NE250_HW01_mnegus-prob2-ntbk

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1 NE 250 – Homework 1

1.1 Problem 2

9/22/2017

The mean free path of a particle is given by the formula

$$\lambda = \frac{1}{\Sigma_t}$$

when scattering is considered to be isotropic.

The macroscopic scattering cross section can be reexpressed in terms of the number density of the material, n, and the microscopic cross section, σ_t. For mixtures, the macroscopic cross section is the sum of the macroscopic cross sections of its components.

$$\Sigma_{x,\text{mix}} = \sum_i \Sigma_{x,i} = \sum_i n_i \sigma_{x,i}$$

Additionally, the number density of the material can be found from the material density, ρ, the molar mass of the material, m, and Avogadro's number.

$$n = \frac{\rho_i N_A}{m_i}$$

Then the mean free path is

$$\lambda = \frac{1}{\sum_i \frac{\rho_i N_A \sigma_{t,i}}{m_i}}$$

```
In [1]: def mfp(energy,medium,xs,rho,m):
            # Mean free path [cm]
            return 1/macroXS_mix(energy,medium,rho,m,xs)

        def macroXS_mix(energy,medium,rho,m,xs):
            # Macroscopic cross section of a mixture of isotopes [cm^2]
            Sig_t_mix = 0
            if energy == '14MeV': E = 0
            elif energy == '1MeV': E = 1
            elif energy == '0.05eV': E = 2
            for isotope in rho:
```

```
            Sig_t_mix += macroXS(rho[isotope],m[isotope],xs[isotope][E])
        return Sig_t_mix

    def macroXS(rho_i,m_i,xs_i):
        # Macroscopic cross section of an isotope [cm^2]
        N_A = 6.022e23
        Sig_t = rho_i*N_A*xs_i*1e-24/m_i
        return Sig_t
```

1.1.1 Densities

Air Air is 75.5% nitrogen, 23.1% oxygen, and 1.3% argon by mass according to NIST. We will assume that the nitrogen is entirely ^{14}N, oxygen is entirely ^{16}O, and ^{40}Ar, which comprise more than 99.5% of their respective element naturally.

```
In [2]: # Density [g/cm^3]
        rho_air = 1.20e-3
        rho_a = {'N14': 0.755*rho_air,
                 'O16': 0.231*rho_air,
                 'Ar40': 0.013*rho_air
                }
```

Water Water is 11.2% hydrogen and 88.8% oxygen by mass. We are assuming the hydrogen is entirely ^{1}H and the oxygen is entirely ^{16}O.

```
In [3]: # Density [g/cm^3]
        rho_water = 1
        rho_w = {'H1': 0.112*rho_water,
                 'O16': 0.888*rho_water
                }
```

Uranium Natural uranium is 99.3% U238 and 0.7% U235 by mass according to the World Nuclear Association.

```
In [4]: # Density [g/cm^3]
        rho_uranium = 19.1
        rho_u = {'U235': 0.007*rho_uranium,
                 'U238': 0.993*rho_uranium
                }
```

1.1.2 Molar Masses

```
In [5]: # Molar mass [g/mol]
        m = {'H1': 1.008,
             'N14': 14.003,
             'O16': 15.995,
             'Ar40': 39.962,
             'U235': 235.044,
```

```
            'U238': 238.051
           }
```

1.1.3 Cross Sections

Microscopic cross sections are from ENDF/B-VII.1, found using KAERI

```
In [6]: # Cross sections at 14 MeV, 1 MeV, and 0.05 eV [b]
        xs = {'H1': (0.687,4.246,20.673),
                   'N14': (1.569,2.345,11.264),
                   'O16': (1.592,8.154,3.852),
                   'Ar40': (2.290,3.135,1.116),
                   'U235': (5.831,6.800,472.885),
                   'U238': (5.858,7.068,9.862)
                  }
```

1.1.4 Calculations

```
In [7]: def loop_media(energy):
            print('Mean Free Path in')
            for medium in ['air','water','uranium']:
                if medium == 'air': rho = rho_a
                elif medium == 'water': rho = rho_w
                elif medium == 'uranium': rho = rho_u
                print('\t{}\t{} cm'.format(medium,round(mfp(energy,medium,xs,rho,m)
```

a) 14 MeV neutrons in air, water, and uranium

```
In [8]: energy = '14MeV'
        loop_media(energy)

Mean Free Path in
        air         12773.78 cm
        water         10.08 cm
        uranium        3.53 cm
```

b) 1 MeV neutrons in air, water, and uranium

```
In [9]: energy = '1MeV'
        loop_media(energy)

Mean Free Path in
        air         5643.26 cm
        water         1.8 cm
        uranium        2.93 cm
```

c) 0.05 eV Neutrons in air, water, and uranium

In [10]:
```
energy = '0.05eV'
loop_media(energy)
```

```
Mean Free Path in
        air        2086.21 cm
        water         0.66 cm
        uranium         1.57 cm
```