

HW2

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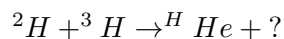
1 Homework 2

1.1 NUCE 2100

1.1.1 Dane Sabo

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).

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



- a. What is the missing product in the reaction?

A neutron!

- b. Calculate the binding energy of ${}^2\text{H}$, ${}^3\text{H}$, and ${}^4\text{He}$

```
[1]: def binding_energy(mass,z,n):  
    c = 299792458 # m/s  
    h1_mass = 1007825.03190 #micro AMU  
    neutron_mass = 1008664.9159 #micro AMU  
  
    mass_defect = (z*h1_mass + n*neutron_mass - mass)/1e6 #calculate mass_  
↪defect, micro amu to u  
    energy = (mass_defect*1.6606e-27)*c**2 #convert amu to kg, answer in J  
  
    return energy*6.242e12 #Convert J to MeV, and return value  
  
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

```
[2]: neutron_mass = 1008664.9159 #micro AMU
c = 299792458 # m/s

#Calculate difference in mass of products - reactants, multiply by c^2
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

```
[3]: 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:

- ${}^6\text{Li}$
- ${}^{12}\text{C}$
- ${}^{51}\text{V}$
- ${}^{138}\text{Ba}$
- ${}^{235}\text{U}$

Atomic Mass Data

```
[4]: #For each part, find the binding energy of the nuclide, then divide by the
    ↪number of nucleons.

sixLi_mass = 6015122.8874 #micro AMU
print("A: Average 6Li Binding Energy:", binding_energy(sixLi_mass,3,3)/6, "MeV",
    ↪per nucleon")

twelveC_mass = 12000000.0 #micro AMU
print("B: Average 12C Binding Energy:", binding_energy(twelveC_mass,6,6)/12,
    ↪"MeV per nucleon")

fiftyoneV_mass = 50943957.66 #micro AMU
```

```

print("C: Average 51V Binding Energy:", binding_energy(fiftyoneV_mass,23,28)/
↳51, "MeV per nucleon")

onethirtyeightBa_mass = 137905247.06 #micro AMU
print("D: Average 138Ba Binding Energy:",
↳binding_energy(onethirtyeightBa_mass,56,82)/138, "MeV per nucleon")

twothirtyfiveU_mass = 235043928.1 #micro AMU
print("E: Average 235U Binding Energy:",
↳binding_energy(twothirtyfiveU_mass,92,143)/235, "MeV per nucleon")

```

A: Average 6Li Binding Energy: 5.332946257554306 MeV per nucleon
 B: Average 12C Binding Energy: 7.681030488461077 MeV per nucleon
 C: Average 51V Binding Energy: 8.743093705441115 MeV per nucleon
 D: Average 138Ba Binding Energy: 8.394390417035352 MeV per nucleon
 E: Average 235U Binding Energy: 7.5917907582946915 MeV per nucleon

-
3. Compute the atom densities of ^{235}U and ^{238}U in UO_2 of physical density 10.8 g/cm³ if the uranium is enriched to 3.5 w/o in ^{235}U .

```

[5]: 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 cm³
 There are 3.187437478703836e+20 238U atoms per cm³

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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

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[6]: graphite_density = 1.82 #g/cm^3
graphite_nuclei_density = graphite_density/12.000*0.6022e24 #atoms/cm^3
#Take the density of graphite, divide by 12.000 g 12C / mole, then multiply by
↳Avogadro's Number to get to atoms
print("The nuclei density of graphite is ",graphite_nuclei_density," atoms/
↳cm^3")

```

```
mean_free_path = 1/(4.8*10e-24)/graphite_nuclei_density
#Follow the formula from the slides, where we are converting Barns to cm.
print("The mean free path is ",mean_free_path,"cm in graphite.")
```

The nuclei density of graphite is 9.133366666666668e+22 atoms/cm³
The mean free path is 0.22810135729431646 cm in graphite.

[]: