See **Tools\ Units Converter** menu)
-  Nuclear Decay Schemes (See **Tools\Decay Schemes** menu)
-  Decay Calculator (See **Tools\Decay Calculator** menu)
-  Library Manager (See **Tools\Library Manager** menu)
-  Library Lister (See **Tools\Library Lister** menu)

2.1 File Menu

2.1.1 Open Source Library

Displays a standard File-Open dialog to browse to the desired library in SQLite database format (default for NuclideNavigator-Pro) or Microsoft Access database format (compatible with standard NuclideNavigator). See Appendix A for information related to the reference materials associated with the database included with NuclideNavigator-Pro.

2.1.2 Library Information

Displays a brief description of the source data as well as the numbers of alpha, beta and gamma records contained in the database

2.1.3 Recent Files

Displays paths to recently opened source libraries which can be selected instead of using the Open Source Library browse dialog.

2.1.4 Page Setup

Opens a dialog box to set the paper size and source, orientation and margins for printing a portion of the nuclide chart.

2.1.5 Print Preview

Displays a preview of the current nuclide chart that can be printed.

2.1.6 Print

Displays a dialog box to select a printer, set properties, and print the currently displayed nuclide chart.

2.1.7 Exit

Closes the application.

2.2 Tools Menu

2.2.1 Zoom (In/Out)

Decreases/Increases the number of nuclides displayed on the chart view.

2.2.2 Search Library (Gammas/Alphas)

Opens the Search Dialog with the search type set to Gammas or Alphas respectively. See Section 2.8.

2.2.3 Periodic Chart

Opens the Periodic Chart of the Elements application. See Section 6.

2.2.4 Units Converter

Opens the Units Converter application. See Section 7.

2.2.5 Decay Schemes

Opens the Decay Scheme PDF file. See Appendix A.2.

2.2.6 Decay Calculator

Opens the Decay Calculator application. See Section 5.

2.2.7 Library Manager

Opens the Library Manager application. See Section 4.

2.2.8 Library Lister

Opens the Library Lister application. See Section 3.

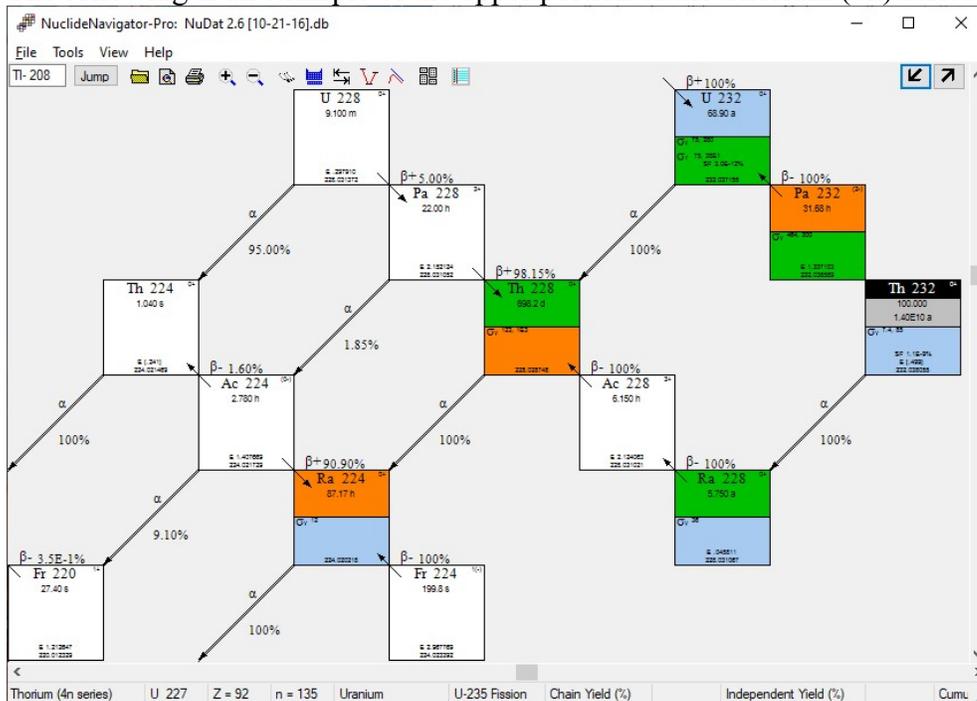
2.3 View Menu

2.3.1 Nuclides

The Nuclide Chart can be set to display only the natural decay chains of ^{232}Th , ^{233}U , ^{238}U , and ^{235}U to easily “walk” down these decay chains using the following options:

- All Nuclides in the Library
- Thorium (4n) Series (^{232}Th Natural Chain)
- Neptunium (4n + 1) Series (^{233}U Natural Chain)
- Uranium (4n + 2) Series (^{238}U Natural Chain)
- Actinium (4n + 3) Series (^{235}U Natural Chain)

The following is an example of the upper portion of the Thorium (4n) series:



2.3.2 Fission Yields

While hovering over a nuclide in the chart the information bar at the bottom of the window displays the nuclide information and fission yields for that nuclide as a result of fission from the selected nuclide. Fission yield data is available for the following nuclides:

- ^{233}U
- ^{235}U
- ^{237}Np
- ^{239}Pu
- ^{240}Pu

2.3.3 Chart Format

Display the Chart of the Nuclides in one of the following formats:

- General Electric: Color scheme based on half-life and thermal neutron cross section.
- Karlsruhe: Color scheme based on decay mode.
- TriLinear Layout with Standard (General Electric) or Decay Colors (Karlsruhe) color scheme

The Knolls Atomic Power Laboratory (KAPL) was operated by General Electric for more than four decades and in 1946, produced the first of fourteen editions of the Chart of the Nuclides, or as it came to be known as, the General Electric (GE) Chart. While three more editions have subsequently been published by KAPL, under two different operating contractors, it is still often referred to as the GE Chart. The GE format of proton number on the vertical axis and neutron number on the horizontal axis quickly became the standard configuration for most Charts of the Nuclides, along with the use of color to display additional information. In this case, stable and naturally radioactive isotopes, as well as the magnitudes of a nuclide's half-life and neutron cross sections.

The Karlsruhe format was first published in 1958 by the Radiochemistry Institute in the Nuclear Research Center (Kernforschungszentrum Karlsruhe, GmbH). It uses the standard layout (proton number on the vertical axis and neutron number on the horizontal axis) and color to indicate stable isotopes and the decay modes of radioactive isotopes.

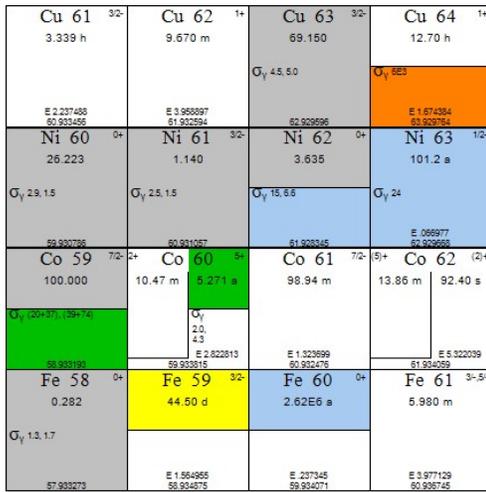
The Trilinear display was developed at the Oak Ridge National Laboratory (ORNL) in the late 1940's² by W. H. Sullivan and published in 1957³. It is a unique way of looking at the chart of the nuclides where isotopes and isotones are diagonal, isobaric decay is vertical, and alpha decay is horizontal. Either of the color schemes (half-life or decay mode) can be applied with this view.

A full description of the color coding is available by selecting the Help - Legend menu item. (Section 2.4.1)

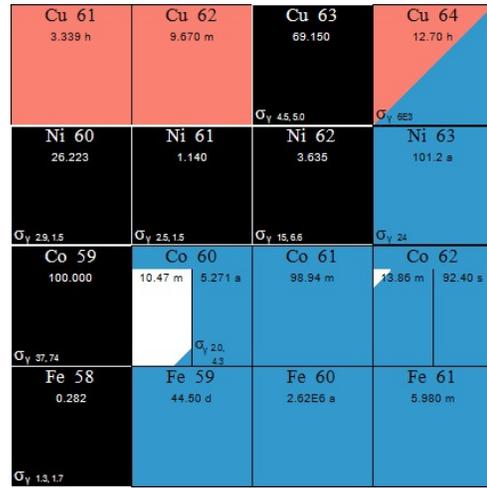
¹ Nuclides and Isotopes, Chart of the Nuclides, Seventeenth Edition, Revised 2009, E. M. Baum et al., Knolls Atomic Power Laboratory, operated by Bechtel Marine Propulsion Corporation.

² Trilinear Chart of Nuclides, William H. Sullivan, OR-WHS-2159

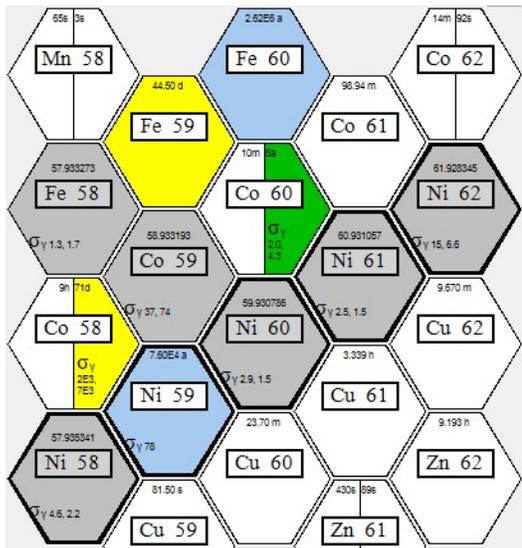
³ W. H. Sullivan, Trilinear Chart of the Nuclides, 2nd Edition, (U.S. Government Printing Office, Washington D.C., 1957).



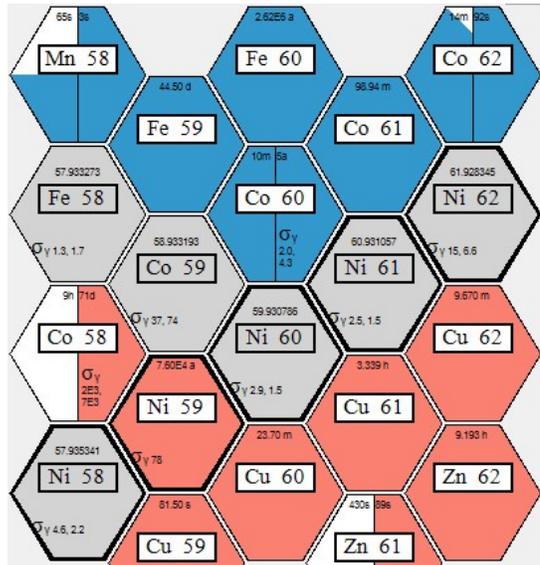
General Electric Display Format



Karlsruhe Display Format



Trilinear Format with GE Color Scheme



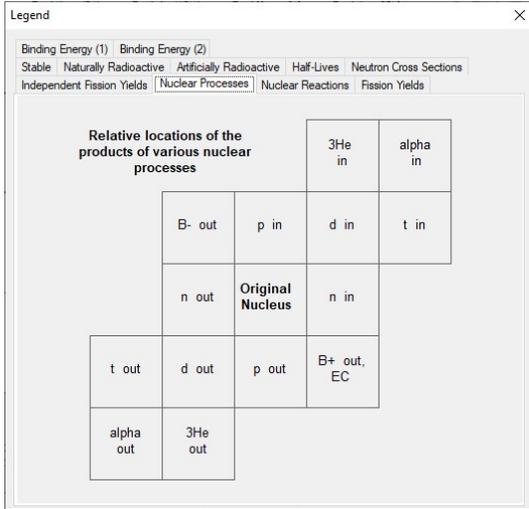
Trilinear Format with Decay Color Scheme

2.4 Help Menu

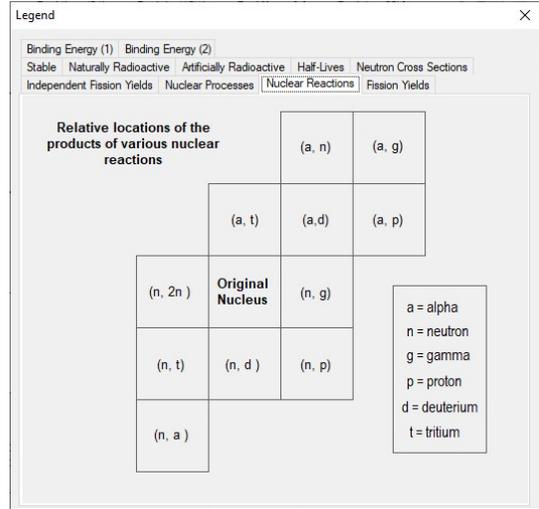
2.4.1 Legend

The Legend Dialog contains tabs that dynamically change depending on the selected Chart Format as well as tabs for parameters that are independent of the chart format.

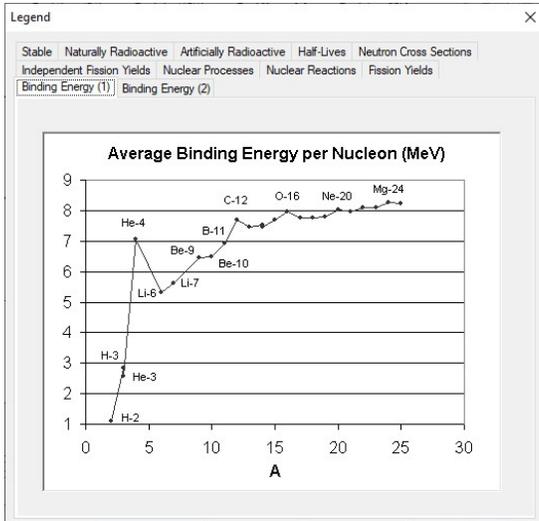
The independent tabs include Nuclear Processes and Nuclear Reactions that demonstrate how to navigate the Chart of the Nuclides based on the specified processes, Binding Energy plots with a full view of all atomic numbers and a zoomed region for atomic numbers up to 25, and a fission yield chart for U-233, U-235, and Pu-239.



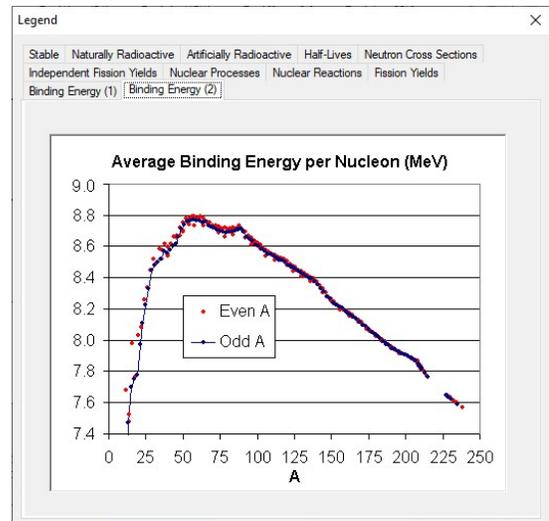
Nuclear Processes



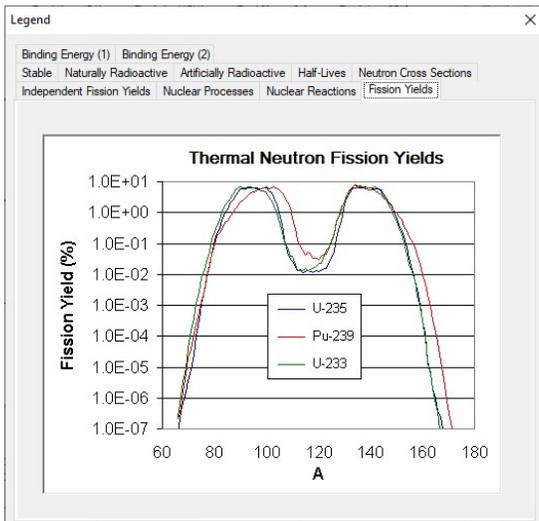
Nuclear Reactions



Binding Energy 1 <= A <= 25

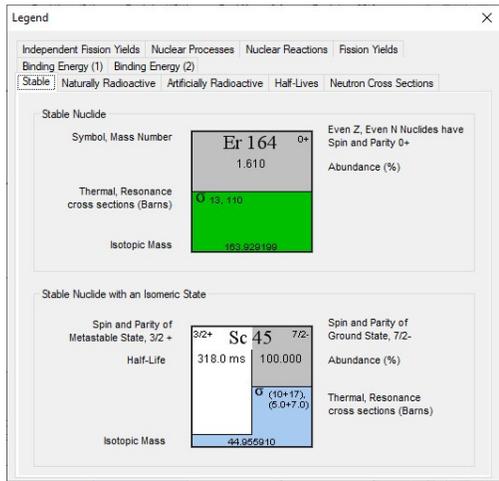


Binding Energy 1 <= A <= 238

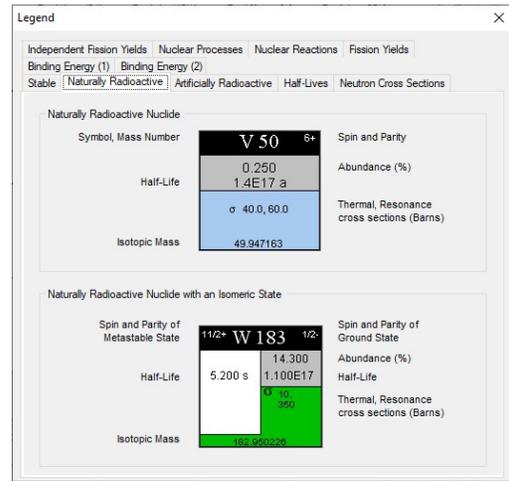


Fission Yields

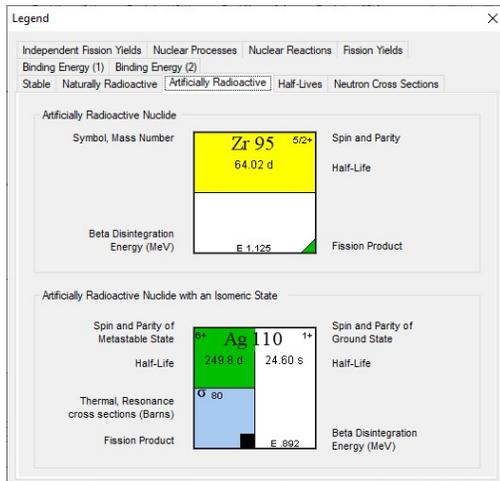
When the General Electric or Trilinear (Standard) Chart display is selected the Legend includes color codes for the following tabs:



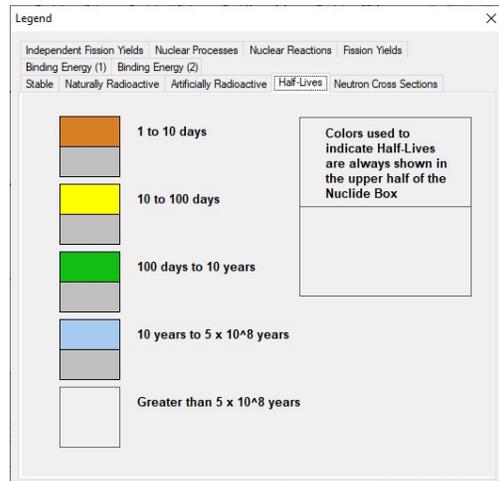
Stable



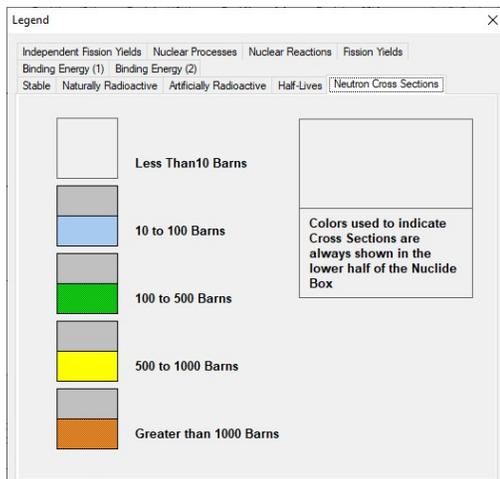
Naturally Radioactive



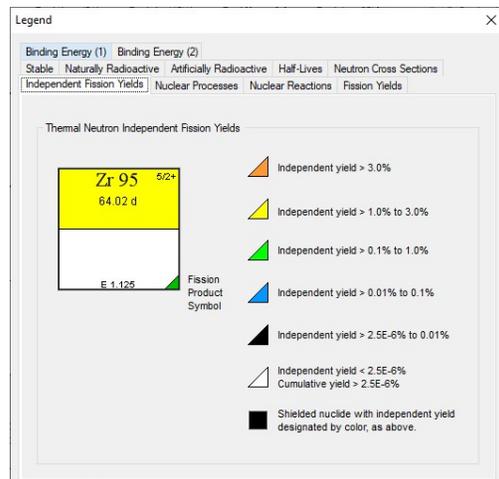
Artificially Radioactive



Half Lives



Neutron Cross Sections

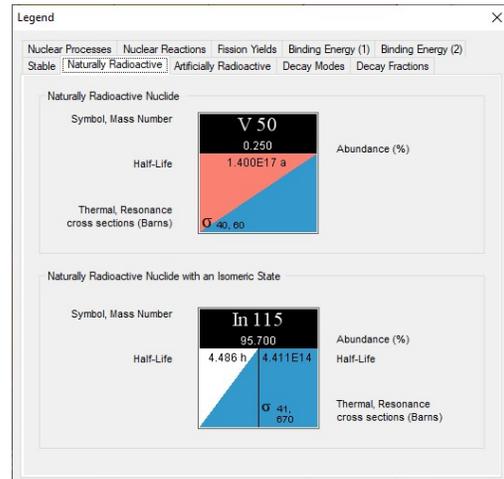


Independent Fission Yields

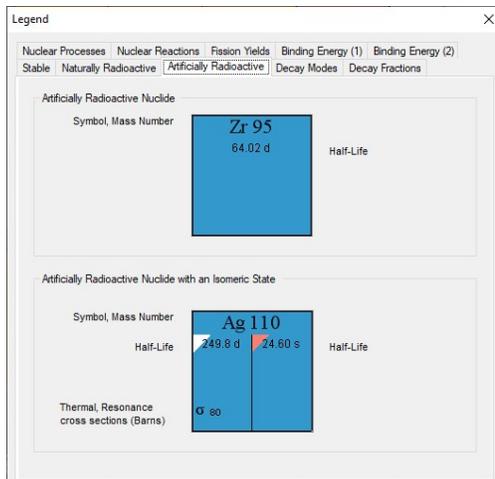
When the Karlsruhe or Trilinear (Decay Colors) Chart display is selected the Legend includes color codes for the following tabs:



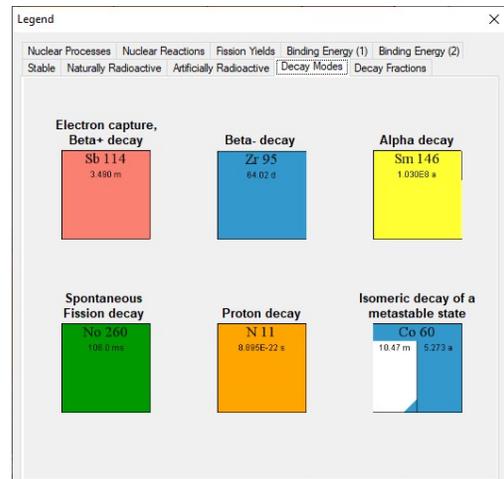
Stable



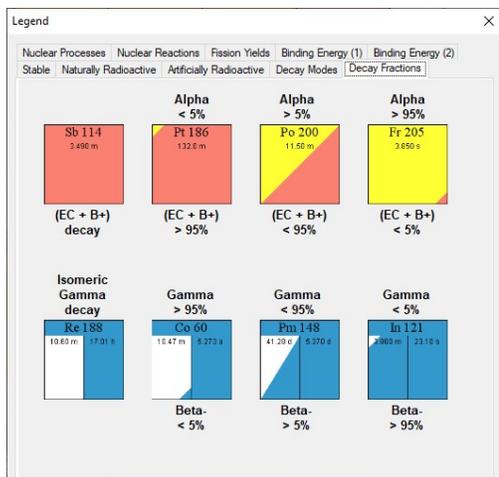
Naturally Radioactive



Artificially Radioactive



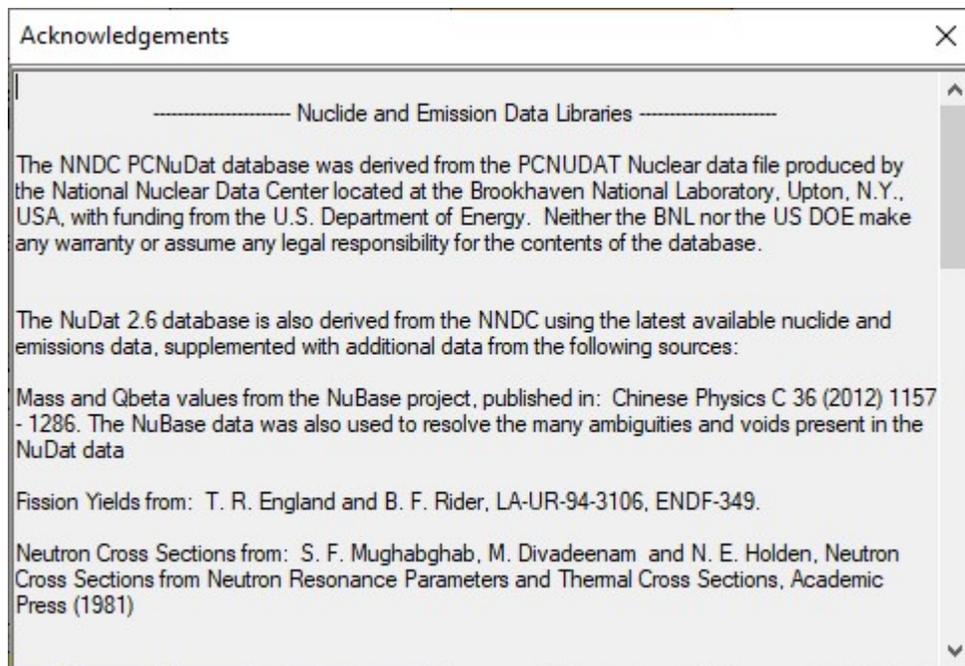
Decay Modes



Decay Fractions

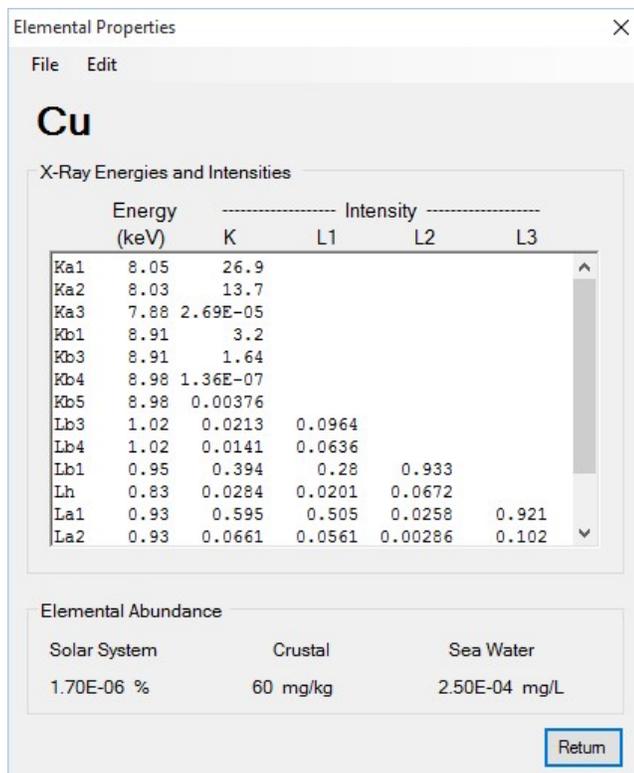
2.4.2 About

Displays the about page with acknowledgements as follows:



2.5 Elemental Properties

The Elemental Properties shown below are accessed by Double-Clicking on an element box (to the far left of isotope boxes when the General Electric and Karlsruhe Chart formats are displayed).



The screenshot shows a window titled "Elemental Properties" for the element Copper (Cu). The window has a menu bar with "File" and "Edit". Below the element symbol, there is a section for "X-Ray Energies and Intensities" which contains a table with columns for Energy (keV) and Intensity (K, L1, L2, L3). Below this is a section for "Elemental Abundance" with columns for Solar System, Crustal, and Sea Water. A "Return" button is located at the bottom right of the window.

	Energy (keV)	Intensity			
		K	L1	L2	L3
Ka1	8.05	26.9			
Ka2	8.03	13.7			
Ka3	7.88	2.69E-05			
Kb1	8.91	3.2			
Kb3	8.91	1.64			
Kb4	8.98	1.36E-07			
Kb5	8.98	0.00376			
Lb3	1.02	0.0213	0.0964		
Lb4	1.02	0.0141	0.0636		
Lb1	0.95	0.394	0.28	0.933	
Lh	0.83	0.0284	0.0201	0.0672	
La1	0.93	0.595	0.505	0.0258	0.921
La2	0.93	0.0661	0.0561	0.00286	0.102

Elemental Abundance		
Solar System	Crustal	Sea Water
1.70E-06 %	60 mg/kg	2.50E-04 mg/L

2.5.1 File Menu

2.5.1.1 Exit

Closes the window.

2.5.2 Edit Menu

2.5.2.1 Copy All

Copies all of the X-ray data to the clipboard.

2.5.2.2 Copy All

Copies only the selected X-ray data to the clipboard.

2.5.3 Controls

2.5.3.1 Return Button

Closes the window.

2.6 Nuclide Information

The Nuclide Properties shown below are accessed by Double-Clicking on a nuclide in the chart.

Co- 60

Properties

Half Life: 5.271 a

Abundance: [] Spectrum

Thermal: Meta: -, Ground: 2.0

Resonance: Meta: -, Ground: 4.3

Daughters

Ni- 60: 1.000e+00

Parents

Fe- 60

Co- 60m

Radiation

Gamma (selected), Beta, Alpha

State

g (selected), m, n, a, b, c

Gamma Rays

Energy	Branch (%)	BR Codes	A Gamma 1	A Gamma 2
0.85	0.00033	AX	1332.49	1173.23
7.46	0.00322	AX	1332.49	1173.23
7.48	0.00630	AX	1332.49	1173.23
8.27	0.00039	AX	1332.49	1173.23
8.27	0.00076	AX	1332.49	1173.23
347.14	0.00750	A	1332.49c	1173.23
826.10	0.00760	A	1332.49c	1173.23
1173.23	99.85000	A	1332.49c	826.10
1332.49	99.98260	A	1173.23c	826.10c
2158.57	0.00120	A	1332.49	1173.23
2505.69	2.0E-06	A	1332.49	1173.23

2.6.1 File Menu

2.6.1.1 Exit

Closes the window.

2.6.2 Listing Menu

Generates a report of the nuclide's information as shown in the example below with several of the fission yield and energy emissions omitted for brevity. The content of this report is dependent on the Radiation Type button selected (Gamma, Beta, or Alpha). The content may be saved to a file or printed from the File menu options, or copied to the clipboard from the Edit menu options.

```

Data from Library: NuDat 2.6 [5-22-15].mdb

Nuclide = Kr- 85      Half life = 10.75 a

Isotopic_Mass      84.912527262
Spin and Parity    9/2+
Beta Decay Energy  0.687000 MeV
Decay Mode(s)      B-

Neutron Cross Sections and Resonance Integrals (Barns, unless otherwise noted)
Energy      Metastable State      Ground State
-----
Thermal     -                      1.7
Resonance   -                      1.8

Parent: Br- 85
Parent: Kr- 85m

Daughter: Rb- 85      Branching Ratio = 1.000E+00

----- Nuclide Flags -----
Thermal  Fast  Thermal Natural  Photon  Charged
neutron  neutron  Fission  Isotope  Reaction  Particle
X        X        X

-----
Generators: IFT

----- Fission Yields (%) -----
                Independent      Cumulative      Chain
U-233 Thermal      0.0956          0.523          2.2837173
...
U-233 Fast         0.056           0.468
...
U-233 14 MeV      0.109           0.512
...

-----
Energy      Branching
(keV)      Ratio (%) BrCodes      .... Associated Gammas (keV) ....      Single Double
                                                Escape Escape
-----
514.00     0.43400  A      151.18 362.81 129.81 0.00
13.40     0.00104  AX     514.00 151.18 362.81 129.81
...

-----
The nuclide Kr- 85 has 10 gamma(x) rays. (10 were listed.)

Associated Gammas followed by a 'c' (362.81c) are in cascade coincidence with the
primary gamma

-----
Br Codes:
A = Absolute intensity, photons per 100 decays
R = Relative Intensity, the most intense transition is set to 100
X = X-ray line
D = Unresolved Doublet
C = Complex line, contains two or more unresolved lines
W = Line with weak intensity
? = Existence of transition is doubtful
< = Intensity is less than or equal to the value given
P = Positron annihilation radiation
S = Single Escape Peak
D = Double Escape Peak

```

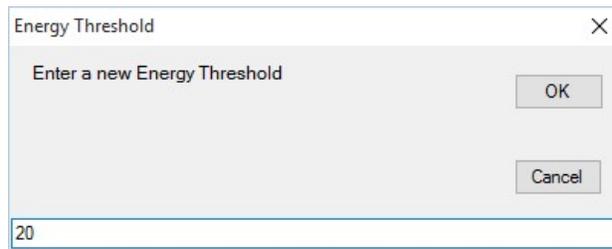
2.6.3 Options Menu

2.6.3.1 View / Report

Specifies the number of gamma and alpha energies to include in the nuclide information report generated from the Listing Menu. Options include All energies or Top 5, 10, 15, or 20 based on branching ratio.

2.6.3.2 Display Threshold Energy

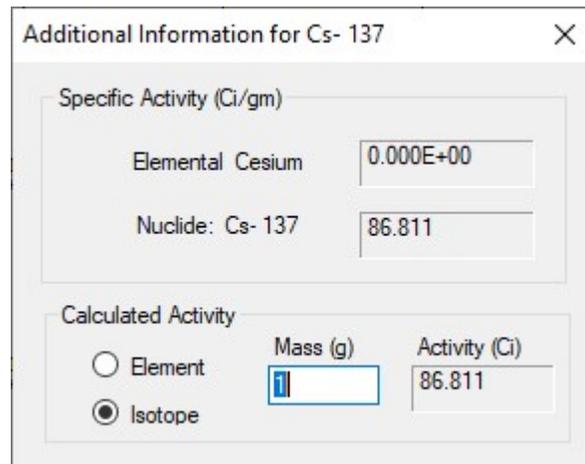
Displays a dialog box to enter a minimum gamma/alpha energy in keV. Energy emissions less than the threshold energy are not included in the nuclide information report generated from the Listing Menu.



The dialog box is titled "Energy Threshold" and contains a text input field with the value "20". To the right of the input field are two buttons: "OK" and "Cancel".

2.6.4 Specific Activity Menu

Displays a dialog showing the specific activity for this nuclide and element in Curies per Gram. An optional mass may be entered to calculate the activity for the element or isotope.



The dialog box is titled "Additional Information for Cs- 137" and is divided into two sections: "Specific Activity (Ci/gm)" and "Calculated Activity".

Specific Activity (Ci/gm)

Elemental Cesium	0.000E+00
Nuclide: Cs- 137	86.811

Calculated Activity

<input type="radio"/> Element	Mass (g)	Activity (Ci)
<input checked="" type="radio"/> Isotope	1	86.811

2.6.5 Controls

2.6.5.1 Properties

The properties section includes the nuclide half-life, natural abundance, and the thermal and resonance neutron capture cross sections (barns, if not otherwise noted) for the meta-stable and ground states.

Properties		
Half Life	432.6 a	Spectrum
Abundance		
	Meta	Ground
Thermal	54	533
Resonance	195	1E3

2.6.5.2 Spectrum Button

Displays a synthetic gamma, beta, or alpha spectrum depending on the Radiation button selected. (See Section 2.7.)

2.6.5.3 Radiation Buttons

The selected button specifies the type of emission information displayed in the energy table, nuclide information reported from the Listing Menu, and the synthetic spectrum generated when clicking the Spectrum button.

Radiation		
<input checked="" type="button" value="Gamma"/>	<input type="button" value="Beta"/>	<input type="button" value="Alpha"/>

2.6.5.4 Daughters and Parents

Displays the Daughter(s) and branching ratio(s) of different decay modes and Parent(s) of the current selected nuclide. Clicking on a daughter or parent nuclide will shift the current selection to that nuclide and allowing walking up or down a decay chain. Note that Spontaneous fission (Sp-Fiss) is a special case that does not change the nuclide selection.

Daughters		Parents
<input type="text" value="Np- 237"/>	<input type="text" value="1.000E+0"/>	<input type="text" value="Pu- 241"/>
<input type="text" value="Sp-Fiss"/>	<input type="text" value="4.000E-12"/>	<input type="text" value="Cm- 241"/>
<input type="text" value="-"/>	<input type="text" value="-"/>	<input type="text" value="Bk- 245"/>

2.6.5.5 State Buttons

Sets the state of the nuclide (ground, first meta-stable, second meta-stable, etc.) to be displayed.



2.6.5.6 Energy Emissions Table

This table displays Gamma, Beta, or Alpha emissions based on the Radiation button selected as shown below.

Gamma Rays				
Energy	Branch (%)	BR Codes	A Gamma 1	A Gamma 2
4.29	5.80000	AX	81.00	79.61
30.63	13.60000	AX	81.00	79.61
30.97	25.00000	AX	81.00	79.61
34.99	4.56000	AX	81.00	79.61
81.00	36.90000	A	79.61c	160.61

Betas				
E.P. Energy	Branch (%)	Avg. Energy	Type	
43.60	0.00870	11.10	B-	
266.80	1.40000	75.16	B-	
346.40	98.50000	100.62	B-	

Alphas				
Energy	Branch (%)		A Alpha 1	A Alpha 2
4215.80	6.01000		4395.40	4364.30
4364.30	18.92000		4395.40	4215.80
4395.40	57.73000		4364.30	4215.80
4556.10	3.82000		4395.40	4364.30
4597.40	4.77000		4395.40	4364.30

Click on the Energy (Gamma/Alpha) or End Point Energy (Beta) buttons to sort the table by ascending energy order.

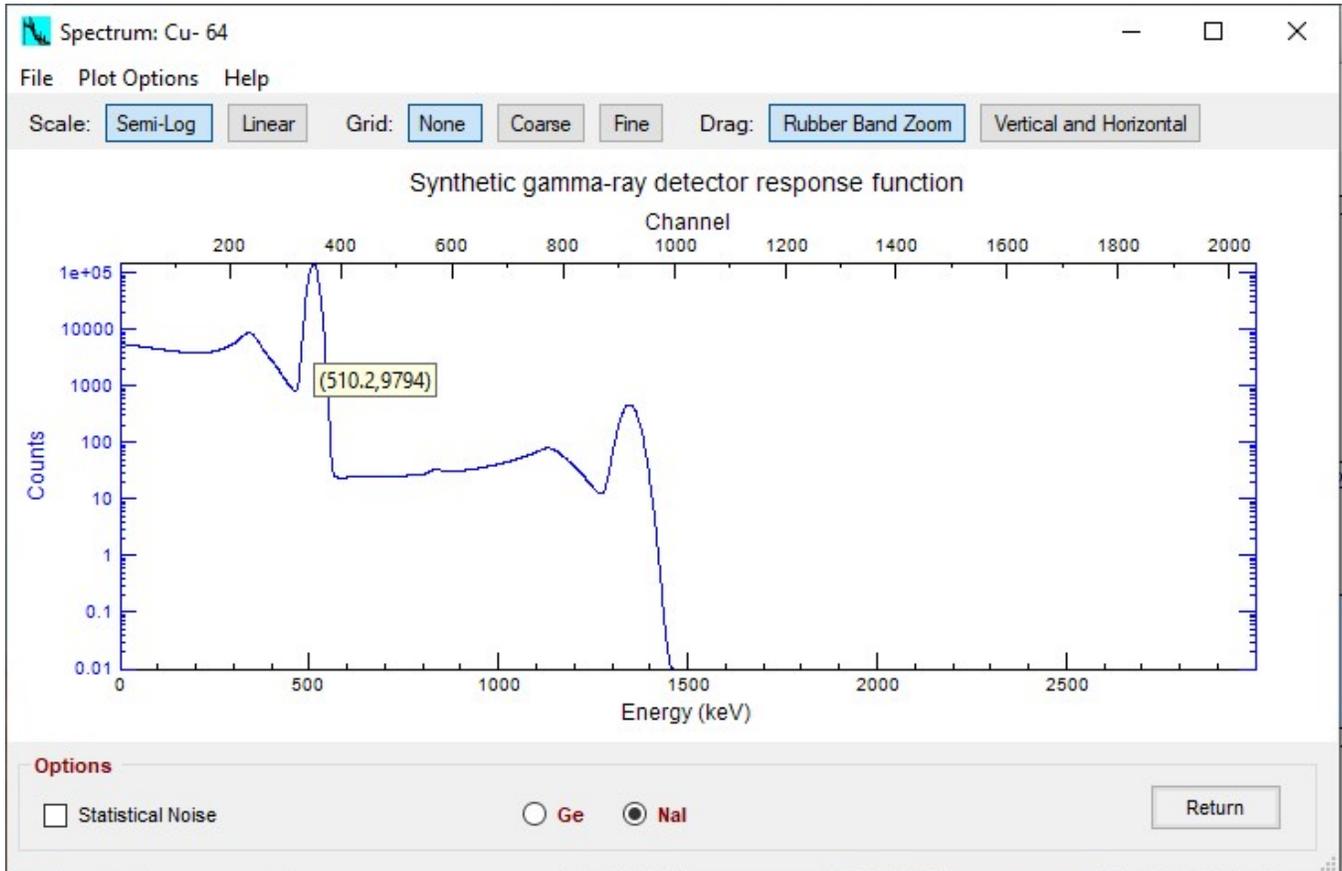
Click on the Branch (%) button to sort the table by descending Branching Ratio order.

Click on the BR codes button to display a list of codes and their meanings.

The A Gamma or Alpha 1 and A Gamma or Alpha 2 columns display associated gamma or alpha energies based on abundance/branching ratio. Energies followed by “c” indicate that those gammas are emitted in cascade coincidence.

2.7 Spectrum Viewer

The spectrum view displays synthetic spectra for the specified emission type. For gamma emissions the spectra can be displayed for both High Resolution (Germanium) and Low Resolution (Sodium Iodide) detector types. See Appendix A.5 for methodologies employed for synthetic spectra.



2.7.1 File Menu

2.7.1.1 Exit Form

Closes the window.

2.7.2 Plot Options Menu

2.7.2.1 Scale

Sets the axis to **Linear** or **Semi-Log** scale.

2.7.2.2 Display

Sets plot display properties for grid lines and guidelines.

2.7.2.2.1 Grid

Set grid lines to None, Course, or Fine.

2.7.2.2.2 Guidelines

Optionally display vertical and/or horizontal lines across the plot based on the cursor (mouse pointer) location. The options are enabled when checked and disabled when not checked.

2.7.2.3 Drag

Specifies spectrum navigation properties.

2.7.2.3.1 Rubber Band Zoom

Click and drag the mouse around a region of the plot to zoom in on that region. To restore the display to the full spectrum, right-click and select "Original Dimensions".

2.7.2.3.2 Vertical and Horizontal

The spectrum is treated as a "window" that can be dragged vertically and horizontally. To restore the display to the full spectrum, right-click and select "Original Dimensions".

2.7.2.3.3 Axis

When enabled (checked) the range of each axis can be changed by dragging the mouse along the desired axis outside of the plot area.

2.7.3 Help

2.7.3.1 Graph Options

Displays a dialog which indicates that Right-Clicking on the graph will show additional plot options.

2.7.4 Right-Click menu

Right clicking on the spectrum will display a menu of functions related to the plot area.

2.7.4.1 Original Dimensions

Returns the spectrum to full view after zooming or dragging.

2.7.4.2 Show World Coordinates

Displays the energy and counts at the cursor (mouse) location as it is moved over the spectrum.

2.7.4.3 Print

Prints an image of the spectrum plot to the specified printer.

2.7.4.4 Copy to Clipboard

Copies an image of the spectrum plot to the clipboard which can be pasted into documents that support graphics.

2.7.4.5 Copy Data to Clipboard

Copies the data set used to create the spectrum plot (energy/counts data pairs) to the clipboard. This data set can be pasted into text documents or spreadsheet applications for evaluation.

2.7.5 Controls

2.7.5.1 Toolbar Buttons

Scale, Grid and Drag buttons duplicate the related menu functions.

2.7.5.2 Statistical Noise Checkbox

Adds statistical noise variation from channel to channel when checked or smooth the spectrum data when unchecked.

2.7.5.3 Return Button

Closes the Window.

2.8 Library Search

The Library Search utility shown below is accessed from the menu Tools\Search Library (Gammas or Alphas) or the Toolbar Search button. It is effectively a visual query tool with multiple parameters and criteria settings to limit the results to the most relevant information.

Search for Gammas by Energy and Selected Options

File Search For

Generator Search Options

- Thermal Neutron Activation (T)
- Fast Neutron Activation (F)
- Fission Product (I)
- Naturally Occuring Isotope (N)
- Photon Reaction (P)
- Charged Partical Reaction (C)

Additional Search Options

- Prompt Capture Gammas

Energy (keV) 375

Window (+/- keV) 2

Match Associated Lines

First 414 +/- 2

Second 0 +/- 2

Half Life Search Options

Minimum 30 d

Maximum 0 y

Search Close

2.8.1 File Menu

2.8.1.1 Select Prompt Gamma Library

Standard File Open dialog is displayed to select the library used for prompt gamma searches. This library is only used when the Prompt Capture Gammas option is selected.

2.8.1.2 Exit

Closes the search window.

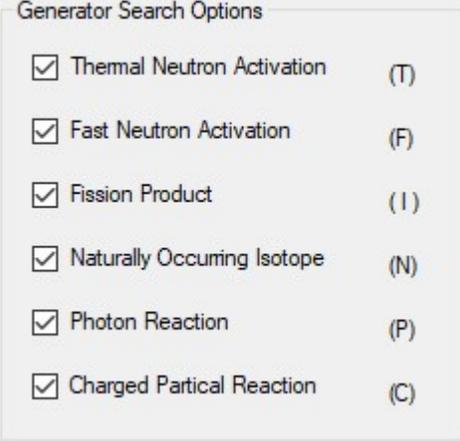
2.8.2 Search For Menu

Sets the query criteria to either Gamma or Alpha emissions.

2.8.3 Search Controls

2.8.3.1 Generator Search Options

Only nuclides generated by the generation processes that are checked will be returned in the data search.



Generator Search Options	
<input checked="" type="checkbox"/> Thermal Neutron Activation	(T)
<input checked="" type="checkbox"/> Fast Neutron Activation	(F)
<input checked="" type="checkbox"/> Fission Product	(I)
<input checked="" type="checkbox"/> Naturally Occuring Isotope	(N)
<input checked="" type="checkbox"/> Photon Reaction	(P)
<input checked="" type="checkbox"/> Charged Partical Reaction	(C)

2.8.3.2 Energy (keV) and Window (+/- keV)

Sets the energy range for the gamma or alpha peak search

2.8.3.3 Match associated Lines

This option limits the search results to only nuclides that emit up to two additional peaks in a specified range in addition to the primary target energy.

2.8.3.4 Half-Life Search Options

This option limits the search results to only those nuclides with half-lives within the specified Minimum and Maximum criteria.

2.8.3.5 Additional Search Options Prompt Capture Gamma

This option allows running a second independent search on a Prompt Gamma Library (gammas emitted immediately following the capture of a neutron) in addition to the main Source Library.

2.8.3.6 Search

Runs the search and displays the results as shown in Section 2.8.4..

2.8.3.7 Close

Close the Library Search window.

2.8.4 Search Results

The search results are displayed in a report format as shown below. If the Prompt Capture Gammas option was selected then independent search results from the specified database are shown after the primary search results.

Search Results

File Edit

----- Library Search -----
 Library: C:\ProgramData\AMETEK\Data Libraries\NuDat 2.6 [10-21-16].db

SEARCH CRITERIA:
 Gamma Energy = 1330 keV - 1334 keV
 Associated line(s) = 1171 keV - 1175 keV
 = 824 keV - 828 keV
 Half Lives = Unbounded
 Generators = Unbounded

.... Gamma-Ray				First Associated		Second Associated		
Energy	Br Ratio	Nuclide	Gen	Half Life	Gamma	Br Ratio	Gamma	Br Ratio
1330.03	6.9E-05	Sr- 83	FC	32.41 h	1174.08	4.5E-04	827.81	4.0E-05
1331.81	4.7E-03	Ir- 188	C	41.50 h	1174.59	1.3E-02	824.34	1.0E-02
1331.95	1.8E-05	Re- 188	TF	17.00 h	1174.57	1.9E-04	825.20	1.9E-04
1331.95	1.8E-05	Re- 188	TF	17.00 h	1174.57	1.9E-04	826.90	7.0E-05
1332.49	1.0E+00	Co- 60	TF	5.271 a	1173.23	1.0E+00	826.10	7.6E-05
1332.50	8.8E-01	Cu- 60	C	23.70 m	1173.20	2.6E-03	826.40	2.2E-01
1332.80	2.6E-03	Ba- 143	I	14.50 s	1171.70	7.5E-04	827.00	1.9E-03
1333.10	3.0E-04	Ba- 143	I	14.50 s	1171.70	7.5E-04	827.00	1.9E-03

RESULTS:
 8 Line(s) Matched the Search Criteria.

----- Prompt Gamma Library Search -----
 Library: C:\ProgramData\AMETEK\Data Libraries\NuDat 2.6 [10-21-16].db

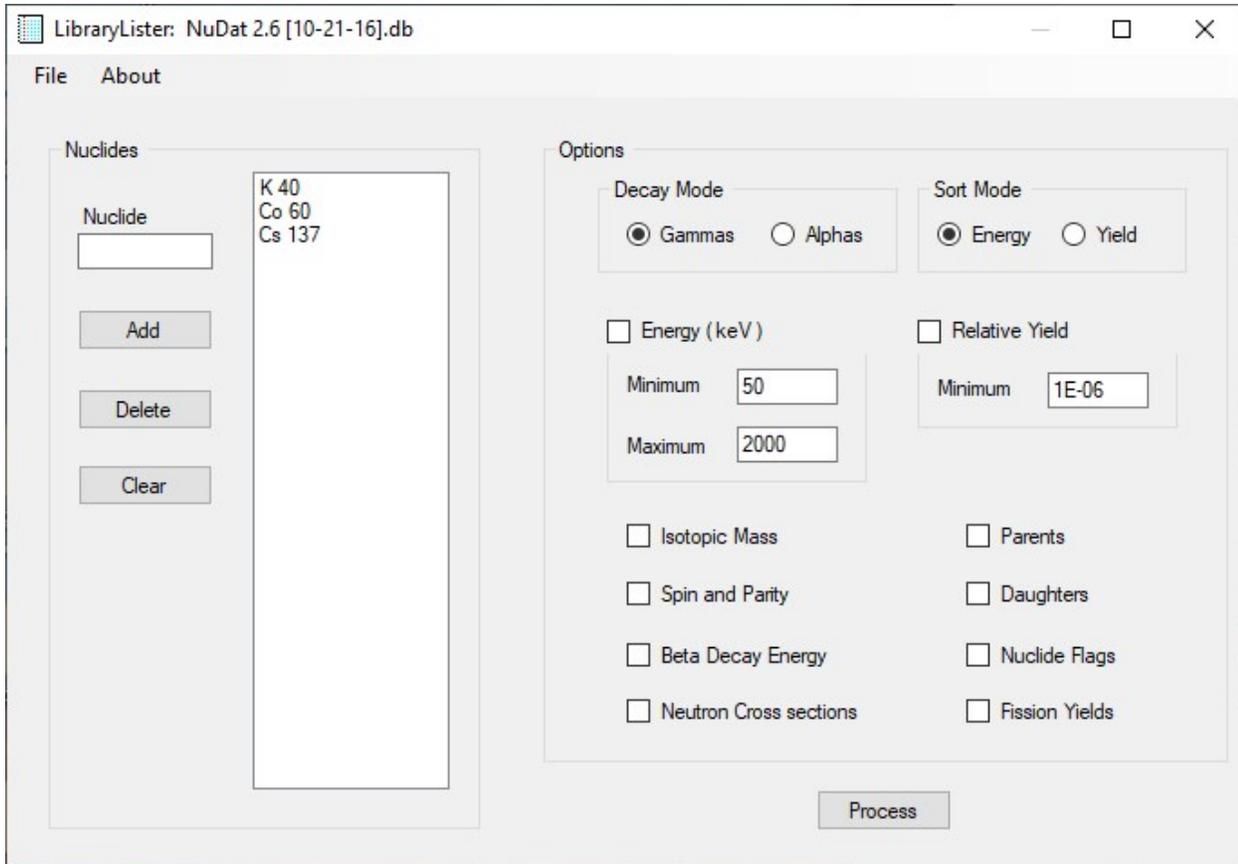
SEARCH CRITERIA:
 Energy: Between 1330 AND 1334 keV

The results can be saved to a text file or printed from the File Menu options or copied to the clipboard using the Edit menu options.

Double-Clicking on a row in the search results will display the nuclide information dialog described in Section 2.6 for the nuclide on that row.

3. Library Lister

The Library Lister is a tool for reporting the emissions and properties of selected nuclides from a specified library.



3.1 File Menu

3.1.1 Open

Displays a standard File-Open dialog to browse to the desired library in SQLite database format (default for NuclideNavigator-Pro) or Microsoft Access database format (compatible with standard NuclideNavigator).

3.1.2 Library Information

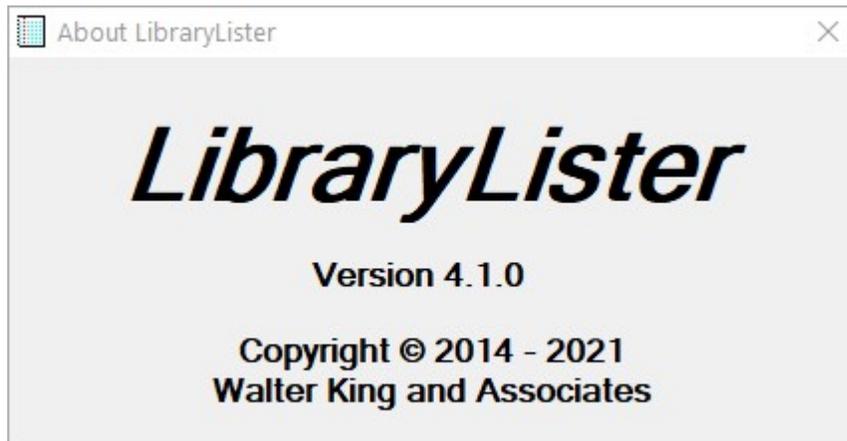
Displays a brief description of the source data as well as the numbers of alpha, beta and gamma records contained in the database

3.1.3 Exit

Closes the Library Lister application.

3.2 About Menu

Displays the Library Lister About page.



3.3 Reporting Controls

3.3.1 Nuclide List

3.3.1.1 Add Button

Add the name specified in the nuclide field to the list.

3.3.1.2 Delete Button

Remove the nuclide currently selected from the list.

3.3.1.3 Clear Button

Remove all nuclides from the list.

3.3.2 Options

These options specify the content of the Library Lister report

3.3.2.1 Decay Mode

Specifies the type of emissions reported (Gamma or Alpha energies).

3.3.2.2 Sort Mode

Specifies how the energy emission table will be sorted by Energy (ascending) or Yield/Branching Ratio (descending).

3.3.2.3 Energy (keV)

Optionally specify a minimum and maximum energy range to report. If unchecked all energy emissions are reported unless restricted by the Relative Yield criteria.

3.3.2.4 Relative Yield

Optionally specify a minimum Yield (Branching Ratio) for energies to report. If unchecked all energy emissions are reported unless restricted by the Energy criteria.

3.3.2.5 Nuclide Properties

Optionally include (checked) or exclude (not checked) the specified nuclide properties.

3.3.3 Process Button

Generate a report based on the nuclide list and options specified as shown in the example below.

```
Output
File Edit

Data from Library: NuDat 2.6 [10-21-16].db
Data Source: National Nuclear Data Center, information extracted from NuDat 2.6 database,
version 10/21/2016, http://www.nndc.bnl.gov/nudat2/

Minimum Energy Displayed: 50 keV
Maximum Energy Displayed: 3000 keV

Nuclide = Co-60    Half life = 5.271 a

Isotopic_Mass      59.933815002
Spin and Parity    5+
Beta Decay Energy  2.822813 MeV
Decay Mode(s)      B-

Neutron Cross Sections and Resonance Integrals (Barns, unless otherwise noted)
Energy  Metastable State  Ground State
-----
Thermal      -                2.0
Resonance    -                4.3

Parent: Fe- 60
Parent: Co- 60m

Daughter: Ni- 60    Branching Ratio = 1.000E+00

----- Nuclide Flags -----
Thermal  Fast  Thermal  Natural  Photon  Charged
neutron  neutron Fission  Isotope  Reaction Particle
X        X

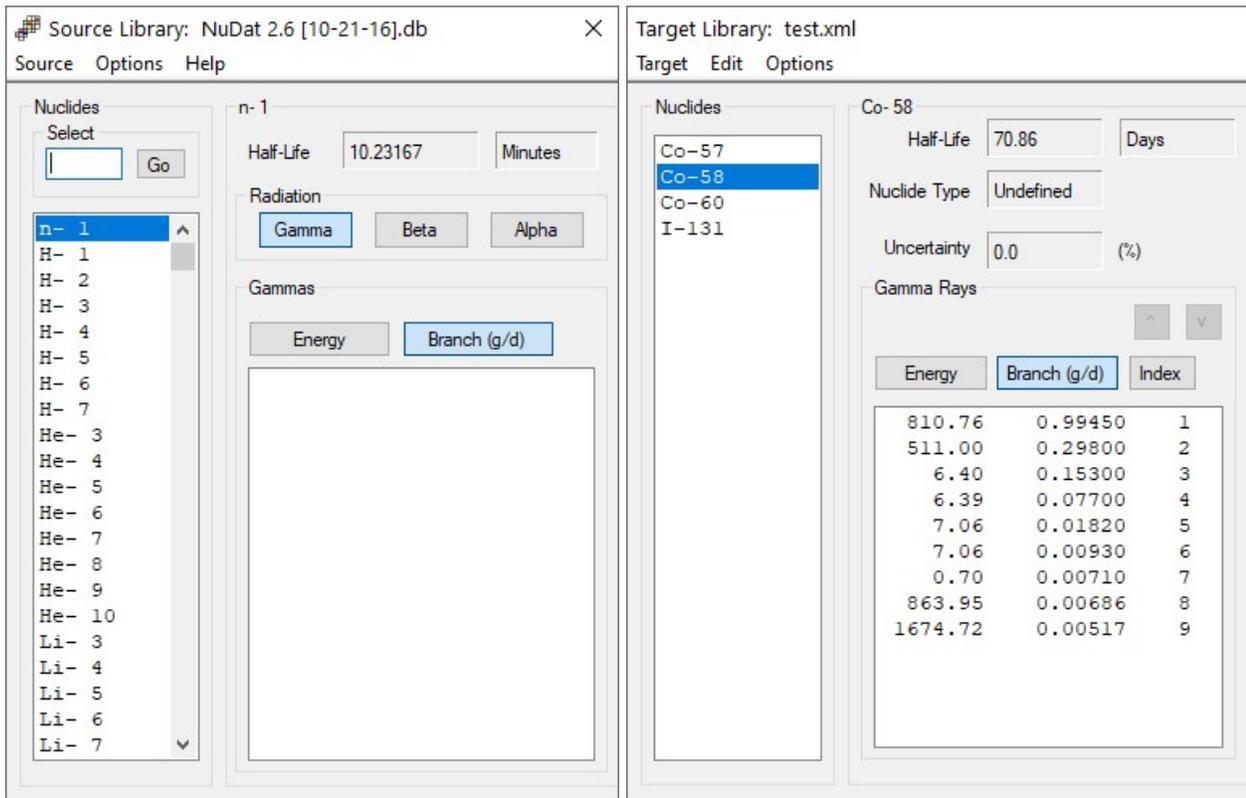
-----
Generators: FT

Energy  Branching  BrCodes  Associated Gammas (keV)
(keV)   Ratio (%)
-----
347.14  0.00750  A        1332.49c  1173.23  826.10c  2158.57c
826.10  0.00760  A        1332.49c  1173.23  347.14c  2158.57
1173.23 99.85000  A        1332.49c  826.10   347.14   2158.57
1332.49 99.98260  A        1173.23c  826.10c  347.14c  2158.57
```

The results can be saved to a text file or printed from the File Menu options or copied to the clipboard using the Edit menu options.

4. Library Manager

The Library Manager is used to create application specific libraries compatible with standard ORTEC applications, such as GammaVision, or XML formats that can be used with other applications. The application is designed with Source and Target library windows as shown below. Nuclides may be added to the Target library by simply selecting the nuclide from the Source list and dragging it with the mouse to the Target nuclide list. The energies copied are based on the Radiation button selected (Gamma, Beta, or Alpha) and various options to control/limit the energies copied with the nuclide can be set in the Options/Preferences settings. Once copied to the Target library, the nuclide and energy data can be edited, or nuclides and associated data can be entered manually if desired.



4.1 Source Menu

4.1.1 Open Source Library

This menu has options for opening a library to be used as the Source. Library types include Master Library (SQLite or Access database format) and Target Library (.LIB, .XML, and Access file formats). Either option will display a standard File Open dialog to select the desired file type. Alternatively, a library may be selected from the **Recent Files** menu.

4.1.2 Library Information

Displays a brief description of the source data as well as the numbers of alpha, beta and gamma records contained in the database.

4.1.3 Nuclide Information

Displays a report similar to the Library Lister for the nuclide selected in the Source list. The number and order of the emission lines listed are controlled by selections made on the Options/Preferences pages.

4.2 Options Menu

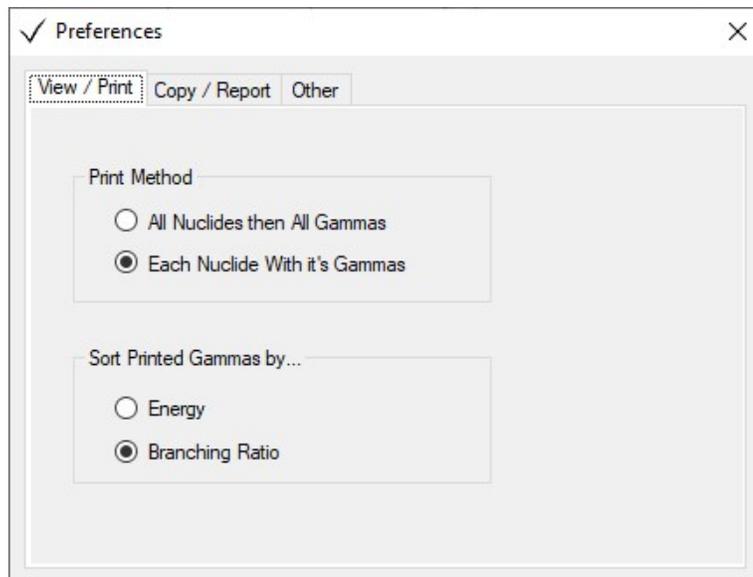
Displays the Preferences dialog which has three tabs (View/Print, Copy/Report, and Other) that match the Options submenus. When selecting the submenus the respective tab is set as the active menu when the Preferences dialog opens. The other tabs may be selected directly in the Preferences dialog after it is displayed.

Note that the Preferences dialog can be accessed from both the Source and Target window menus.

4.2.1 View / Print

The **Print Method** selection specifies the order for displaying nuclides and peaks when displaying the Nuclide Information reports.

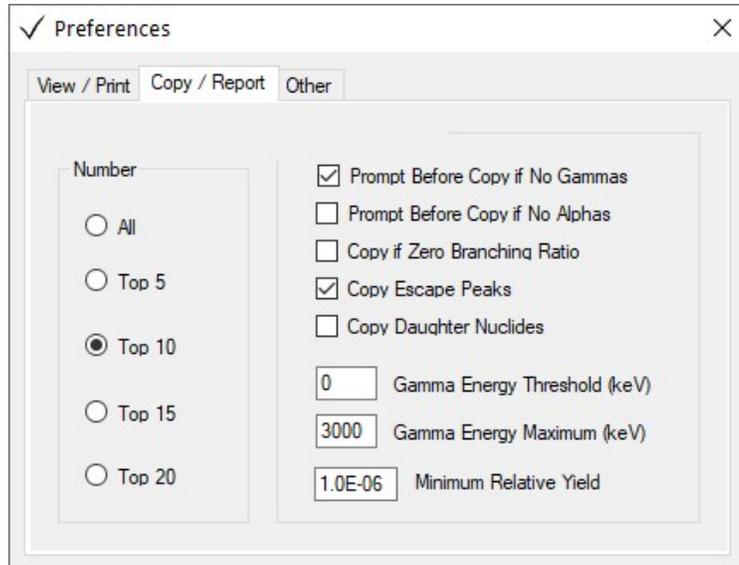
The **Sort Printed Gammas** by selection specifies the sort order of energy emissions by energy (ascending) or Branching Ratio (descending) when the Print Method is set to Each Nuclide with its Gammas. This selection does not affect the peak order when the Print Method is set to All Nuclides then All Gammas.



4.2.2 Copy / Report

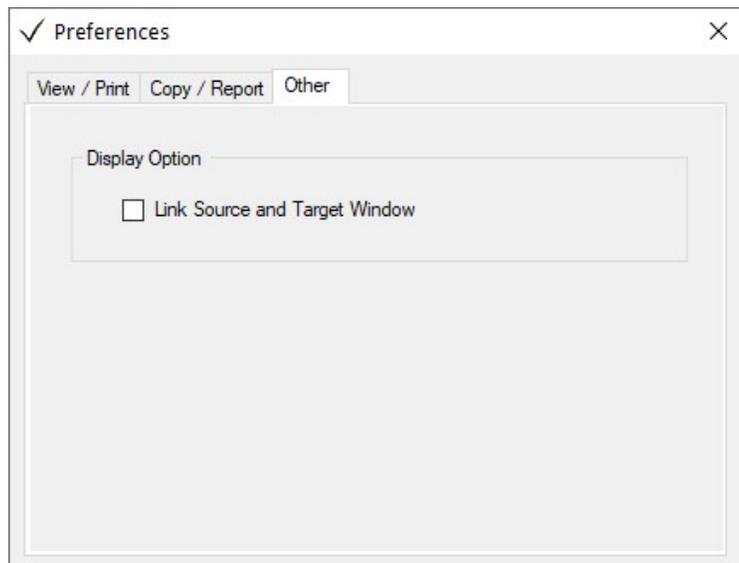
The **Number** selection specifies how many energies will be included when copying a nuclide to the Target. The Top N records are determined based on the highest Branching Ratios. It also specifies how many energies will be displayed on the Source Nuclide Information report. It does not restrict the number of peaks displayed in the list of Source Gammas or the Target Nuclide Information report.

The other options set prompts (or warnings) before copying nuclides that do not have energies of interest, automatically include daughter nuclides, and restrict which peaks are copied to the Target.



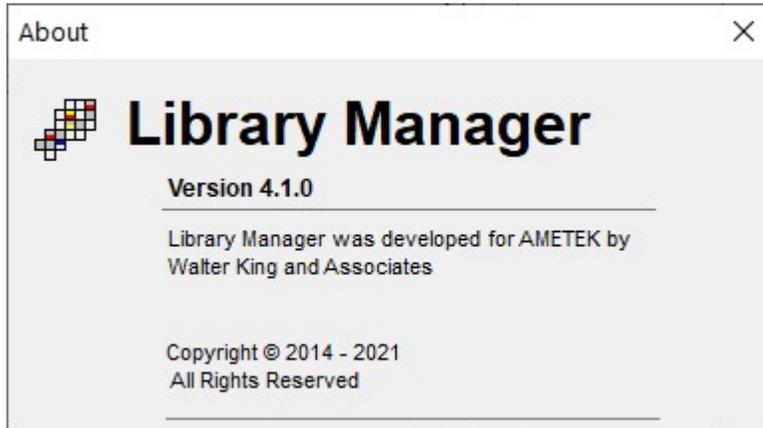
4.2.3 Other

This tab has an option to link the Source and Target windows so that they remain in a constant proximity to one another when either window is moved. When this option is not checked the Source and Target windows can be moved independently without affecting the position of the other.



4.3 Help Menu

Displays the Library Manager about page.



4.4 Target Menu

4.4.1 New Target Library

Clears the Target Library editor fields and current file path.

4.4.2 Open Target Library

Displays a standard File-Open dialog to browse to a support library type (either ORTEC GammaVision .LIB or XML format). Alternatively, a library may be selected from the **Recent Targets** menu.

4.4.3 Save Target As...

Displays a standard File-Save dialog to specify the file location and save the Target library to either the ORTEC GammaVision .LIB or XML format.

4.4.4 Library Information

Displays a brief description of the source data as well as the numbers of alpha, beta and gamma records contained in the database.

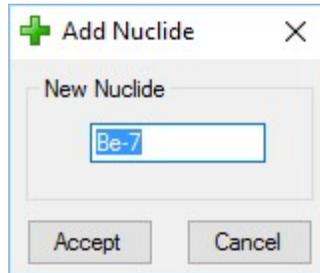
4.4.5 Nuclide Information

Displays a report similar to the Library Lister for all of the nuclides in the Target list. The order of the emission lines listed are controlled by selections made on the Options/Preferences pages.

4.5 Edit Menu

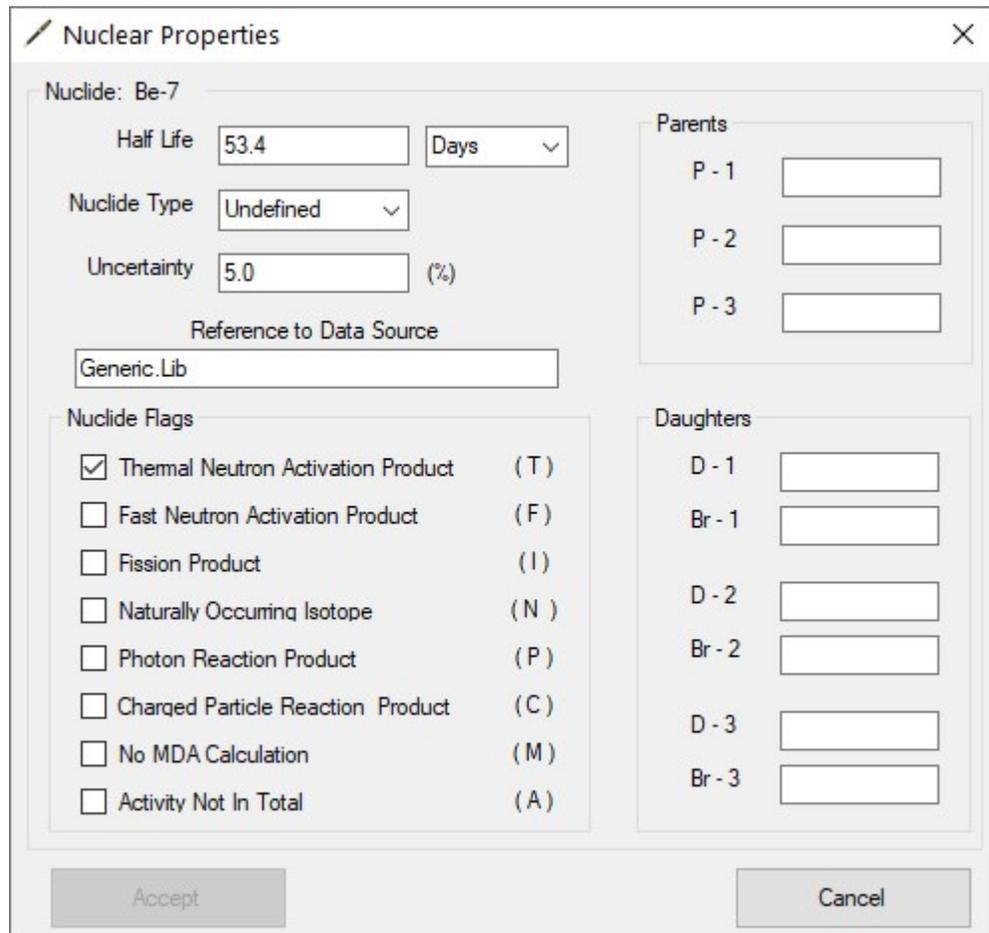
4.5.1 Add Nuclide...

Displays the following dialog where the new isotope name is specified. When the Accept button is clicked the nuclide is added to the Target list.



4.5.2 Edit Nuclide...

Displays the Nuclear Properties dialog to enter or modify nuclide data including the half-life, nuclide type, uncertainty, reference source, nuclide flags, parent nuclides, and daughter nuclides and branching ratios. The **Nuclide Flags** are the same as those used in ORTEC's GammaVision software. The **Accept** button is disabled until changes are made in one of the fields.



Nuclear Properties

Nuclide: Be-7

Half Life: 53.4 Days

Nuclide Type: Undefined

Uncertainty: 5.0 (%)

Reference to Data Source: Generic.Lib

Nuclide Flags

- Thermal Neutron Activation Product (T)
- Fast Neutron Activation Product (F)
- Fission Product (I)
- Naturally Occurring Isotope (N)
- Photon Reaction Product (P)
- Charged Particle Reaction Product (C)
- No MDA Calculation (M)
- Activity Not In Total (A)

Parents

P - 1

P - 2

P - 3

Daughters

D - 1

Br - 1

D - 2

Br - 2

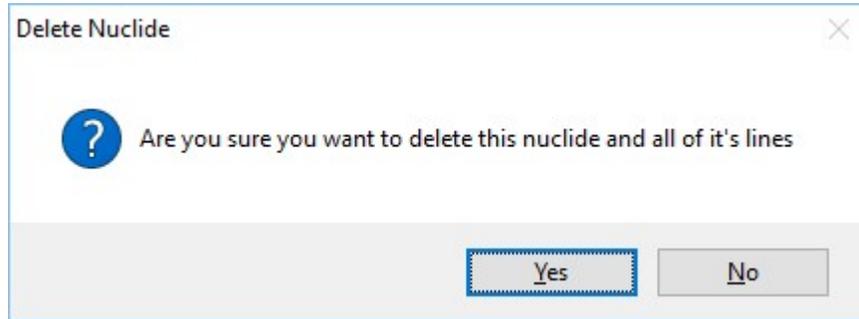
D - 3

Br - 3

Accept Cancel

4.5.3 Delete Nuclide...

Deletes the selected nuclide in the list after acknowledging the following warning prompt.



4.5.4 Add Gamma Ray, Beta, or Alpha...

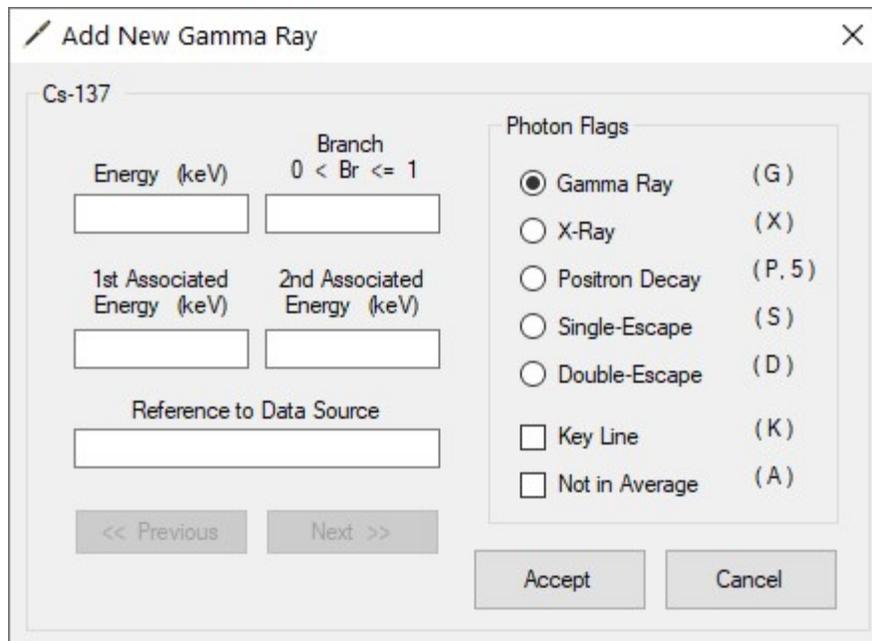
This menu changes to match the **Radiation** type button selected on the Source window, and displays the Add dialog for the associated type.

The Branching Ratio is entered as a fractional value as opposed to a percentage.

The 1st and 2nd Associated Energies (Gamma Ray and Alpha) and Average Energy (Beta) fields require a numeric entry even if only zero.

The **Photon flags** are the same as those used in ORTEC's GammaVision software.

After data is entered click on the **Accept** button to store the peak data or **Cancel** button to close the dialog without saving.



4.5.5 Edit Gamma Ray, Beta, or Alpha...

This menu changes to match the **Radiation** type button selected on the Source window, and displays the Edit dialog for the associated type.

The Branching Ratio is entered as a fractional value as opposed to a percentage.

The 1st and 2nd Associated Energies (Gamma Ray and Alpha) and Average Energy (Beta) fields require a numeric entry even if only zero.

The **Photon flags** are the same as those used in ORTEC's GammaVision software.

After data is entered click on the **Accept** button to store changes.

The << **Previous** and **Next** >> buttons can be used to navigate through peaks in the list without having to close the editor first.

Click the **Cancel** button to close the dialog.

Edit Gamma Rays [Close]

Cs-137

Energy (keV)	Branch 0 < Br <= 1
661.66	0.85100

1st Associated Energy (keV)	2nd Associated Energy (keV)
283.50	0.00

Reference to Data Source
NuDat 2.6 [10-21-16].db

<< Previous Next >>

Photon Flags

- Gamma Ray (G)
- X-Ray (X)
- Positron Decay (P. 5)
- Single-Escape (S)
- Double-Escape (D)
- Key Line (K)
- Not in Average (A)

Accept Cancel

4.5.6 Delete Gamma Ray, Beta, or Alpha...

This menu changes to match the **Radiation** type button selected on the Source window, and deletes the selected energies after acknowledging a warning prompt.

4.5.7 Resort Gammas, Betas, or Alphas by

This menu changes to match the **Radiation** type button selected on the Source window, and sorts the energy table Energy, Branching Ratio, or Sort Index as selected.

4.6 Source Library Controls

4.6.1 Nuclides

All nuclides in the selected library are displayed in the list grouped by element with metastable states list after the ground state isotopes. Enter a nuclide name in the **Select** field and click on the **Go** button to jump to that item in the list. Note that the dash ("-") is optional.

4.6.2 Radiation

Selects the emission type for the library manager. Note that different libraries can be created for Gamma Rays, Betas, and Alphas, but only Gamma Ray libraries are generally used in conjunction with ORTEC's GammaVision software.

4.6.3 Energy List

Displays emissions for the selected nuclide based on the **Radiation** type button selected. The list can be sorted by ascending energy or descending Branching ratio by clicking on the **Energy** and **Branch** buttons in this section.

4.7 Target Library Controls

4.7.1 Nuclides

All nuclides in the selected library are displayed in the list and updated as nuclides are added manually or by dragging from the Source nuclide list.

Right-Click on the nuclide list to display a menu to **Add Nuclide**, **Edit Nuclide**, **Delete Nuclide**, and generate the **Nuclide Information** report.

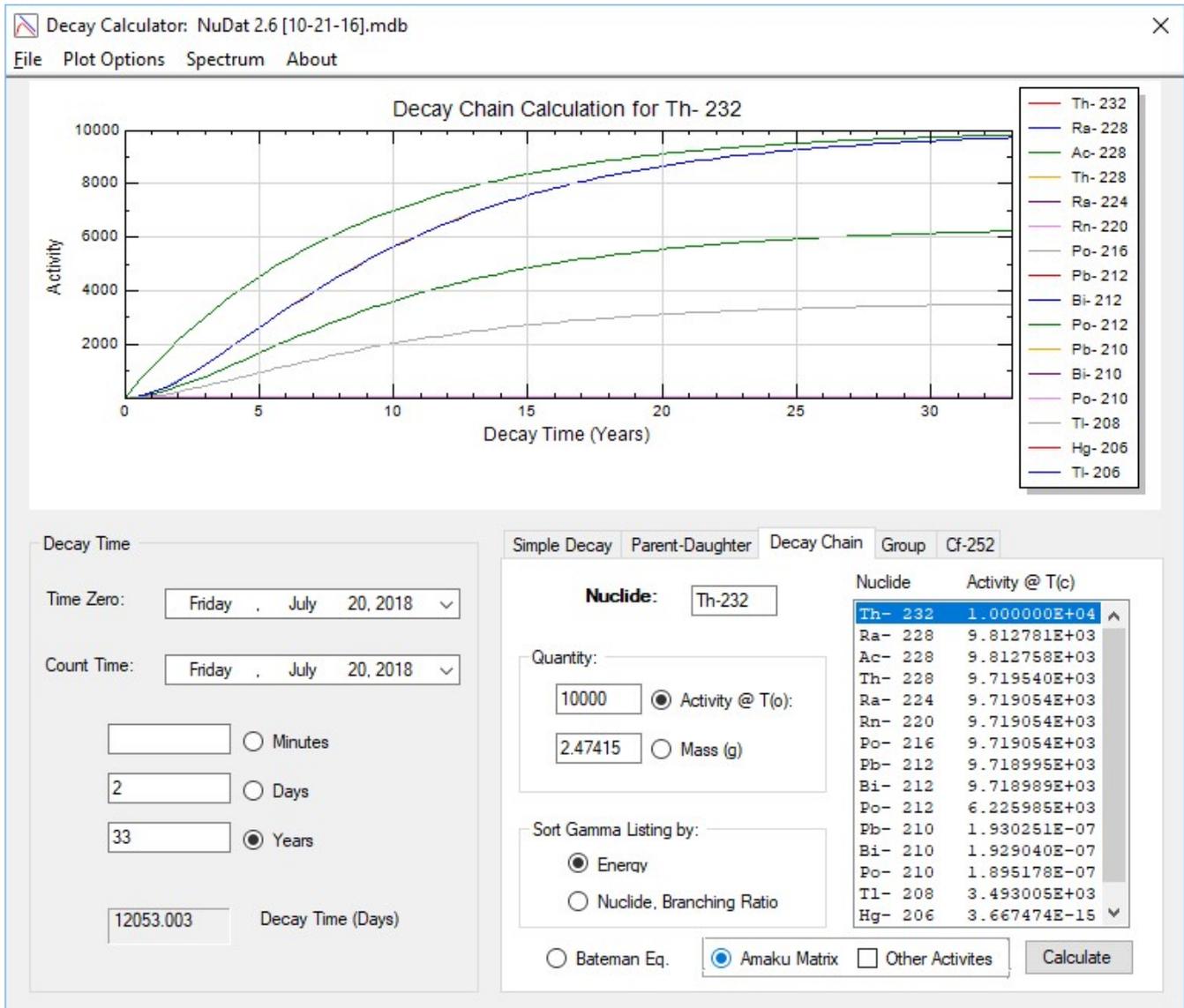
4.7.2 Energy List

Displays emissions for the selected nuclide. The list can be sorted by ascending Energy and Index, or descending Branching ratio by clicking on the **Energy**, **Branch**, and **Index** buttons in this section. When the list is sorted by Index, the Index value of a selected energy can be modified using the "^" and "v" buttons to move it up or down in the list. When establishing libraries for use in GammaVision, the peak order is important for optimal analysis results and that order is specified using the Index value.

Right-Click on the energy list to display a menu to **Add**, **Edit**, **Delete** peaks.

5. Decay Calculator

The Decay Calculator provides several decay options including simple decay of a single nuclide, parent-daughter decay/build-up, full decay chains for a nuclide and its progeny, user-defined nuclide groups, and special treatment for the case of Cf-252.



5.1 File Menu

5.1.1 Open Source Library

Displays a standard File-Open dialog to browse to the desired library in SQLite database format (default for NuclideNavigator-Pro) or Microsoft Access database format (compatible with standard NuclideNavigator).

5.1.2 Library Information

Displays a brief description of the source data as well as the numbers of alpha, beta and gamma records contained in the database.

5.1.3 Listing

Displays a report that contains a summary of the calculation and data used to generate the graph. The calculation type and source of data is based on the tab selected in the bottom right panel and decay time specified. The menu options in the Report window allow the data to be saved to a file, printed, or copied to the clipboard.

5.1.4 Exit

Closes the Decay Calculator application.

5.2 Plot Options Menu

5.2.1 Legend

This menu is only displayed when the **Decay Chain** tab is selected in the lower right panel for decay calculations. It has options to show the legend if it will not reduce the size of the chart beyond readability (**Automatic**), always display the legend (**Show**), or always hide the legend (**Hide**).

5.2.2 Display

Sets the axis to **Linear** or **Semi-Log** scale.

5.2.3 Drag

Specifies spectrum navigation properties.

5.2.3.1 Rubber Band Zoom

Click and drag the mouse around a region of the plot to zoom in on that region. To restore the display to the full spectrum, right-click and select "Original Dimensions".

5.2.3.2 Vertical and Horizontal

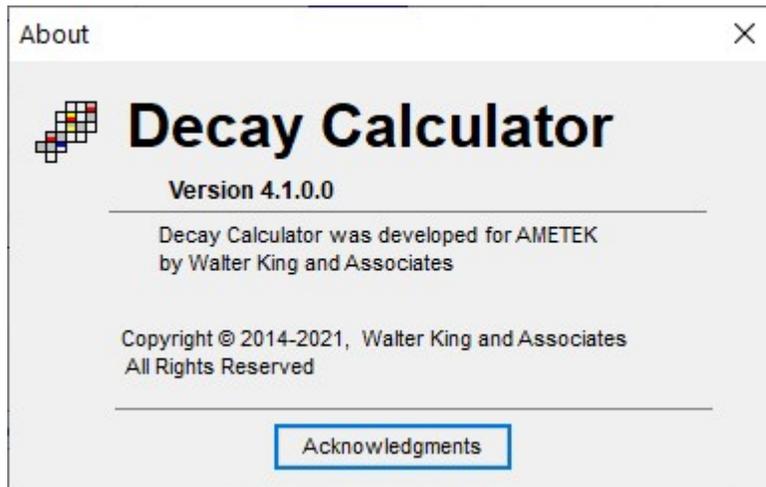
The spectrum is treated as a "window" that can be dragged vertically and horizontally. To restore the display to the full spectrum, right-click and select "Original Dimensions".

5.3 Spectrum Menu

This menu is only displayed when the **Decay Chain** tab is selected in the lower right panel for decay calculations. A synthetic spectrum is displayed in the Spectrum Viewer (Section 2.7) for the decay chain gamma rays in High Purity Germanium format.

5.4 About Menu

Displays the Decay Calculator about page.



5.5 Chart Right-Click menu

Right clicking on the chart will display a menu of functions related to the plot area.

5.5.1 Original Dimensions

Returns the spectrum to full view after zooming or dragging.

5.5.2 Show World Coordinates

Displays the coordinate data at the cursor (mouse) location as it is moved over the spectrum.

5.5.3 Print

Prints an image of the spectrum plot to the specified printer.

5.5.4 Copy to Clipboard

Copies an image of the spectrum plot to the clipboard which can be pasted into documents that support graphics.

5.5.5 Copy Data to Clipboard

Copies the data set used to create the spectrum plot (energy/counts data pairs) to the clipboard. This data set can be pasted into text documents or spreadsheet applications for evaluation.

5.6 Decay Time Controls

The decay time can be set in minutes, days, or years with a consistent conversion of decay time to days which is used for all subsequent calculations.

The decay time can be established using the Time Zero and Count Time calendar controls to determine the decay time in days. These controls are useful when determining the decay of a reference source from a certification date to measurement date. Fractional days can then be added to the decay time directly in the Days field to account for differences in the reference and measurement times if necessary.

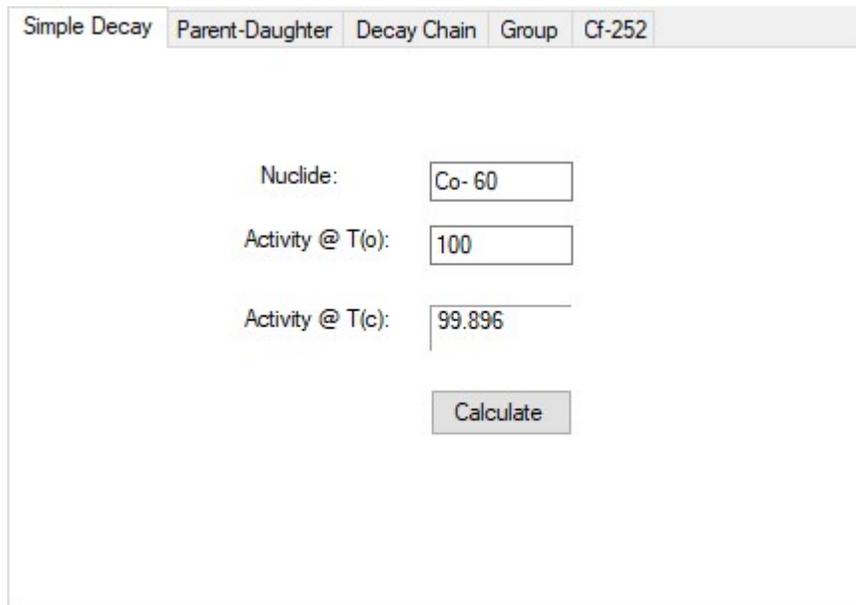
Select the **Calculate** button to update the decay calculations for the selected decay type.

5.7 Decay Types

The decay types are set by selecting the tabs in the lower right panel.

5.7.1 Simple Decay

This method is for a single nuclide which must be available in the Source library.



The screenshot shows a software interface with five tabs: "Simple Decay", "Parent-Daughter", "Decay Chain", "Group", and "Cf-252". The "Simple Decay" tab is selected. Below the tabs are three input fields and a button:

Nuclide:	Co- 60
Activity @ T(0):	100
Activity @ T(c):	99.896
Calculate	

Enter the starting activity at Time Zero and click the **Calculate** button to update the decayed activity at Count Time.

If the decay time is subsequently changed then click on the **Calculate** button to update the decayed activity value.

5.7.2 Parent-Daughter

This method is for calculating the activity of a parent nuclide and its daughter. The parent nuclide must be available in the Source library, and list of available daughters established in the library will be available for selection.

Simple Decay Parent-Daughter Decay Chain Group Cf-252

Parent: Zr-97
Activity @ T(o): 1000
Activity @ T(c): 0.000E+00

Daughter: Nb-97
Activity @ T(o): 0
Activity @ T(c): 0.000E+00

Calculate

Enter the starting activity at Time Zero for both the parent and the daughter, then click the **Calculate** button to update the decayed activity at Count Time for both nuclides.

If the decay time is subsequently changed then click on the **Calculate** button to update the decayed activity value.

5.7.3 Decay Chain

This method is for calculating the activity of an entire decay chain starting with the parent nuclide.

Simple Decay Parent-Daughter Decay Chain Group Cf-252

Nuclide: Ra-228

Quantity: 10000 Activity @ T(o): Mass (g)

Sort Gamma Listing by: Energy Nuclide, Branching Ratio

Bateman Eq. Amaku Matrix Other Activites

Nuclide	Activity @ T(c)
Ra- 228	6.965265E+03
Ac- 228	6.966115E+03
Th- 228	5.385964E+03
Ra- 224	5.377639E+03
Rn- 220	5.377637E+03
Po- 216	5.377637E+03
Pb- 212	5.376619E+03
Bi- 212	5.376523E+03
Po- 212	3.444201E+03
Pb- 210	1.235045E-08
Bi- 210	1.222533E-08
Po- 210	9.067243E-09
Tl- 208	1.932321E+03
Pb- 208	0.0
Hg- 206	2.346558E-16

Calculate

Enter the starting activity or mass of the starting nuclide at Time Zero, then click the **Calculate** button to update the decayed activity for all daughter products which will be displayed in the nuclide list.

If the decay time is subsequently changed then click on the **Calculate** button to update the decayed activity value.

The **Sort Gamma Listing** by **Energy** or **Nuclide, Branching Ratio** sets the format of the report generated from the **File\Listing** menu.

The decay calculations are based on either the classic Bateman equations or the Amaku Matrix method.

When using the Amaku Matrix method the initial activity of daughter products may be specified by checking the **Other Activities** checkbox. When running the calculation, a dialog will be displayed to enter the initial activity of each daughter as desired. Double-Click on a nuclide in the list to set the Isotope, then enter the initial activity and click the **Update** button. When the dialog is closed the decay calculation will result using the updated initial activities.

Initial Isotope Activities

File

Isotope

Activity

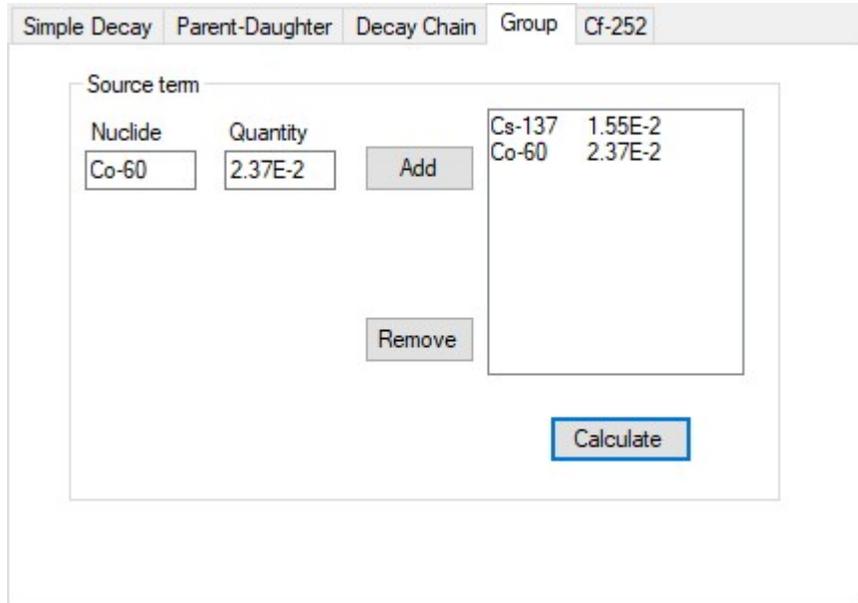
Update

Isotope - Initial Activity Pairs

Ra	226,	1.000E+04
Rn	222,	0.000E+00
Po	218,	0.000E+00
At	218,	0.000E+00
Rn	218,	0.000E+00
Pb	214,	0.000E+00
Bi	214,	0.000E+00
Po	214,	0.000E+00
Pb	212,	0.000E+00
Bi	212,	0.000E+00
Po	212,	0.000E+00
Tl	210,	0.000E+00
Pb	210,	0.000E+00
Bi	210,	0.000E+00
Po	210,	0.000E+00
Pb	209,	0.000E+00
Bi	209,	0.000E+00
Tl	208,	0.000E+00

5.7.4 Group

This method allows multiple nuclides and their initial activities to be loaded into a list for decay calculations of the entire group at the same time. The results are included in the chart and the report generated from the **File\Listing** menu.



Enter a nuclide name and activity then click the **Add** button to add it to the list.

Click on an item in the list and click the **Remove** button to remove it from the list.

After populating the list click the **Calculate** button to update the decay calculations which are displayed on the chart.

If the decay time is subsequently changed then click on the **Calculate** button to update the decay calculations.

5.7.5 Cf-252

This method is for the special treatment of Cf-252 based on decay of certified sources.

Composition	
Nuclide	Activity %
Cf-249	0.0235
Cf-250	2.83
Cf-251	0.0137
Cf-252	97.132
Cf-253	0
Cf-254	0.0004

Cf-252	
Activity @ To	20 uCi
Neutrons @ To	8.614E+04 n / s
Activity @ Tc	3.925E-01 uCi
Neutrons @ Tc	1.690E+03 n / s

Total	
Activity @ Tc	6.642E-01 uCi
Neutrons @ Tc	1.718E+03 n / s

Cf-252 neutrons / Total (%) 98.42

Calculate

Enter the activity percentages of each nuclide and the Cf-252 activity when it was certified.

Click the **Calculate** button to update the following fields and the chart:

- Initial Cf-252 neutron count rate
- Decayed Cf-252 activity and neutron count rate
- Total Decayed activity and neutron count rate for all Cf isotopes combined
- Percentage of the total neutron count rate from Cf-252

If the decay time is subsequently changed then click on the **Calculate** button to update the decay calculations.

6. Periodic Chart of the Elements

A standard periodic table of the elements that is connected to a small database of chemical and physical properties, as well as a brief history of each of the elements.

The Periodic Chart of the Elements provides an intuitive interface to view elements by physical form and chemical groups with easy access to basic physical properties.

The screenshot shows a software application window titled "Periodic Chart of the Chemical Elements". The window has a menu bar with "File" and "Help". The main content is a periodic table of elements. A pop-up window titled "Physical Properties" is open over the Hydrogen element (H), displaying a list of properties: Density, Abundance, Melting Point, and Boiling Point. The periodic table is color-coded by groups: IA (red), IIA (green), IIIA (blue), IVA (cyan), VA (magenta), VIA (blue), VIIA (orange), VIIIA (red), IIB (blue), IB (orange), VIII (yellow), VIIIB (orange), VIB (orange), IVB (yellow), IIIB (yellow). The Lanthanide and Actinide series are shown at the bottom of the table.

6.1 File Menu

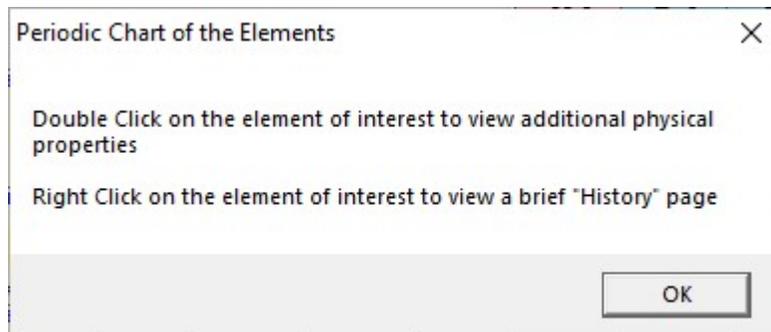
6.1.1 Exit

Closes the application.

6.2 Help Menu

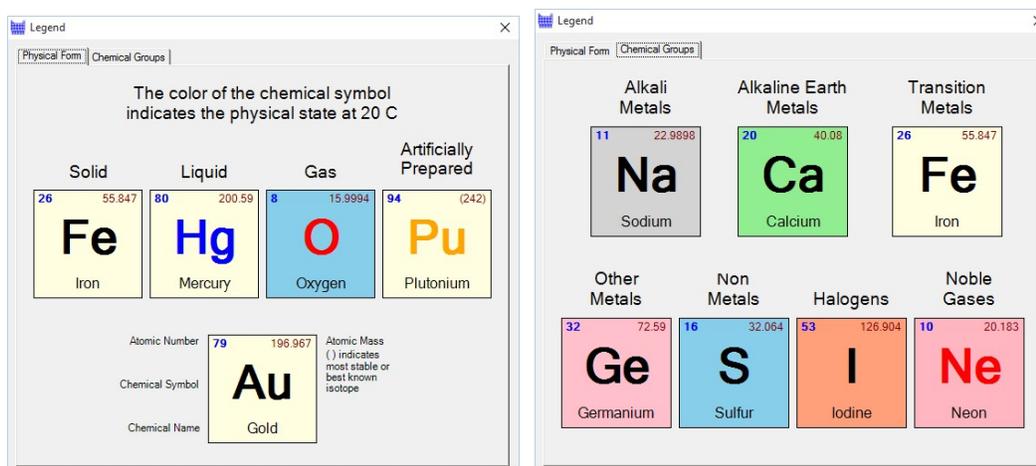
6.2.1 Usage

Displays the following dialog box with instructions for navigating the chart.



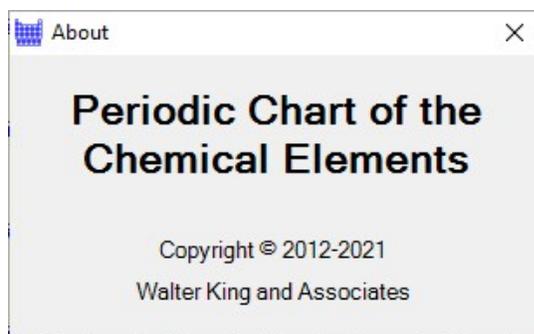
6.2.2 Legend

Displays the following Legend pages which describe the chart color codes which indicate the element's chemical group and the physical form of the element at room temperature.



6.2.3 About

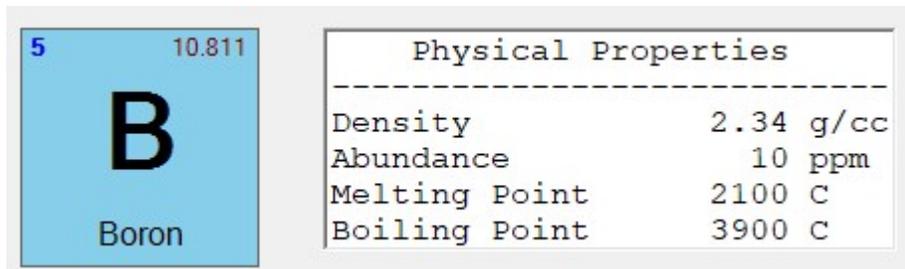
Displays the Chart of the Nuclides About page.



6.3 Navigation Controls

6.3.1 Mouse Hovering

Move the mouse pointer over an element box to update the selected element and physical properties box in the upper middle portion of the chart.

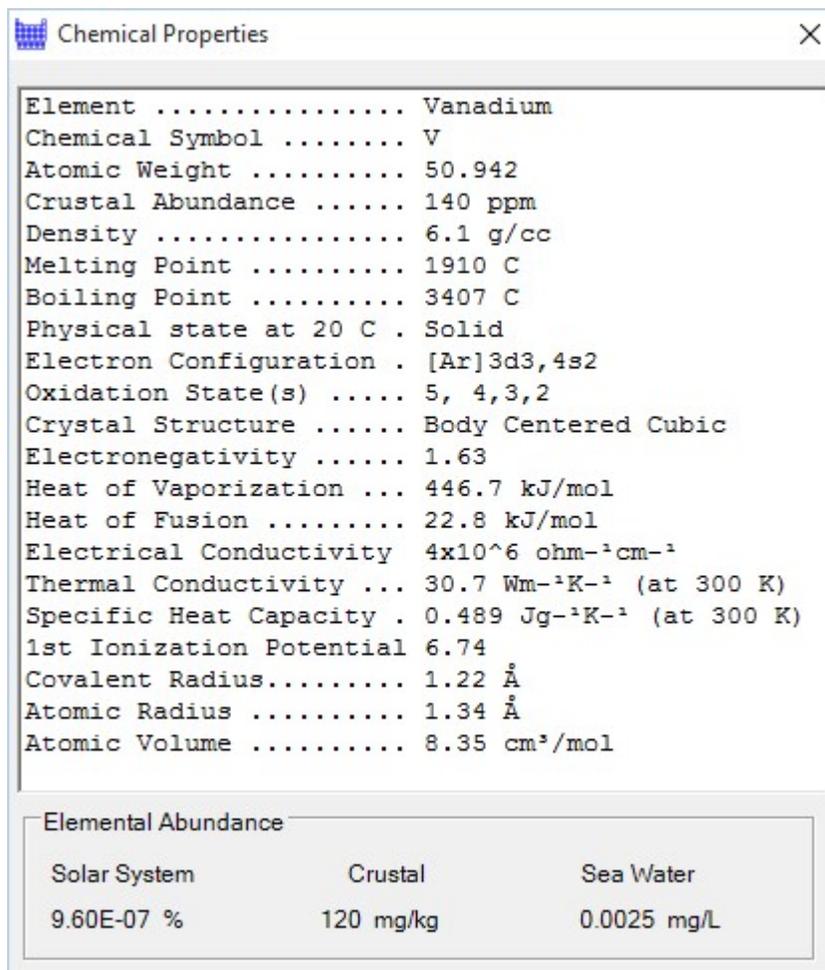


The image shows a user interface element for Boron. On the left is a blue square representing the element box, containing the atomic number '5' in the top left, the atomic weight '10.811' in the top right, the symbol 'B' in the center, and the name 'Boron' at the bottom. To the right of this box is a white rectangular area titled 'Physical Properties' with a dashed line separator. Below the title, the following properties are listed:

Physical Properties	
Density	2.34 g/cc
Abundance	10 ppm
Melting Point	2100 C
Boiling Point	3900 C

6.3.2 Left Double Click

Double click an element box to display the Chemical Properties dialog.



The image shows a dialog box titled 'Chemical Properties' with a close button (X) in the top right corner. The main area of the dialog contains a list of properties for Vanadium:

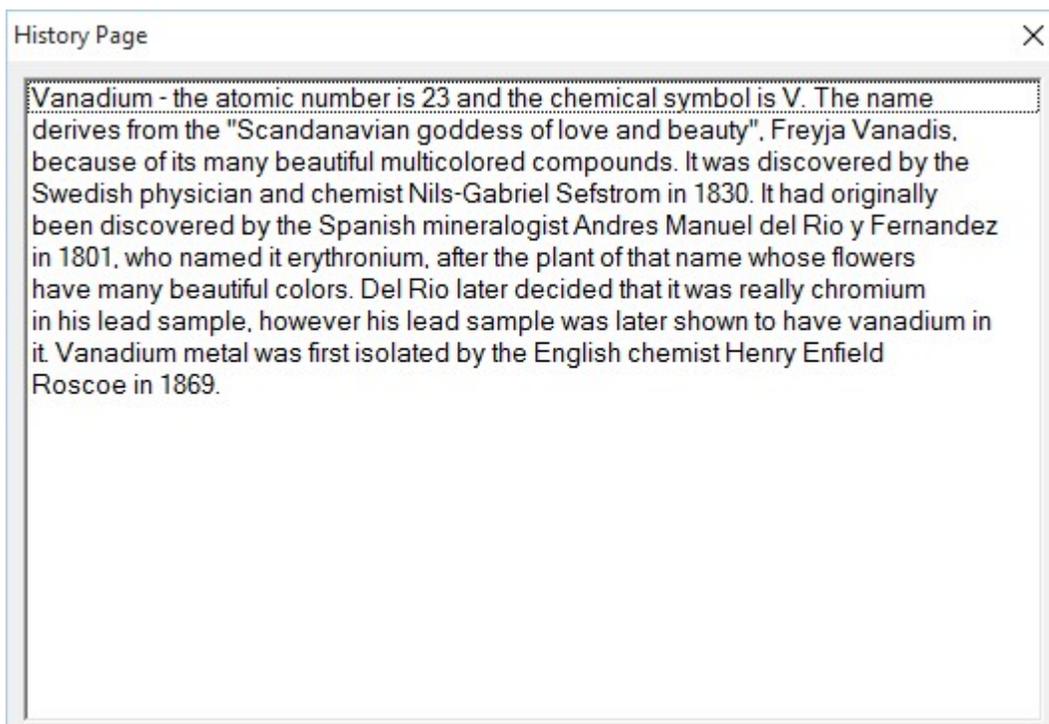
```
Element ..... Vanadium
Chemical Symbol ..... V
Atomic Weight ..... 50.942
Crustal Abundance ..... 140 ppm
Density ..... 6.1 g/cc
Melting Point ..... 1910 C
Boiling Point ..... 3407 C
Physical state at 20 C . Solid
Electron Configuration . [Ar]3d3,4s2
Oxidation State(s) ..... 5, 4,3,2
Crystal Structure ..... Body Centered Cubic
Electronegativity ..... 1.63
Heat of Vaporization ... 446.7 kJ/mol
Heat of Fusion ..... 22.8 kJ/mol
Electrical Conductivity 4x10^6 ohm^-1cm^-1
Thermal Conductivity ... 30.7 Wm^-1K^-1 (at 300 K)
Specific Heat Capacity . 0.489 Jg^-1K^-1 (at 300 K)
1st Ionization Potential 6.74
Covalent Radius..... 1.22 Å
Atomic Radius ..... 1.34 Å
Atomic Volume ..... 8.35 cm^3/mol
```

At the bottom of the dialog, there is a section titled 'Elemental Abundance' with a table:

Elemental Abundance		
Solar System	Crustal	Sea Water
9.60E-07 %	120 mg/kg	0.0025 mg/L

6.3.3 Right Click

Right click on an element box to display the "History" page for that element.

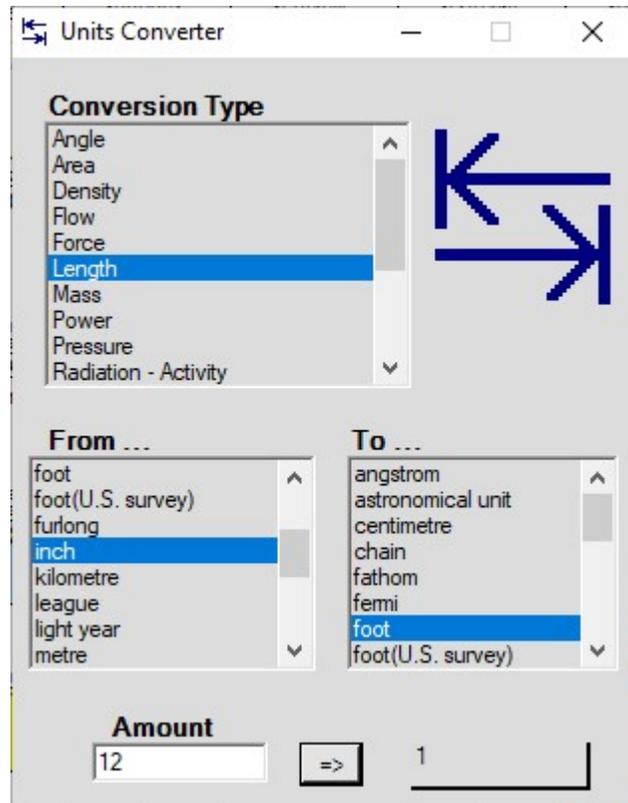


History Page

Vanadium - the atomic number is 23 and the chemical symbol is V. The name derives from the "Scandinavian goddess of love and beauty", Freyja Vanadis, because of its many beautiful multicolored compounds. It was discovered by the Swedish physician and chemist Nils-Gabriel Sefstrom in 1830. It had originally been discovered by the Spanish mineralogist Andres Manuel del Rio y Fernandez in 1801, who named it erythronium, after the plant of that name whose flowers have many beautiful colors. Del Rio later decided that it was really chromium in his lead sample, however his lead sample was later shown to have vanadium in it. Vanadium metal was first isolated by the English chemist Henry Enfield Roscoe in 1869.

7. Units Converter

The Units Converter application is a simple tool to convert units for an extensive list of engineering and scientific parameters.



7.1 Navigation

Select the **Conversion Type** desired to update the applicable From and To units lists.

Select the known quantity units in the **From** list.

Select the units to be calculated in the **To** list.

Enter the amount of From units and click the  button to display the amount in To units.

Appendix A – References

A.1 Nuclide and Emissions Data

Erdtmann_Soyka

The Gamma Rays of the Radionuclides, G. Erdtmann and W Soyka, Verlag Chemie, Weinheim, 1979.

TORI-99c5x

Table of Radioactive Isotopes, The Isotopes Project at LBNL, <http://ie.lbl.gov/toi/> supplemented with:

- Cascade coincidence data derived from ENSDF
- Positron annihilation data from PC_NuDat-04
- Fission yields, see below
- Neutron cross sections, see below

PC_NuDat-04

National Nuclear Data Center, <http://www.nndc.bnl.gov/>

NuBase 2012

Used to sort out the many inconsistencies in the NuDat 2.6 data, Chinese Physics C 36 (2012) 1157 - 1286, <https://www-nds.iaea.org/amdc/>

NuDat 2.6 [10-21-16]

National Nuclear Data Center, information extracted from the NuDat 2 database, <http://www.nndc.bnl.gov/>, and supplemented with:

- Fission yields, see below
- Neutron cross sections, see below

RSICC-Prompt

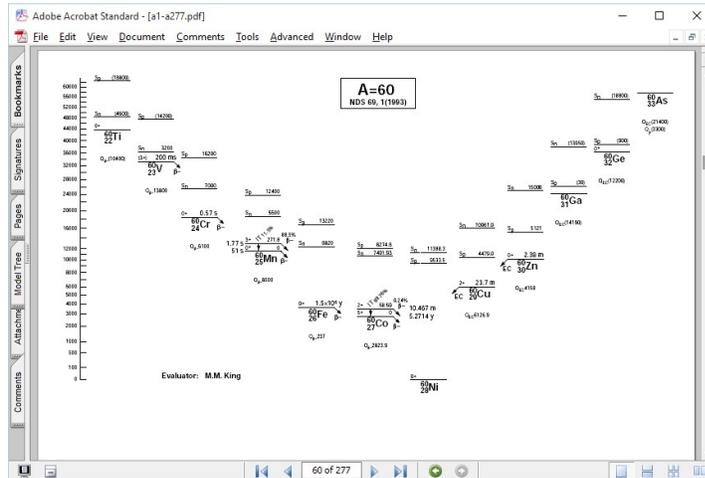
THERMGAM, DLC-140, 1981, RSICC, Oak Ridge National Laboratory, <https://rsicc.ornl.gov>

CapGam-2013

National Nuclear Data Center, information extracted from the CapGam data, <http://www.nndc.bnl.gov/capgam>

A.2 Decay Schemes

The Isotopes Project at LBNL, <http://ie.lbl.gov>. Example page shown below.



A.3 Fission Yields

T. R. England and B. F. Rider, LA-UR-94-3106, ENDF-349

A.4 Neutron Cross Sections

S. F. Mughabghab, M. Divadeenam and N. E. Holden, Neutron Cross Sections from Neutron Resonance Parameters and thermal Cross Sections, Academic Press (1981)

A.5 Example Spectra

Synthetic emission spectra for gamma rays and alpha particles are generated using algorithms developed by the author for typical HPGe and NaI sensors. A significant amount of credit is due to the published works of, and private communications with Ray Gunnink.

Beta particle shapes are generated using the equations associated with the standard (Fermi) theory of beta decay. Coulomb corrections for positrons are non-relativistic point-charge approximations. Corrections for electrons are calculated using the equations from G. K. Schenter and P. Vogel, Nuclear Science 1983, Volume 83, page 393-396.

A.6 Decay Calculation Methodology

H. Bateman The solution of a system of differential equations occurring in the theory of radioactive transformations, Proc. Cambridge Phil. Soc., v.15 (1910) 423-427

M. Amaku, P.R. Pascholati, V. R. Vanin, Decay chain differential equations: Solution through matrix algebra, Computer Physics Communications 181 (2010) 21-23.

A.7 Elemental Data

Based on the “History of the Origin of the Chemical Elements and Their Discoverers” generated by Norman E. Holden, National Nuclear Data Center, Brookhaven National Laboratory