Homework 2

NUCE 2100

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Instructions: Complete the problems below being sure to show your work. If you need to lookup nuclear data from an external source please reference the source in your solutions (once is sufficient).

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1. Consider the so-called DT (deuterium, tritium) fusion reaction

$^2H +^3 H \rightarrow^H He+?$

a. What is the missing product in the reaction?

```
A neutron!
```

b. Calculate the binding energy of ^2H, ^3H, and ^4He

```
def binding_energy(mass,z,n):
    c = 299792458 # m/s
    h1_mass = 1007825.03190 #micro AMU
    neutron_mass = 1008664.9159 #mirco AMU

    mass_defect = (z*h1_mass + n*neutron_mass - mass)/1e6 #micro
amu to u
    energy = (mass_defect*1.6606e-27)*c**2 #amu to kg, answer in J

    return energy*6.242e12 #Convert J to MeV

twoH_mass = 2014101.77784 #micro AMU
print("2H Binding Energy:", binding_energy(twoH_mass,1,1), "MeV")
```

```
threeH_mass = 3016049.281328 #micro AMU
print("3H Binding Energy:", binding_energy(threeH_mass,1,2), "MeV")

fourHe_mass = 4002603.25413 #micro AMU
print("4He Binding Energy:", binding_energy(fourHe_mass,2,2),
"MeV")
```

```
2H Binding Energy: 2.22482284320947 MeV
3H Binding Energy: 8.482774677373571 MeV
4He Binding Energy: 28.298926363869242 MeV
```

c. Calculate the Q value of the reaction

```
neutron_mass = 1008664.9159 #mirco AMU
c = 299792458 # m/s

Q = (fourHe_mass + neutron_mass - twoH_mass -
threeH_mass)/1e6*1.6606e-27 * c**2
print("Q is ", Q*6.242e12, "MeV")
```

```
Q is  -17.59132884328642 MeV
```

d. Show that the Q value is equal to the change in binding energy

```
Q_from_binding = binding_energy(threeH_mass,1,2) +
binding_energy(twoH_mass,1,1) - binding_energy(fourHe_mass,2,2)
print("Q from binding is ", Q_from_binding, "MeV")
```

```
Q from binding is  -17.5913288432862 MeV
```

2. Using atomic mass data, compute the average binding energy per nucleon of the following
nuclei:

a. ^{6}Li

b. ^{12}C

c. ^{51}V

d. ^{138}Ba

e. ^{235}U

[Atomic Mass Data]

```
sixLi_mass = 6015122.8874 #micro AMU
print("6Li Binding Energy:", binding_energy(sixLi_mass,3,3), "MeV")

twelveC_mass = 12000000.0 #micro AMU
print("12C Binding Energy:", binding_energy(twelveC_mass,6,6),
"MeV")

fiftyoneV_mass = 50943957.66 #micro AMU
print("51V Binding Energy:", binding_energy(fiftyoneV_mass,23,28),
"MeV")

onethirtyeightBa_mass = 137905247.06 #micro AMU
print("138Ba Binding Energy:",
binding_energy(onethirtyeightBa_mass,56,82), "MeV")

twothirtyfiveU_mass = 235043928.1  #micro AMU
print("235U Binding Energy:",
binding_energy(twothirtyfiveU_mass,92,143), "MeV")
```

```
6Li Binding Energy: 31.997677545325832 MeV
12C Binding Energy: 92.17236586153292 MeV
```

```
51V Binding Energy: 445.8977789774969 MeV
138Ba Binding Energy: 1158.4258775508786 MeV
235U Binding Energy: 1784.0708281992524 MeV
```

3. Compute the atom densities of ^{235}U and ^{238}U in UO2 of physical density 10.8 g/cm3 if the uranium
   is enriched to 3.5 w/o in ^{235}U.

```
twothirtyeightU_mass = 238050786.9 # micro AMU
UO2_density = 10.8 #g/cm^3

N_235 = (100-3.5)/3/100 *
UO2_density*0.6022e24/(twothirtyfiveU_mass*1e-6)
#(abundance of U235 in UO2, remember only 1 U for every 2 O!) *
converting to atoms / cm^3
print("There are ", N_235, " 235U atoms per cm^3")

N_238 = (3.5)/3/100 *
UO2_density*0.6022e24/(twothirtyeightU_mass*1e-6)
print("There are ", N_238, " 238U atoms per cm^3")
```

```
There are  8.900646006519835e+21  235U atoms per cm^3
There are  3.187437478703836e+20  238U atoms per cm^3
```

4. Calculate the mean free path of 1-eV neutrons in graphite. The total cross section of carbon at
   this energy is 4.8 b.

[Graphite Density Source]

```
graphite_density = 1.82 #g/cm^3
graphite_nuclei_density = graphite_density/12.000*0.6022e24
#atoms/cm^3
```

```
print("The nuclei density of graphite is ",graphite_nuclei_density,"
atoms/cm^3")

mean_free_path = 1/(4.8*10e-24)/graphite_nuclei_density
print("The mean free path is ",mean_free_path,"cm in graphite.")
```

```
The nuclei density of graphite is  9.133366666666668e+22
atoms/cm^3
The mean free path is  0.22810135729431646 cm in graphite.
```