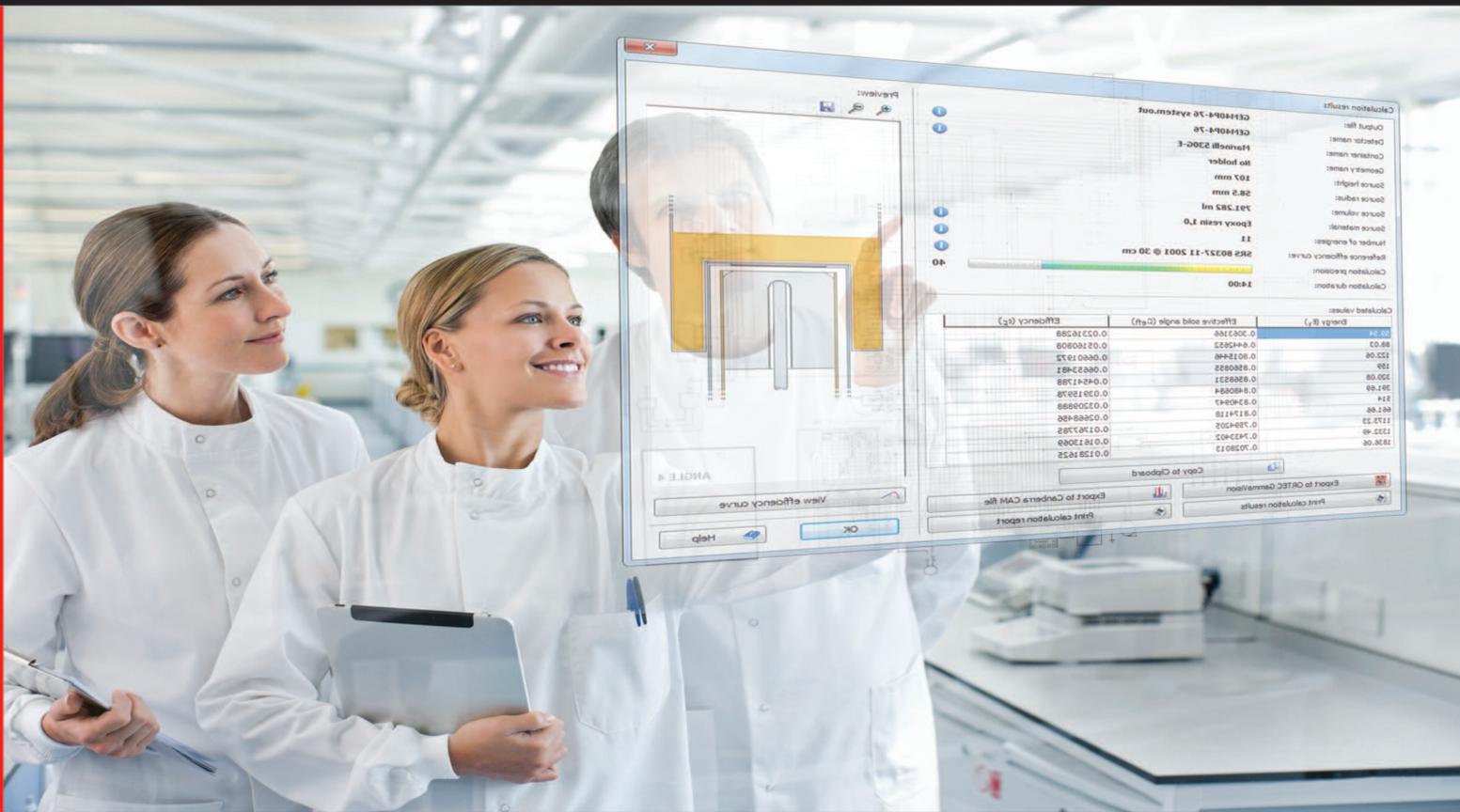


ORTEC[®]

AMETEK[®]

ANGLE 5

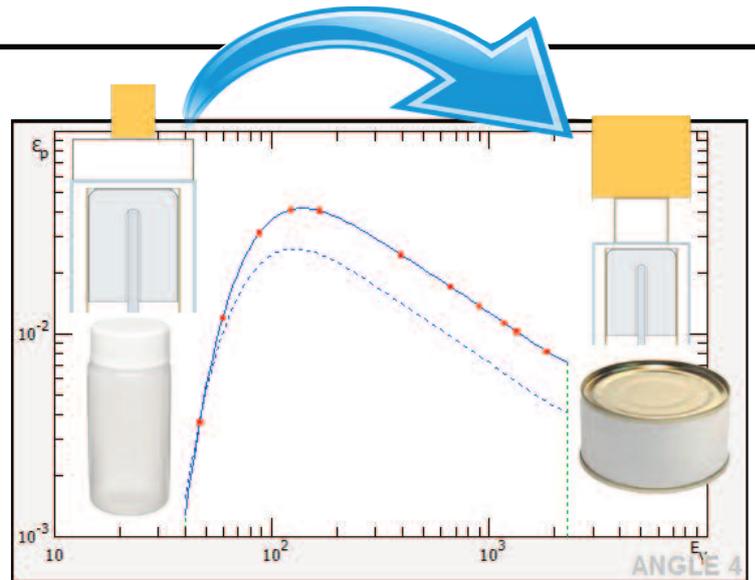
Advanced Gamma Spectroscopy
Efficiency Calibration Software



“Compatible, Efficient, and Defendable Calibrations
for Gamma Spectroscopy Applications.”

ANGLE 5

ANGLE is an advanced efficiency calculation application for High Purity Germanium and Sodium Iodide detectors based on the concept of Efficiency Transfer. This method combines the measured efficiency of a known reference configuration and solid angle models to derive the efficiency for different containers, sample materials, and sample positions. This semi-empirical approach is more accurate than pure mathematical models due to large errors that can be imposed by detector characteristics that are not precisely known – such as crystal defects, contact thickness, and dead layers – as these errors largely cancel out in the reference efficiency measurement. And, since the Reference Efficiency can be determined from any standard source, there is no need for complex and costly factory characterization of the detector!



WHY ANGLE?

Compatibility

- All 32-bit and 64-bit versions of Windows from Windows XP to Windows 11
- Multiple Language: English, French, Spanish, Russian, Chinese, and Japanese
- High Purity Germanium and Sodium Iodide Detector Types
- Monte Carlo Modeling methodology for most common laboratory measurement containers

Process Efficiency

- No Factory Detector Characterization Necessary
- Import and Export GammaVision and Genie file formats
- Command line scripting and XML Data files for automation and application integration
- Rapid modeling using Container, Geometry, and Source Matrix configurations

Defendable Results

- Comprehensive Reporting of Efficiency Calculation Model
- Actual and Relative Efficiency Method provides Calibration Standard Traceability
- Graphical Display of model
- High Accuracy with Extensive Comparison Testing

New Features in ANGLE 5!

- New!** Monte Carlo Calculation Methodology
- New!** Cascade Photon Emission Coincidence Summing Corrections
- New!** Example Sample Materials composed of editable Compounds and Mixtures
- New!** Calculation File results in YAML and JSON formats
- New!** Save model graphics to PNG and SVG image formats

ANGLE Overview

Detector, Container, Matrix, and Position Models

Detector



Demo detector #1

Demo detector #1 (Closed-end coaxial HPGe)

Container



Cylindrical 250 ml

The example of a 250 ml cylindrical container



Marinelli 500 ml

The example of a 500 ml Marinelli container

Source

Source height: **100 mm**
 Source radius: **55.75 mm**
 Source volume: **640.662 ml**
 Source material: **Granite**
 Source mass: **1.730 kg**

Geometry



Holder example

The example of a source holder



Protective cap

Protective cap for 76 mm detector

Reference Configuration and Measured Efficiency

Detector

Detector name: **GEM40-83-ICS_55-P42871A**

Container

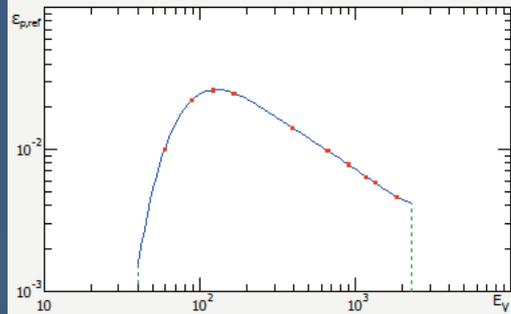
Container: **20ml Scintillation Vial**

Geometry

Geometry: **1 in Stand-Off**

Source

Source height: **34.9 mm**
 Source radius: **13.5 mm**
 Source material: **Water**



Calculated Efficiency

Calculation results

Output file: **250ml Bottle from Point Source.outx**
 Detector name: **55-P42871A**
 Container name: **Cylindrical 250 ml**
 Geometry name: **No holder**
 Source height: **50 mm**
 Source radius: **31.75 mm**
 Source volume: **158.346 ml**
 Source material: **Water**
 Source mass: **157.871 g**
 Number of energies: **15**
 Reference efficiency curve: **ISO-CAL Point Source at 0 cm**
 Calculation precision: **1%**
 Calculation duration: **0:02**
 Build version: **5.0.0.471**

Calculated efficiencies Cascade summing corrections

| Energy (E _γ) | Effective solid angle (Ω _{eff}) | Precision (Ω _{eff}) | Efficiency (ε _p) | Precision (ε _p) |
|--------------------------|---|-------------------------------|------------------------------|-----------------------------|
| 59 | 0.1452962 | 0.9542% | 0.008999381 | 1.340% |
| 59.54 | 0.1509044 | 0.9522% | 0.009413955 | 1.333% |
| 58.03 | 0.3904285 | 0.9127% | 0.03053720 | 1.194% |
| 122.06 | 0.5029212 | 0.9125% | 0.04087993 | 1.188% |
| 136.47 | 0.5217866 | 0.9159% | 0.04189251 | 1.195% |
| 165.86 | 0.5358562 | 0.9237% | 0.04147378 | 1.211% |
| 279.2 | 0.5293390 | 0.9434% | 0.03317996 | 1.253% |
| 391.7 | 0.5184337 | 0.9531% | 0.02632012 | 1.275% |

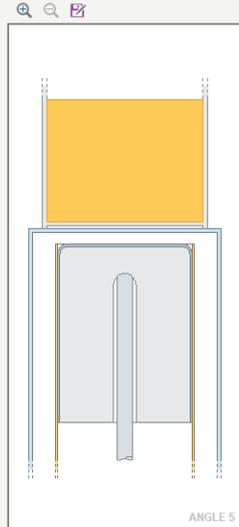
Copy to Clipboard

Export to ORTEC GammaVision | Export to Canberra CAM file

Save in JSON format | Save in VAML format

Print calculation results | Print calculation report

Preview



View efficiency curve

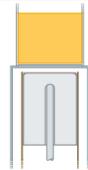
OK | Help

ANGLE 5 Calculation Report

Version of ANGLE used for calculations: 5.0.0.471

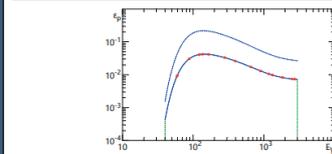
SUMMARY

Output file: **250ml Bottle from Point Source.outx**
 Detector name: **55-P42871A**
 Container name: **Cylindrical 250 ml**
 Geometry name: **No holder**
 Source height: **50 mm**
 Source radius: **31.75 mm**
 Source volume: **158.346 ml**
 Source material: **Water**
 Source mass: **157.871 g**
 Number of energies: **15**
 Reference efficiency curve: **ISO-CAL Point Source at 0 cm**
 Calculation precision: **1%**
 Calculation duration: **0:02**



CALCULATED VALUES

| Energy (E _γ) | Effective solid angle (Ω _{eff}) | Precision (Ω _{eff}) | Efficiency (ε _p) | Precision (ε _p) |
|--------------------------|---|-------------------------------|------------------------------|-----------------------------|
| 59 keV | 0.1452962 | 0.9542% | 0.008999381 | 1.340% |
| 59.54 keV | 0.1509044 | 0.9522% | 0.009413955 | 1.333% |
| 58.03 keV | 0.3904285 | 0.9127% | 0.03053720 | 1.194% |
| 122.06 keV | 0.5029212 | 0.9125% | 0.04087993 | 1.188% |
| 136.47 keV | 0.5217866 | 0.9159% | 0.04189251 | 1.195% |
| 165.86 keV | 0.5358562 | 0.9237% | 0.04147378 | 1.211% |
| 279.2 keV | 0.5293390 | 0.9434% | 0.03317996 | 1.253% |
| 391.7 keV | 0.5184337 | 0.9531% | 0.02632012 | 1.275% |
| 661.66 keV | 0.4998403 | 0.9656% | 0.01706231 | 1.303% |
| 898.04 keV | 0.4837734 | 0.9733% | 0.01310401 | 1.320% |
| 1173.23 keV | 0.4658038 | 0.9806% | 0.01061208 | 1.336% |
| 1332.49 keV | 0.4553769 | 0.9840% | 0.009722910 | 1.343% |
| 1836.05 keV | 0.4326464 | 0.9921% | 0.008280660 | 1.360% |
| 2505.69 keV | 0.4125564 | 0.9984% | 0.007458504 | 1.373% |
| 2734.07 keV | 0.4071610 | 1.000% | 0.007313606 | 1.377% |



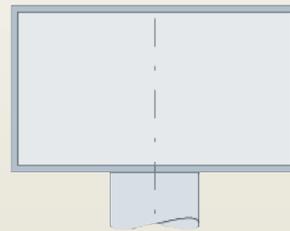
Detector Model

The Detector Model defines the physical construction of the detector. The input parameters are dependent on the detector type which may be Germanium or Sodium Iodide in Coaxial, Planar, or Well configurations. A graphic display of each model helps validate the appropriate detector type in the configuration process. Some parameters, such as the Inactive material thickness and the Contact thickness, are usually not precisely known for each detector so nominal values are typically used. These minor deviations are typically inconsequential with the Efficiency Transfer calculation method implemented in ANGLE because the minor error in transmission cancels out in the Reference and Target solid angle models. This is one of the significant advantages of Efficiency Transfer over modeling alone. And, if the detector response is affected by changes to any of these parameters, then a new Reference calibration can be generated with standard sources in the lab instead of having to return the detector to the factory for an expensive and time consuming characterization.

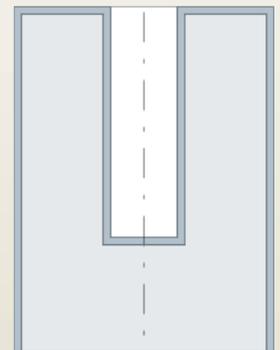
Detector Types:

- γ HPGe: Closed or open end coaxial, Planar, and Well
- γ Ge(Li): Closed or open end coaxial
- γ NaI: Cylinder and Well

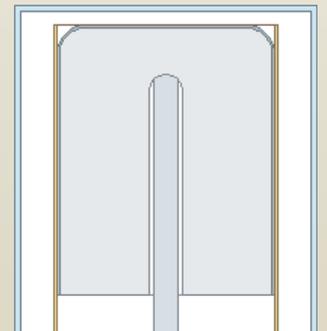
| Detector | |
|----------|---|
| | Demo detector #1 Demo detector #1 (Closed-end coaxial HPGe) |
| | Demo detector #2 Demo detector #2 (True coaxial HPGe) |
| | Demo detector #3 Demo detector #3 (Closed-end coaxial Ge(Li)) |
| | Demo detector #4 Demo detector #4 (Open end coaxial Ge(Li)) |
| | Demo detector #5 |



NaI Cylinder



NaI Well



HPGe Closed End Coaxial

Detector change [X]

Detector: End-cap window | Antimicrophonic shield | End-cap | Vacuum | Housing

Detector name: GEM40-83-ICS_55-P42871A

Detector type: Closed-end coaxial HPGe

Detector crystal height: 74.5 mm

Detector crystal radius: 29.9 mm

Bulletizing radius (0 = none): 8 mm

Core top type: Rounded Flat

Core height: 60.8 mm

Core radius: 4.5 mm

Inactive Ge top thickness: 0.7 mm

Inactive Ge side thickness: 0.7 mm

Contact top thickness: 0.0003 mm

Contact side thickness: 0.0003 mm

Contact material: Germanium

Contact pin radius: 3.175 mm

Contact pin material: Brass

Preview

End-cap outer radius: 41.5 mm

Detector description: GEM40-83-ICS_55-P42871A

OK Save as... Cancel Help

ANGLE 5

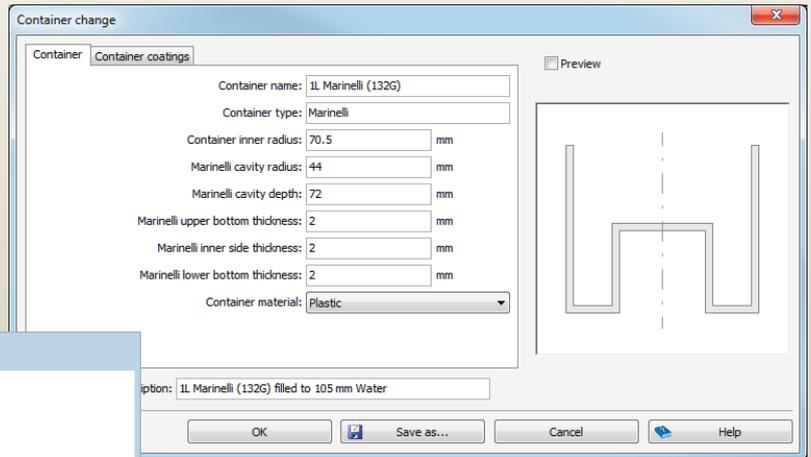
Container and Source Model

Containers define the physical holders of source or sample material, and Sources define the actual material within the container. Containers and Sources are defined independently in ANGLE to simplify the process of establishing different combinations of material and volume in each container. Common materials are pre-defined for Containers and Sources, and additional materials can easily be added based on user-defined compounds or mixtures.

Container Types:

- γ Marinelli
- γ Cylinder to define Point Source, Filter Paper, Disk, Charcoal Cartridge, and Bottles

| Container | |
|---|--|
|  | Cylindrical 250 ml The example of a 250 ml cylindrical container |
|  | Marinelli 500 ml The example of a 500 ml Marinelli container |

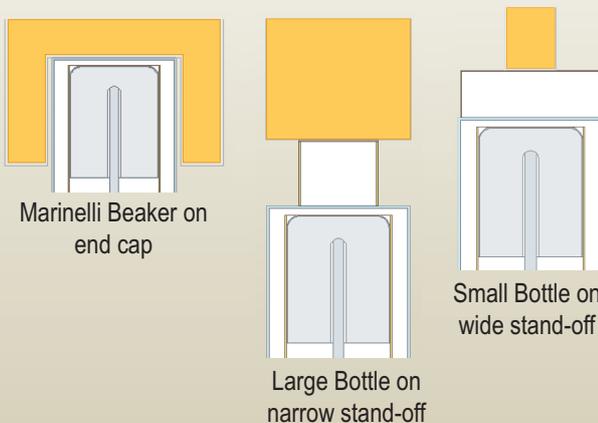
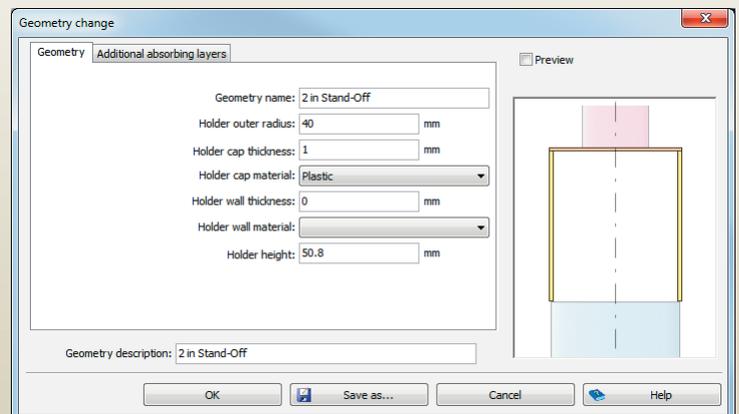


| Source | |
|------------------|------------|
| Source height: | 100 mm |
| Source radius: | 55.75 mm |
| Source volume: | 640.662 ml |
| Source material: | Granite |
| Source mass: | 1.730 kg |

Geometry Model

The Geometry defines the relative position of the Container to the Detector including any sample holders that may be used and up to five additional absorbing layers between the detector and the container. Common materials for sample holders and absorbers are pre-defined, and additional materials are easily added by the user.

| Geometry | |
|---|--|
|  | Holder example The example of a source holder |
|  | Protective cap Protective cap for 76 mm detector |

Reference Efficiency Calibration

ANGLE eliminates complex, expensive, and time consuming detector characterization because the Reference Calibration can be determined by direct measurement of a known source within the lab. Optimally, the Reference Calibration is determined using a source/geometry that is similar to the one being modeled in order to minimize uncertainty in the modeled efficiency; however, any source/geometry can be used as the reference when modeling any other source/geometry with good results when all of the detector and source/geometry configuration parameters are well known.

The Reference Energy/Efficiency pairs can be manually entered into ANGLE, or imported from either ORTEC GammaVision Efficiency Tables or Genie CAM files. A calibration curve is then generated using up to a 6-order logarithmic polynomial function over each of up to ten different energy regions to optimize the calibration fit. Alternatively, the reference Energy/Efficiency pairs can exclude the fit function in order to calculate the modeled efficiency for only the input energy points without any uncertainty imposed by using a fit function. The choice to use a fit function or discrete energy/efficiency pairs is largely determined by how the extrapolated efficiency calibration will be used. In many cases, the extensive calibration fit algorithms in ANGLE can achieve a much more precise calibration fit than is possible with other spectroscopy applications.

Reference efficiency curve

Experimental points
Number of points: 10

| E_γ | $\epsilon_{p,ref}$ |
|------------|--------------------|
| 59.54 | 0.0069450857 |
| 88.03 | 0.015166297 |
| 122.07 | 0.017898895 |
| 165.85 | 0.017524855 |
| 391.69 | 0.010177825 |
| 661.66 | 0.0071321442 |
| 898.02 | 0.0056748125 |
| 1173.24 | 0.004700603 |
| 1332.5 | 0.0042652902 |
| 1836.01 | 0.0034205941 |

Copy to Clipboard
Paste from Clipboard
Import from Canberra CAM file

Energy regions
Number of regions: 1

| [keV | , keV] | Polynomial order |
|-------|---------|------------------|
| 40 | 2300 | 6 |

Interpolation data

Detector
Detector name: GEM40-83-ICS_55-P42871A

Container
Container: 20ml Scintillation Vial

Geometry
Geometry: Plastic Stand-off @ 1.5 inches

Source
Source height: 40 mm
Source radius: 13.5 mm
Source material: Water

Reference efficiency curve name: 55-P42871A_20cc Vial 1.5 in
Reference efficiency curve description: 55-P42871A_20cc Vial 1.5 in

New curve Load saved curve Import from ORTEC GammaVision
OK Cancel Help

Calculated Efficiency

ANGLE uses an Efficiency Transfer method, which is a semi-empirical approach comprised of experimental evidence (i.e. measured efficiency of a known reference source) and mathematical comparison of effective solid angle modeling for the reference and target configurations. The effective solid angle is based on the Monte Carlo methodology with the precision of the calculations set from 0.1 to 5.0%.

$$\epsilon_p = \epsilon_{p,ref} \frac{\bar{\Omega}}{\bar{\Omega}_{ref}}$$

The derived efficiency data can be comprised of the same energy points used in the reference calibration or user-defined energy points derived by ANGLE's robust fitting algorithms. These Energy/Efficiency pairs can then be used to generate efficiency calibrations in standard gamma spectroscopy applications. A Geometry correction file can also be generated for use in ORTEC's GammaVision application so that the final analysis results retain traceability to the Reference calibration while applying the necessary efficiency corrections to the derived geometry configuration.

| Additional parameters | |
|-----------------------------|------------------------------------|
| Energies: | Energy example |
| Reference efficiency curve: | Reference efficiency curve example |
| Calculation precision: | 5% |
| Units: | Millimeters |

Cascade Summing Corrections are calculated with correction factors applied to the nuclide branching ratios to account for coincidence summing of photon emissions from a single atom. This correction is geometry dependent and more significant when the sample is closer to the detector.

Detailed and Summary reports of the reference and derived efficiency calibrations and their associated configurations are also available for verification and record retention.

Calculation results
✕

Output file: 250ml Bottle from Point Source.outx

Detector name: 55-P42871A

Container name: Cylindrical 250 ml

Geometry name: No holder

Source height: 50 mm

Source radius: 31.75 mm

Source volume: 158.346 ml

Source material: Water

Source mass: 157.871 g

Number of energies: 15

Reference efficiency curve: ISO-CAL Point Source at 0 cm

Calculation precision: 1%

Calculation duration: 0:02

Build version: 5.0.0.471

Preview:

Calculated efficiencies Cascade summing corrections

| Energy (E _y) | Effective solid angle (Ω _{eff}) | Precision (Ω _{eff}) | Efficiency (ε _p) | Precision (ε _p) |
|--------------------------|---|-------------------------------|------------------------------|-----------------------------|
| 59 | 0.1452962 | 0.9542% | 0.008999381 | 1.340% |
| 59.54 | 0.1509044 | 0.9522% | 0.009413955 | 1.333% |
| 88.03 | 0.3904285 | 0.9127% | 0.03053720 | |
| 122.06 | 0.5029212 | 0.9125% | 0.04087993 | |
| 136.47 | 0.5217866 | 0.9159% | 0.04189251 | |
| 165.86 | 0.5358562 | 0.9237% | 0.04147378 | |
| 279.2 | 0.5293390 | 0.9434% | 0.03317996 | |
| 391.7 | 0.5184337 | 0.9531% | 0.02632012 | |

Calculated efficiencies Cascade summing corrections

Sort nuclides by: Symbol

Nuclides of interest: Standard Mixed Gamma Source

| Nuclides: | Energy | Correction coefficient | Branching ratio | Corrected branching ratio |
|-----------|----------|------------------------|-----------------|---------------------------|
| Am-241 | | | | |
| Cd-109 | 347.14 | 0.88580532849521 | 7.5E-5 | 6.64354E-5 |
| Ce-139 | 826.1 | 0.883445617255112 | 7.6E-5 | 6.714187E-5 |
| Co-57 | 1173.228 | 0.942859904545169 | 0.9985 | 0.9414456 |
| Co-60 | 1332.492 | 0.940981864294764 | 0.999826 | 0.9408181 |
| Cs-134 | 2158.57 | 1.08497893125734 | 1.2E-5 | 1.301975E-5 |
| Cs-137 | 2505.692 | 1114709.13241316 | 2E-8 | 0.02229418 |
| Hg-203 | | | | |
| Y-88 | | | | |

ANGLE 5

Ordering Information

| Model | Description |
|----------|---|
| ANGLE-BW | Advanced Gamma Spectroscopy Efficiency Calibration Software – Single PC License |
| ANGLE-UW | Update from ANGLE Version 4 to Version 5 |
| ANGLE-GW | Additional Hard Copy Documentation for ANGLE |

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Specifications subject to change
012523

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