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SDT6. Experiment on Secondary Gamma-Ray Production Cross Sections Arising from Thermal-Neutron Capture in Iron, Stainless Steel, Nitrogen, and Sodium

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Reference: R. E. Maerker and F. J. Muckenthaler, "Gamma-Ray Spectra Arising from Thermal-Neutron Capture in Elements Found in Soil, Concretes, and Structural Materials," ORNL-4382 (1969).

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Abstract

The experimental and calculational details for a CSEWG integral data testing shielding experiment are presented. This particular experiment measured the secondary gamma-ray production cross sections arising from thermal-neutron capture for iron, a type 321 stainless steel, nitrogen, and sodium. Gamma-ray cross sections were binned into ∿ 0.5-MeV wide energy intervals.

Description

Gamma-ray production cross sections arising from thermal-neutron capture in iron, stainless steel, nitrogen, and sodium in 0.5-MeV bins were obtained from gamma-ray spectral measurements described in the reference. These measurements were made at the Oak Ridge National Laboratory Tower Shielding Facility using a carefully calibrated 5 x 5 in. NaI(Tℓ) detector in good geometry. The experimental arrangement is shown in Fig. 1. The resulting reduced spectral intensities in photons per 100 captures were summed over 0.5-MeV intervals and converted to units of millibarns using handbook values of the radiative capture cross section at 0.0253 eV.

Results

The experimental results for iron, stainless steel, nitrogen, and sodium are given in Tables I through IV, respectively. Note that they are given for $\sim$ 1 MeV and greater. The estimated accuracy is $\pm$15% and contributions from both discrete and continuum gamma rays are included in these results.

Method of Calculation

No transport calculations are necessary for this benchmark, hence model description, atom densities, etc. are not needed. Calculations could simply consist of summing the thermal-neutron absolute capture spectra over appropriate energy intervals; however, it is recommended that a "standard" ENDF/B photon production group averaging code such as LAPHANO (written by Los Alamos) or LAPHFØR (Oak Ridge's modified version of LAPHANO) be used to accomplish this task.

The input for LAPHANO or LAPHNGAS, for example, is relatively straight-forward. Note the following input items:

NGG - number of gamma groups is given in Table III.
NGF - number of neutron fine groups - 1.
NBF - number of neutron broad groups - 1.

All flags for numbers of nuclides, mixtures, zones, etc. are set for one

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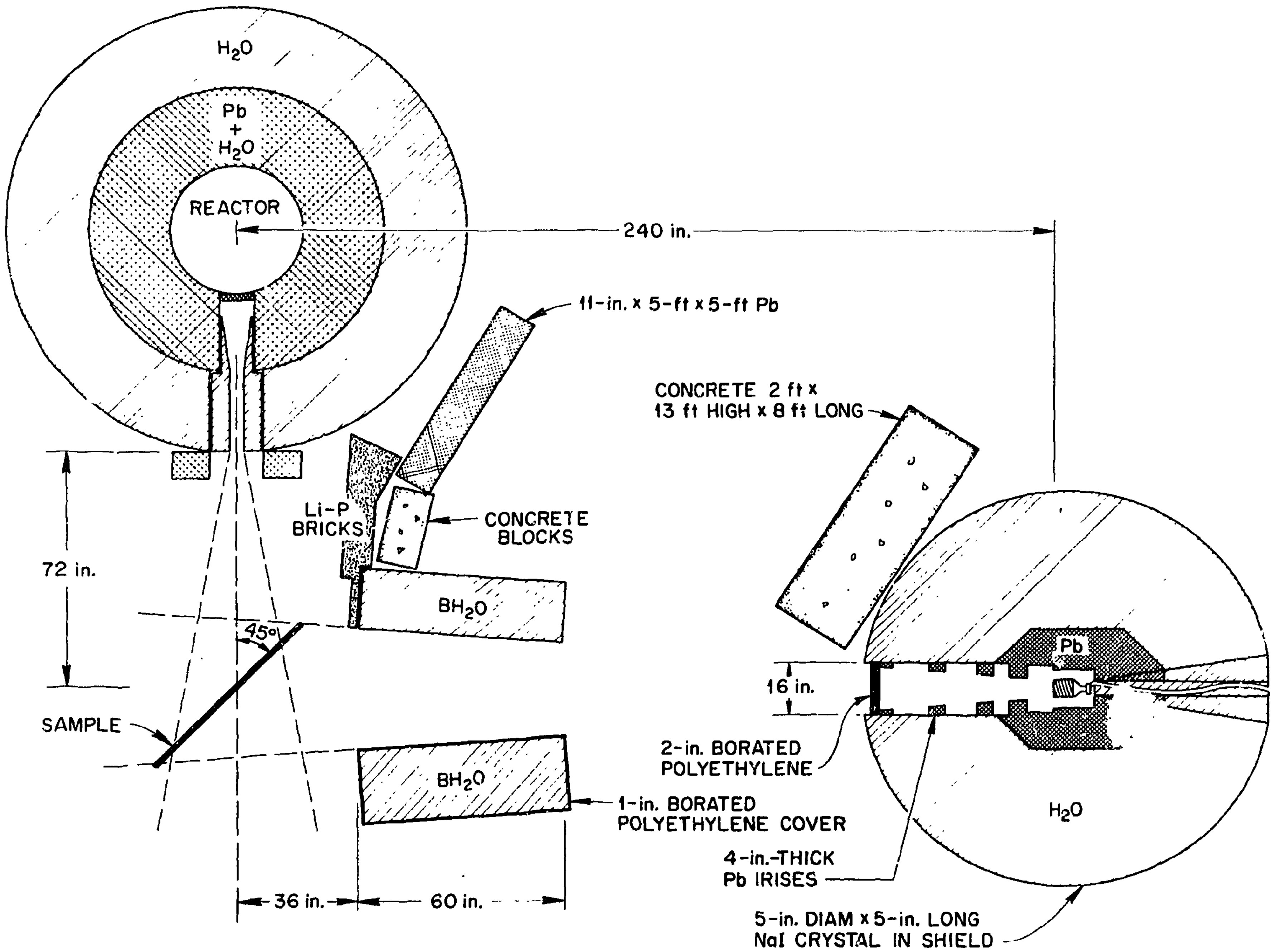

Fig. 1. Schematic Diagram of Geometry for Thermal-Neutron Capture Gamma-Ray Experiments.

Table I

Gamma-ray production cross sections arising from thermal-neutron capture in iron are the following, in millibarns at 0.0253 eV.

Gamma-Ray Energy Interval (MeV)*	Cross Section (mb)
1.15 - 1.5	126
1.5 - 2.0	455
2.0 - 2.5	99
2.5 - 3.0	152
3.0 - 3.5	233
3.5 - 4.0	88
4.0 - 4.5	182
4.5 - 5.0	83
5.0 - 5.5	25
5.5 - 6.0	250
6.0 - 6.5	255
6.5 - 7.0	13
7.0 - 7.5	139
7.5 - 8.0	1280
8.0 - 9.0	20
$\geq$ 9.0	83

*Upper energy limit of each group not included in summation.

Table II

Gamma-ray production cross sections arising from thermal-neutron capture in stainless steel (67.4 weight percent iron, 18.3 weight percent chromium, 9.7 weight percent nickel, 1.5 weight percent manganese, 0.3 weight percent cobalt, and the remainder may be neglected) are the following, in millibarns at 0.0253 eV:

Gamma-Ray Energy Interval (MeV)*	Cross Section (mb)
1.0 - 1.5	442
1.5 - 2.0	355
2.0 - 2.5	186
2.5 - 3.0	134
3.0 - 3.5	226
3.5 - 4.0	113
4.0 - 4.5	177
4.5 - 5.0	98
5.0 - 5.5	107
5.5 - 6.0	287
6.0 - 6.5	229
6.5 - 7.0	125
7.0 - 7.5	259
7.5 - 8.0	1025
8.0 - 8.5	110
8.5 - 9.0	372
9.0 - 9.5	58
9.5 - 10.0	55
$\geq$ 10.0	0

*Upper energy limit of each group not included in summation.

Table III

Gamma-ray production cross sections arising from thermal-neutron capture in nitrogen are the following, in millibarns at 0.0253 eV:

Gamma-Ray Energy Interval (MeV)*	Cross Section (mb)
1.0 - 1.5	0
1.5 - 2.0	30.0
2.0 - 2.5	0
2.5 - 3.0	6.4
3.0 - 3.5	0
3.5 - 4.0	22.8
4.0 - 4.5	0
4.5 - 5.0	13.4
5.0 - 5.5	43.3
5.5 - 6.0	25.2
6.0 - 6.5	15.2
6.5 - 7.0	0
7.0 - 7.5	7.8
7.5 - 8.0	0
8.0 - 8.5	3.5
8.5 - 9.0	0.17
9.0 - 9.5	1.6
9.5 - 10.0	0
10.0 - 10.5	0
10.5 - 11.0	11.0
≥ 11.0	0

*Upper energy limit of each group not included in summation.

Table IV

Gamma-ray production cross sections arising from thermal-neutron capture in sodium are the following, in millibarns at 0.0253 eV:

Gamma-Ray Energy Interval (MeV)*	Cross Section (mb)
1.0 - 1.5	79†
1.5 - 2.0	76
2.0 - 2.5	143
2.5 - 3.0	254†
3.0 - 3.5	76
3.5 - 4.0	182
4.0 - 4.5	34
4.5 - 5.0	14
5.0 - 5.5	12
5.5 - 6.0	31
6.0 - 6.5	115
≥ 6.5	0

*Upper energy limit of each group not included in summation.

†Does not include the contribution of 534 mb from ^{24}Na activation (i.e., gamma rays resulting from decay to ^{24}Mg).

material, one mixture, one zone with radius = 1.0, etc. A single MT number equal 102 is specified. The gamma bounds are given in Table III, the two boundaries of the neutron fine group equal those of the broad group, namely 0.0254 eV and 0.0252 eV; the single value of the neutron weighting function is 1.0. Note that the production cross sections are outputted in units of barns.*

Method of Reporting

The calculational results should be tabulated as shown in Tables V-VIII.

*Acknowledgments should be made to R. J. LaBauve of Los Alamos Scientific Laboratory and W. E. Ford III of Oak Ridge National Laboratory for providing the general description of the input to the LAPHANO and **LAPHFØR** processing codes.

Table V

Report sheet for gamma-ray production cross sections arising from thermal-neutron capture in iron.

Gamma-Ray Energy Interval (MeV)*	Cross Section at 0.0253 eV (mb)
1.15 - 1.5	______
1.5 - 2.0	______
2.0 - 2.5	______
2.5 - 3.0	______
3.0 - 3.5	______
3.5 - 4.0	______
4.0 - 4.5	______
4.5 - 5.0	______
5.0 - 5.5	______
5.5 - 6.0	______
6.0 - 6.5	______
6.5 - 7.0	______
7.0 - 7.5	______
7.5 - 8.0	______
8.0 - 9.0	______
$\geq$ 9.0	______

*Do not include upper energy limit of each group in summation.

Table VI

Report sheet for gamma-ray production cross sections arising from thermal-neutron capture in stainless steel:

Gamma-Ray Energy Interval (MeV)*	Cross Section at 0.0253 eV (mb)
1.0 - 1.5	______
1.5 - 2.0	______
2.0 - 2.5	______
2.5 - 3.0	______
3.0 - 3.5	______
3.5 - 4.0	______
4.0 - 4.5	______
4.5 - 5.0	______
5.0 - 5.5	______
5.5 - 6.0	______
6.0 - 6.5	______
6.5 - 7.0	______
7.0 - 7.5	______
7.5 - 8.0	______
8.0 - 8.5	______
8.5 - 9.0	______
9.0 - 9.5	______
9.5 - 10.0	______
$\geq$ 10.0	______

*Do not include upper energy limit of each group in summation.

Table VII

Report sheet for gamma-ray production cross sections arising from thermal capture in nitrogen:

Gamma-Ray Energy Interval (MeV)*	Cross Sections at 0.0253 eV (mb)
1.0 - 1.5	
1.5 - 2.0	
2.0 - 2.5	
2.5 - 3.0	
3.0 - 3.5	
3.5 - 4.0	
4.0 - 4.5	
4.5 - 5.0	
5.0 - 5.5	
5.5 - 6.0	
6.0 - 6.5	
6.5 - 7.0	
7.0 - 7.5	
7.5 - 8.0	
8.0 - 8.5	
8.5 - 9.0	
9.0 - 9.5	
9.5 - 10.0	
10.0 - 10.5	
10.5 - 11.0	
$\geq$ 11.0	

*Do not include upper energy limit of each group in summation.

Table VIII

Report sheet for gamma-ray production cross sections arising from thermal neutron capture in sodium:

Gamma-Ray Energy Interval (MeV)*	Cross Section at 0.0253 eV (mb)†
1.0 - 1.5	______
1.5 - 2.0	______
2.0 - 2.5	______
2.5 - 3.0	______
3.0 - 3.5	______
3.5 - 4.0	______
4.0 - 4.5	______
4.5 - 5.0	______
5.0 - 5.5	______
5.5 - 6.0	______
6.0 - 6.5	______
$\geq$ 6.5	______

*Do not include upper energy limit of each group in summation.

†Do not include the contribution from ^{24}Na activation (i.e., gamma rays resulting from decay to ^{24}Mg).