NE 620/860 - Applied Reactor Physics - Lab 1

References

- Lectures 1, 2, and 3
- NJOY Reference Manual
- Understanding NJOY (http://t2.lanl.gov/nis/njoy/)

Software/Hardware

- Access to *eigendoit.ksu.mne.edu* via an MNE or your machine for using NJOY using SSH **or** an installation of NJOY on your machine (Linux or maybe OS X)

Tasks

Acquiring the Data

Throughout these laboratory exercises, we'll focus exclusively on the materials used in traditional, light-water reactor fuel (UO$_2$) and its surrounding moderator (H$_2$O).

Head to https://t2.lanl.gov/nis/data/endf/endfvii-n.html and acquire the *neutron* data for the following nuclides: - U-235 - U-238 - H-1 - O-16

Save these files as u235, u238, h1, and o16, respectively.

Note, these are text files and quite large. Make sure to place these in a folder that you can access later on and in which you can execute NJOY.

Then head to https://t2.lanl.gov/nis/data/endf/endfvii-thermal.html and acquire the *thermal data* for H in H$_2$O. Save this file as h_in_h20 in the same directory as the other files.

Simple Cross Sections

(Adapted from http://t2.lanl.gov/nis/njoy/exer01.html)

Use your text editor to open the U-235 ENDF file you downloaded. Search for the beginning of the elastic cross section tabulation by looking for MAT=1301, MF=3, and MT=2. Answer the following: - What is the elastic cross section at 0.0253 eV? - What is the mathematical shape of this cross section at low energies? - Where does the cross section begin to deviate from its low-energy shape? - What interpolation law is specified for elastic scattering? - What is the elastic scattering cross section at .0015 eV?

Now, search for the beginning of the radiative capture cross section (MT=102) and answer the following: - What is the capture cross section at 0.0253 eV? - What is the mathematical shape of this cross section at low energies? - Where does the cross section begin to deviate from its low-energy shape? - What interpolation law is specified for capture? - What is the capture cross section at .0015 eV?

Finally, search for the beginning of the total cross section (MT=1): - Does the total cross section at 0.0253 eV match the sum of the elastic and capture cross sections? - Compute the total cross section at .0015 eV using linear interpolation. What is the percent error with respect to the sum of the elastic and capture cross sections at that energy? - Does the more complicated interpolation law given for MT=1 really solve the problem?

Plotting Cross Sections

(Adapted from http://t2.lanl.gov/nis/njoy/exer02.html)

NJOY runs data through its various modules by using files called "tapes" to communicate between the modules. Therefore, NJOY input files give the module name to use, then the input and output units for that module, and then the characteristic input for that module. This is repeated for each module to be used, and then terminated with the module name "stop".

Navigate to your directory containing the ENDF data files, and copy `h1` to tape 20 (i.e., `cp h1 tape20`). Produce the following input file *but leave off the comments to the right of the slash symbol*.

```
reconr
20 21
'exercise 2'/    new tape ID title
1301 1/          MAT
.001/            tolerance
'1-H-1'/         descriptive card for new tape
0/
plotr
22/              output file
/                default page style
1/               new axes, new curve
'1-H-1'/         title line 1
/                no line 2 for titles
4/               log-log
1e-4 1/          x-axis range
/                default label
.01 10/          y-axis range
/                default label
5 21 1301 3 102/ data source for curve
/                default curve style
99/              finished
viewr
22 23/
stop
```

This file says to run RECONR on MAT1301 with a reconstruction tolerance of .001 (.1%). Take the output on tape21 into PLOTR and extract the data for MAT1301, MF3, MT102 onto tape22. A title is provided for the graph, and special scales are specified for the axes. The default axis labels and line type will be used. Finally, a Postscript version of the graph is produced on tape23 using VIEWR.

Run NJOY with this input file to produce the image file. Include this image, in your report and answer the following: - What shape does the *elastic scattering* cross section have? - What shape does the *capture* cross section have? Is there a physical reason for that shape? (You may find that Lamarsh offers some insight!)

Reconstructing Resonances with Doppler Broadening

(Adapted from http://t2.lanl.gov/nis/njoy/exer04.html)

Copy u238 to tape 20. Create an input file containing the following lines, again leaving off the comments after the slashes:

```
reconr
20 21
'exercise 4'/    new tape ID title
9237 1/          MAT
.01/             fractional tolerance
'92-U-238'/      descriptive card for new tape
0/
broadr
20 21 22
9237 1/          MAT, one temperature
.01/             tolerance
900/             temperature is 900 K
0/
plotr
23/              output file
/                default page style
1/               new axes, new curve
'92-U-238'/      title line 1
/                no line 2 for titles
2/               lin x - log y
2 4 .5/          x-axis range and step
/                default label
.1 1000/         y-axis range
/                default label
4 21 9237 3 102 0./ data source for curve
1 3 0/           crosses with solid line
2/               second curve on axes
4 22 9237 3 102 10000./ data source for curve
0 0 1/           crosses with dashed curve
99/              finished
viewr
23 24/
stop
```

Run this input to produce the image on tape24. Include this image in your report and answer the following: - How did the shape of the resonances change between 0K and 900K? - What impact does this resonance shape change have on reactors? - Does the overall "area under the curve" appear to change for a given resonance? (You may wish to repeat this calculation over a smaller energy range to answer this.)

Multigroup Cross Sections

NJOY is most often used to produce data for downstream applications. For example, NJOY can turn ENDF data into ACE files suitable for MCNP. Here, we'll use it to produce multigroup cross sections suitable for *deterministic* codes like CASMO-4 (which we'll use later on in the course).

Specifically, we'll produce a multigroup "library" for U-238 for several different "background" cross sections and temperatures.

```
moder  / Convert data on 20 to binary to 21, id is 9237
20 -21
reconr / Reconstruct cross sections onto 22
-21 -22
'PENDF TAPE FOR U-238'/
9237 0/
0.001  0.  0.005/ Reconstruction 0.1% (0.5% max) with 0K temp
0 /
broadr
-21 -22 -23
9237 3/
.001/
300.0 600.0 900.0/
0/
unresr
-21 -23 -24
9237 3 7 1
300.0 600.0 900.0
1.e10 1.e5 1.e4 1000. 100. 10. 1
0/
groupr
-21 -24 0 -25
9237 9 0 5 0 3 7 1
'92-U-238'/
300. 600. 900.
1.e10 1.e5 1.e4 1000. 100. 10. 1
3 1 'total'/
3 2 'elastic'/
3 18 'fission'/
3 102 'capture'/
6 2 'elastic'/
6 18 'fission'/
0/
3 1 'total'/
3 2 'elastic'/
3 18 'fission'/
3 102 'capture'/
6 2 'elastic'/
6 18 'fission'/
0/
3 1 'total'/
3 2 'elastic'/
3 18 'fission'/
3 102 'capture'/
6 2 'elastic'/
6 18 'fission'/
```

```
0/
0/
stop
```

Now, you should

- Modify this input to produce plots of the continuous and multigroup *capture* cross section between 0 and 50 eV using a linear scale for the horizontal axis and a log scale for the vertical axis. Include the multigroup cross sections for background cross sections of 10, 100, 1000, and 10^{10} barns. The latter is very large and represents the infinite-dilution case. All data should be for the 900 K case.
- See if you can read the the output of GROUPR to pick out the multigroup values shown in your plot. See if you can pick out the same values for 300 K and 600 K. The ratio $f = \sigma/\sigma_0$ is the self-shielding factor. How does f depend on the background cross section? On temperature?