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Title: **ALPHA-N AND SPONTANEOUS FISSION SOURCES AND SPECTRA FROM INDIVIDUAL PLUTONIUM ISOTOPES IN PuF_4 AND PuO_2**

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Alpha-n and Spontaneous Fission Sources and Spectra from Individual Plutonium Isotopes in PuF_4 and PuO_2

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Introduction

Plutonium-containing compounds vary widely in isotopic content, and as a result, the dose as function of isotopic content also varies considerably. Determination of the dose from neutrons, decay and capture gammas from plutonium in the form of compounds, thus requires that the spontaneous fission (SF) and alpha-n (α,n) source and spectra from each individual isotope be known.

To facilitate dose calculations from plutonium-containing compounds, we have calculated the spontaneous fission and (α,n) sources and spectra for 1 g of each of the plutonium isotopes in the form of either PuF_4 or PuO_2. As ^{241}Am is often a component in a mixture of plutonium isotopic compounds, the source and spectra from 1 g of ^{241}Am mixed with PuF_4 or PuO_2 has also been determined. Using these results, the neutron source and spectra may be determined for any sample composition.

Methods

The neutron sources and spectra were calculated using the SOURCES[1] code and library. The code is under development. The code determines (β^-,n) delayed, spontaneous fission and (α,n) neutron sources and spectra due to the decay of a radionuclides in homogeneous media. Spontaneous fission spectra are calculated with evaluated half life, SF branching, and ν data using Watt spectrum parameters for 43 actinides. The (α,n) spectra are calculated with a library of nuclide decay alpha spectra, evaluated (α,n) cross sections and product nuclide level branching fractions, and functional α stopping cross sections using an assumed isotropic neutron angular distribution in the center-of-mass system.

Results

The neutron source strength from spontaneous fission and (α,n) reactions for 1 g of each isotope are given in Table 1. The alphas from ^{241}Am are assumed to slow down in either PuF_4 or PuO_2. The source for ^{243}Pu is from spontaneous fission alone as this isotope decays only by beta emission.

The combined SF and (α,n) spectra for each isotope, in the form PuO_2 or PuF_4, is given in Tables 2 and 3. The first 22 energy groups correspond to those of the MATXS7 69 group neutron transport cross section library.[2] The broad final group contains so few neutrons as to be insignificant. Each spectra is normalized to the total source strength for 1 g of a particular isotope. The spectra for ^{241}Am are those produced from alpha particles slowing down in either PuO_2 or PuF_4. The spectra for ^{243}Pu are the spontaneous fission spectra alone.

Conclusion

The absolute source and spectra for any combination of isotopes may be obtained using the results in Tables 1, 2, and 3. This source, spectra, and a coupled neutron-gamma library input into a transport code, then, would provide a method of determining dose from samples of PuO_2 or PuF_4.

References

1. W.B. Wilson, R.T. Perry, J.E. Stewart, T.R. England, D. G. Madland, and E.D. Arthur, "Development of the SOURCES Code and Data Library for the Calculation of Neutron Sources and Spectra from (α,n) Reactions, Spontaneous Fission, (β^-,n) Delayed Neutrons," Los Alamos National Laboratory progress report LA-9841-PR, pp. 65-66, Los Alamos National Laboratory (August 1993).

2. RSIC Data Library Collection, "MATXS7A - 69 Neutron Group Cross Section Library in MATXS," Oak Ridge National Laboratory report DLC-117 (December 1985).

Table 1
Alpha-n and Spontaneous Fission Neutron Source Strength for One Gram of Metal for Plutonium Isotopes in the Form of PuO_2 or PuF_4 and ^{241}Am in PuO_2 or PuF_4

Isotope	Spontaneous Fission neutrons/gm	PuO_2 alpha-n neutrons/gm	PuO_2 total source neutrons/gm	PuF_4 alpha-n neutrons/gm	PuF_4 total source neutrons/gm
^{238}Pu	2.587E+03	1.412E+04	1.671E+04	2.175E+06	2.178E+06
^{239}Pu	2.181E-02	4.013E+01	4.015E+01	5.653E+03	5.653E+03
^{240}Pu	1.026E+03	1.481E+02	1.174E+03	2.091E+04	2.194E+04
^{241}Pu	4.939E-02	1.357E+00	1.406E+00	1.704E+02	1.705E+02
^{242}Pu	1.717E+03	2.150E+00	1.719E+03	2.696E+02	1.987E+03
^{243}Pu	6.618E-02	0.000E+00	6.618E-02	0.000E+00	6.618E-02
^{244}Pu	1.900E+03	7.531E-03	1.900E+03	7.628E-01	1.901E+03
^{241}Am	1.182E+00	2.817E+03	2.818E+03	4.331E+05	4.331E+05

Table 2
Neutron Spectra Normalized to Total Source Strength for Plutonium Isotopes in the Form of PuO_2 and ^{241}Am in PuO_2

Group Upper Energy Boundary, MeV	$^{238}PuO_2$ neutrons per group	$^{239}PuO_2$ neutrons per group	$^{240}PuO_2$ neutrons per group	$^{241}PuO_2$ neutrons per group	$^{242}PuO_2$ neutrons per group	$^{243}PuO_2$ neutrons per group	$^{244}PuO_2$ neutrons per group	^{241}Am in in PuO_2 neutrons per group
1.000E+01	5.453E+01	5.260E-04	1.702E+01	9.961E-04	3.119E+01	7.996E-04	1.809E+01	3.406E-02
6.065E+00	9.529E+02	7.400E-01	1.067E+02	1.733E-02	1.802E+02	5.819E-03	1.503E+02	1.302E+02
3.679E+00	6.533E+03	1.661E+01	2.827E+02	5.551E-01	3.737E+02	1.373E-02	3.828E+02	1.189E+03
2.231E+00	5.233E+03	1.297E+01	2.952E+02	4.519E-01	4.116E+02	1.622E-02	4.706E+02	9.219E+02
1.353E+00	2.302E+03	6.332E+00	2.125E+02	2.383E-01	3.133E+02	1.275E-02	3.767E+02	3.693E+02
8.210E-01	9.679E+02	2.324E+00	1.250E+02	9.520E-02	1.927E+02	7.936E-03	2.361E+02	1.377E+02
5.000E-01	4.084E+02	8.270E-01	6.805E+01	3.320E-02	1.076E+02	4.446E-03	1.325E+02	5.057E+01
3.025E-01	1.413E+02	2.129E-01	3.417E+01	8.491E-03	5.530E+01	2.285E-03	6.808E+01	1.228E+01
1.830E-01	5.994E+01	7.331E-02	1.673E+01	3.349E-03	2.729E+01	1.127E-03	3.353E+01	4.101E+00
1.110E-01	2.756E+01	2.951E-02	8.114E+00	1.537E-03	1.329E+01	5.479E-04	1.629E+01	1.673E+00
6.734E-02	1.285E+01	1.257E-02	3.896E+00	6.775E-04	6.392E+00	2.634E-04	7.827E+00	7.215E-01
4.085E-02	5.983E+00	5.386E-03	1.858E+00	2.990E-04	3.053E+00	1.257E-04	3.734E+00	3.137E-01
2.478E-02	2.833E+00	2.481E-03	8.832E-01	1.390E-04	1.452E+00	5.978E-05	1.775E+00	1.464E-01
1.503E-02	1.354E+00	1.196E-03	4.188E-01	6.668E-05	6.885E-01	2.834E-05	8.412E-01	7.130E-02
9.118E-03	6.462E-01	5.739E-04	1.985E-01	3.197E-05	3.262E-01	1.342E-05	3.985E-01	3.466E-02
5.530E-03	2.869E-01	2.561E-04	8.754E-02	1.418E-05	1.439E-01	5.923E-06	1.758E-01	1.555E-02
3.519E-03	1.463E-01	1.301E-04	4.451E-02	7.208E-06	7.309E-02	3.012E-06	8.935E-02	7.981E-03
2.239E-03	7.476E-02	6.650E-05	2.259E-02	3.678E-06	3.714E-02	1.526E-06	4.537E-02	4.119E-03
1.425E-03	3.812E-02	3.403E-05	1.145E-02	1.878E-06	1.890E-02	7.768E-07	2.302E-02	2.128E-03
9.069E-04	2.921E-02	2.624E-05	8.780E-03	1.444E-06	1.446E-02	5.926E-07	1.766E-02	1.670E-03
3.673E-04	7.626E-03	6.793E-06	2.290E-03	3.732E-07	3.674E-03	1.520E-07	4.504E-03	4.457E-04
1.487E-04	1.573E-03	1.510E-06	4.901E-04	8.392E-08	8.521E-04	3.653E-08	1.033E-03	1.002E-04
7.550E-05	8.904E-04	8.182E-07	2.717E-04	4.481E-08	4.343E-04	1.713E-08	5.391E-04	5.382E-05

Table 3
Neutron Spectra Normalized to Total Source Strength for Plutonium Isotopes in the Form of PuF_4 and ^{241}Am in PuF_4

Group Upper Energy Boundary, MeV	$^{238}PuF_4$ neutrons per group	$^{239}PuF_4$ neutrons per group	$^{240}PuF_4$ neutrons per group	$^{241}PuF_4$ neutrons per group	$^{242}PuF_4$ neutrons per group	$^{243}PuF_4$ neutrons per group	$^{244}PuF_4$ neutrons per group	^{241}Am in PuF_4 neutrons per group
1.000E+01	5.453E+01	5.260E-04	1.702E+01	9.961E-04	3.119E+01	7.996E-04	1.809E+01	3.406E-02
6.065E+00	2.906E+02	2.588E-03	1.039E+02	5.425E-03	1.802E+02	5.819E-03	1.503E+02	1.513E-01
3.679E+00	1.854E+05	2.737E+02	1.251E+03	4.243E+00	3.794E+02	1.373E-02	3.828E+02	3.640E+04
2.231E+00	8.089E+05	2.046E+03	7.831E+03	5.592E+01	4.992E+02	1.622E-02	4.707E+02	1.610E+05
1.353E+00	5.803E+05	1.853E+03	7.008E+03	6.354E+01	4.136E+02	1.275E-02	3.770E+02	1.159E+05
8.210E-01	2.936E+05	7.430E+02	2.855E+03	2.773E+01	2.365E+02	7.936E-03	2.363E+02	5.827E+04
5.000E-01	1.721E+05	3.763E+02	1.464E+03	1.076E+01	1.246E+02	4.446E-03	1.326E+02	3.416E+04
3.025E-01	8.179E+04	1.932E+02	7.542E+02	4.497E+00	6.237E+01	2.285E-03	6.810E+01	1.633E+04
1.830E-01	3.342E+04	9.743E+01	3.782E+02	2.006E+00	3.044E+01	1.127E-03	3.354E+01	6.680E+03
1.110E-01	1.323E+04	4.118E+01	1.598E+02	9.409E-01	1.476E+01	5.479E-04	1.629E+01	2.644E+03
6.734E-02	5.136E+03	1.625E+01	6.389E+01	4.440E-01	7.090E+00	2.634E-04	7.828E+00	1.075E+03
4.085E-02	2.158E+03	7.026E+00	2.789E+01	2.264E-01	3.410E+00	1.257E-04	3.735E+00	4.304E+02
2.478E-02	9.313E+02	3.139E+00	1.256E+01	1.053E-01	1.619E+00	5.978E-05	1.775E+00	1.854E+02
1.503E-02	3.929E+02	1.373E+00	5.475E+00	4.489E-02	7.597E-01	2.834E-05	8.413E-01	7.801E+01
9.118E-03	1.671E+02	5.931E-01	2.368E+00	1.895E-02	3.564E-01	1.342E-05	3.985E-01	3.322E+01
5.530E-03	6.832E+01	2.441E-01	9.869E-01	7.736E-03	1.563E-01	5.923E-06	1.758E-01	1.364E+01
3.519E-03	3.327E+01	1.193E-01	4.844E-01	3.747E-03	7.906E-02	3.012E-06	8.935E-02	6.652E+00
2.239E-03	1.635E+01	5.879E-02	2.389E-01	1.831E-03	4.005E-02	1.526E-06	4.537E-02	3.269E+00
1.425E-03	8.130E+00	2.932E-02	1.189E-01	9.060E-04	2.034E-02	7.768E-07	2.303E-02	1.626E+00
9.069E-04	6.146E+00	2.218E-02	9.000E-02	6.830E-04	1.555E-02	5.926E-07	1.766E-02	1.229E+00
3.673E-04	1.570E+00	5.672E-03	2.306E-02	1.742E-04	3.951E-03	1.520E-07	4.504E-03	3.140E-01
1.487E-04	3.469E-01	1.252E-03	5.070E-03	3.855E-05	9.134E-04	3.653E-08	1.033E-03	6.939E-02
7.550E-05	1.872E-01	6.773E-04	2.753E-03	2.078E-05	4.673E-04	1.713E-08	5.292E-04	3.746E-02