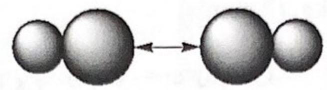
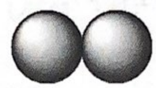
Name: Josh Whitehead UID: U1069343

Homework #3 – Due on March 23, 2021

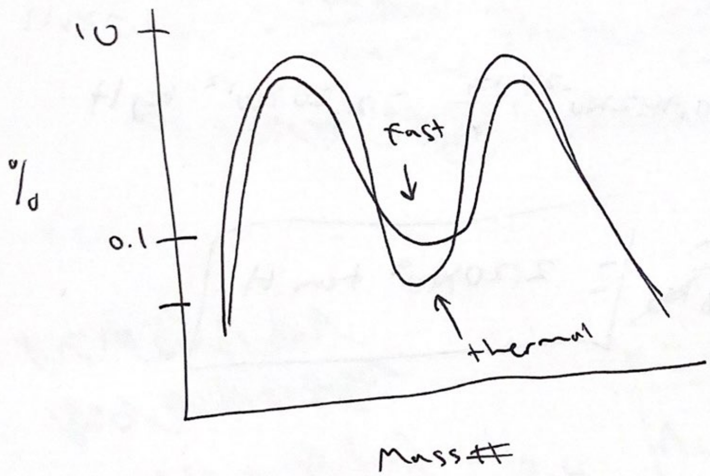
1. When thermal neutrons strike a fissile nucleus, the compound nucleus is placed in an excited state that vibrates between the two states shown below. Fast neutrons form some compound nuclei that look like the second illustration. Based upon this information draw the expected mass yield curve for neutron-induced fission of a fissile nucleus for thermal neutrons and a second mass yield curve for fast neutron induced fission. Be sure to label the axes correctly. (1 point)



Thermal Neutron Compound Nucleus Formation



Fast Neutron Compound Nucleus Formation



2. From careful measurements scientists have determined that the total energy output of the Sun is 3.86×10^{23} kJ/s. All of this energy is produced by a series of approximately 10 nuclear fusion reactions occurring inside the core of the Sun. For the sake of simplicity, let's approximate all of those reactions by one of the more important solar fusion reactions

$$^{2}H + {}^{1}H \rightarrow {}^{3}He + \gamma$$

From the Sun's energy output and the Q-value for this fusion reaction, determine how many tons of hydrogen (both ^{2}H and ^{1}H) are fused per second inside the core of the Sun. Measured masses of the nuclei are ^{2}H = 2.014102 amu, ^{1}H = 1.007825 amu, and ^{3}He = 3.016030 amu. Use 1 ton = 2200 lb = 998.8 kg. (2 points)

$Q = 931.5(3.01603 - 2.014102 - 1.007825) = 5.493055$ MeV

$Q = 5.493055 \text{ MeV} \frac{\text{KJ}}{6.242 \times 10^{15} \text{ MeV}} = \underline{8.80015 \times 10^{-16}} \frac{\text{KJ}}{\text{rxn}}$

$\#\text{ rxn}: \frac{3.86 \cdot 10^{23}}{8.80015 \times 10^{-16}} = \underline{4.39 \times 10^{38} \text{ rxns}}$

$\frac{m\ H}{\text{rxn}} : 1.661 \times 10^{-27} \frac{\text{Kg}}{\text{amu}} \cdot (2.014102 + 1.007825) = 5.01942 \times 10^{-27} \frac{\text{Kg H}}{\text{rxn}}$

$\rightarrow 4.39 \times 10^{38} \cancel{\text{rxn}} \cdot 5.01942 \times 10^{-27} \frac{\text{Kg}}{\cancel{\text{rxn}}} = 2.20 \times 10^{12} \text{ Kg H}$

$2.20 \times 10^{12} \cancel{\text{Kg}} \cdot \frac{1 \text{ ton}}{998.8 \cancel{\text{Kg}}} = \boxed{2.20 \times 10^{9} \text{ ton H}}$

3. ^{24}Na is produced through the reaction $^{26}Mg(d,a)^{24}Na$. A 0.2 mm thick magnesium foil is irradiated for 1 h by a current of 130 mA of 22 MeV D^+ ions in a cyclotron. The foil has a much larger area than the cross-section of the beam. What is the specific activity of ^{24}Na if the magnesium foil (3 cm^2) contains 0.003% Na and the cross-section for the reaction is assumed to be 25 mb? (3 points)

$$A_1 = k(1-e^{-\lambda_1 t_{irr}})e^{-\lambda_1 t_{cool}}$$

$$k = 6.24\times10^{18}\, I\, \sigma\, N_v x\, z^{-1}$$

$\lambda_1 = \frac{\ln 2}{t_{1/2}} = 0.04728 \frac{1}{hr}$

$t_{irr} = 1\,hr$

$t_{cool} = 0$

$I = 130\,mA = 0.130\,A$

$\sigma = 0.25\,mb = 25\times10^{-27}\,cm^2$

$N_v x = \frac{\rho}{M_w} = \frac{1.74\,g/cm^3}{24.3\frac{g}{mol}} \to 0.07160 \frac{mol}{cm^3} \cdot 0.11 \cdot 6.022\times10^{23} \cdot 0.02\,cm$

$N_v x = 9.48336\times10^{19}$

$z^{-1} = 1$

$k = 1.92323\times10^{12}$

$$\boxed{A_1 = 8.881397\times10^{10}\,Bq}$$

$A_1 = k(1-e^{-\lambda_1 t_{irr}}) =$

4. Oxygen can be determined through the reaction $^{16}O(n,p)^{16}N$ (Half-life = 7 s); the cross-section for 14 MeV neutrons is 49 mb. 3.982 g of a fatty acid were irradiated for 20 s in $4x10^{12}$ n m^{-2} s^{-1}. After the irradiation, the sample was rapidly transferred with a rabbit system to a scintillation detector which had an efficiency of 1.1% for the ^{16}N g-rays. Exactly 8 s after the end of the irradiation, the sample was counted for 1 min, yielding 13,418 counts above background. What was the oxygen fraction of the sample? (3 points)

@beginning : $N_N = \dfrac{N_{count}}{(1-\exp(-\lambda t_{count}))\,0.011} = 1.223\times10^{6}$ atoms

@bombard : $N_{0N} = N_N \exp(\lambda t_{cool}) = 2.701\times10^{6}$ atoms

^{16}O : $N_0 = \dfrac{\lambda N_{0N}}{\phi\sigma(1-\exp(-\lambda t_{irr}))} = 1.583\times10^{22}$ atoms

$C_O = \dfrac{N_O}{N_A}\cdot M_O \cdot \dfrac{1}{m_{tot}} = 0.106$ ∴ 10.6% oxygen

$\lambda = \dfrac{\ln 2}{7\,\text{sec}}$

$m_{tot} = 3.982$ g

$\phi = 4\times10^{12}\ \dfrac{1}{\text{sec}\,m^2}$

$\sigma = 49\times10^{-3}\cdot10^{-28}\ m^2$

$M_O = 16\ \dfrac{g}{mol}$

5. ^{199}Au can be formed through two successive n,g-reactions on ^{197}Au (100% in nature). If 1 g of ^{197}Au is irradiated with 10^{18} n m^{-2} s^{-1} for 30 h, how many grams of ^{199}Au will be present at the end of the irradiation? The chain of events to be considered is below. (3 points)

$$^{197}Au(\sigma_{n,g} = 98.8\ b) \rightarrow {}^{198}Au(t_{\frac{1}{2}} = 2.694\ d;\ \sigma_{n,g} = 25{,}100\ b) \rightarrow {}^{199}Au(t_{\frac{1}{2}} = 2.139\ d;\ \sigma_{n,g} = 30\ b)$$

$$N_n(t) = \Lambda_1 N \ldots \Lambda^*_{n-1} N_1^0 \sum C_i e^{-\Lambda_i t}$$

$$C_i = \prod (\Lambda_j - \Lambda_i)^{-1}$$

$$\therefore N_{199} = \Lambda_{197} \Lambda^*_{198} N^0_{197} \sum C_i e^{-\Lambda t}$$

$$C_{197} = \frac{e^{-\Lambda_{197} t}}{(\Lambda_{198} - \Lambda_{197})(\Lambda_{199} - \Lambda_{197})}$$

$$C_{198} = \frac{e^{-\Lambda_{198} t}}{(\Lambda_{197} - \Lambda_{198})(\Lambda_{199} - \Lambda_{198})}$$

$$C_{199} = \frac{e^{-\Lambda_{199} t}}{(\Lambda_{197} - \Lambda_{199})(\Lambda_{198} - \Lambda_{199})}$$

$$\Lambda = \varphi\sigma + \lambda$$

$$\Lambda^* = \varphi\sigma + \lambda^*$$

$$\lambda_{198} = \frac{\ln(2)}{2.694\,d}$$

$$\lambda^*_{198} = \frac{\ln(2)}{2.139\,d}$$

$$N^0 = \frac{1\,g}{196.97\,\frac{g}{mol}} \cdot 6.022\times10^{23}\ \frac{atom}{mol}$$

$t = 108000$ sec

$$\varphi = 1\times10^{14}\ \frac{n}{cm^2\,sec}$$

$$\Lambda_{197} = 9.88\times10^{-9}\ \frac{1}{sec}$$

$$\Lambda^*_{198} = 2.51\times10^{-6}\ \frac{1}{sec}$$

$$\boxed{\therefore N_{199} = 3.11226\times10^{17}\ \text{atoms}}$$