Problem 1.

Calculate the threshold for the following photonuclear reactions:

(a) $^{12}\mathrm{C}(\gamma, \mathrm{n}^0)^{11}\mathrm{C}$

(b) $^{53}\mathrm{Cr}(\gamma, \mathrm{n}^0)^{52}\mathrm{Cr}$

(c) $^{105}\mathrm{Pd}(\gamma, \mathrm{n}^0)^{104}\mathrm{Pd}$

(d) $^{183}\mathrm{W}(\gamma, \mathrm{n}^0)^{182}\mathrm{W}$

(e) How do these thresholds compare with what you would expect for a typical binding energy of a nucleon in a nucleus?

Solution

$$\begin{aligned}
SE_b &= \Delta E_b + \Delta E_Y - \Delta E_X \\
(h\nu)_{min} &= BE_b \left(1 + \frac{BE_b}{2M_X c^2}\right) \\
&= (SE_b + \cancel{E_Y^*}) \times \left(1 + \frac{(SE_b + \cancel{E_Y^*})}{2M_X c^2}\right)
\end{aligned}$$

Part (a)

34.395 MeV

Part (b)

8.5801 MeV

Part (c)

7.3485 MeV

Part (d)

6.2997 MeV

Part (e)

They are slightly higher than expected due to the requirement that the daughter nucleus have some positive momentum (and therefore energy)

Problem 2. Anderson 7.4

Suppose a 140 keV photon undergoes photoelectric effect in a lead sheet with a K-shell electron.

(a) What is the kinetic energy liberated?

(b) If it is assumed that this is all photoelectron kinetic energy, calculate the electron momentum and the photon momentum and compare the two.

Solution

Part (a)

From Appendix 4, the K-shell binding energy is 88.004 keV.

$$\begin{aligned} T_{lib} &= E_\gamma - BE \\ &= 140\,\mathrm{keV} - 88.004\,\mathrm{keV} \\ &= 51.996\,\mathrm{keV} \end{aligned}$$

Part (b)

$$\begin{aligned} p_\gamma &= \frac{h\nu}{c} && (1) \\ &= 140\,\mathrm{keV}\,c^{-1} && (2) \\ p_{\mathrm{e}^-} &= \sqrt{2mE} && (3) \\ &= \sqrt{2 \times 511\,\mathrm{keV}/c^2 \times 51.996\,\mathrm{keV}} && (4) \\ &= 230.521\,\mathrm{keV}\,c^{-1} && (5) \\ & && (6) \end{aligned}$$

Problem 3. Anderson 7.11

Given that the mass attenuation coefficient for ^{63}Cu is $0.474\,\mathrm{m^2/kg}$ at $40\,\mathrm{keV}$ (photoelectron dominates) and $0.0042\,\mathrm{m^2/kg}$ at $2\,\mathrm{MeV}$ (incoherent scatter dominates), estimate the coefficient for ^{56}Fe at these energies.

Solution

Since these are neighboring elements, the general form

$$\left(\frac{\mu}{\rho}\right)_{\mathrm{Fe}} \approx \frac{(Z^n/M_m)_{\mathrm{Fe}}}{(Z^n/M_m)_{\mathrm{Cu}}}\left(\frac{\mu}{\rho}\right)_{\mathrm{Cu}}$$

applies. For photoelectron we use $n = 4$, while for incoherent scattering we use $n = 1$.

For simplicity, use $M_m \approx A_m$

$$\begin{aligned} M_{^{56}\mathrm{Fe}} &\approx 56\,\mathrm{u} \\ Z_{^{56}\mathrm{Fe}} &= 26 \\ M_{^{63}\mathrm{Cu}} &\approx 63\,\mathrm{u} \\ Z_{^{63}\mathrm{Cu}} &= 29 \end{aligned}$$

Part (a)

$E = 40\,\mathrm{keV}$

$$\begin{aligned} \left(\frac{\mu}{\rho}\right)_{\mathrm{Fe}} &\approx \frac{26^4/56}{29^4/63} * 0.474\,\mathrm{m^2/kg} \\ &\approx 0.345\,\mathrm{m^2/kg} \end{aligned}$$

Part (b)

$E = 2\,\mathrm{MeV}$

$$\begin{aligned} \left(\frac{\mu}{\rho}\right)_{\mathrm{Fe}} &\approx \frac{26/56}{29/63} * 0.0042\,\mathrm{m^2/kg} \\ &\approx 0.004\,24\,\mathrm{m^2/kg} \end{aligned}$$

Problem 4.

Go to the NIST XCOM webpage and find the photon energies where the photoelectric effect and Compton scattering (incoherent scattering) have the same magnitudes for:

(a) Carbon

(b) Aluminum

(c) Copper

(d) Tungsten

(e) Uranium

Solution

Part (a)

22 keV

Part (b)

52 keV

Part (c)

130 keV

Part (d)

463 keV

Part (e)

677 keV

NE551_Homework_Chapter_7

October 20, 2016

1 NE551 Homework Chapter 7

1.1 Problem No. 1

In [4]:
```
import scipy.constants as const
amu = const.value("atomic mass constant energy equivalent in MeV") # 931.49
```

In [1]:
```
# Mass excess values from Anderson Appendix 5
n1 = 8071.44
c11 = 10648.4
c12 = 0
cr52 = -55410.7
cr53 = -55280.7
pd104 = -89411.0
pd105 = -88431.0
w182 = -48156.0
w183 = -46272.0
```

In [2]:
```
def se(parent, daughter):
    return (daughter + n1) - parent
```

In [3]:
```
def hv_min(parent, daughter, parent_a):
    be = se(parent, daughter)
    return be * (1 + (be / (2.0 * amu * parent_a)))
```

In [5]:
```
hv_min(c12, c11, 12)
```

Out[5]: 34395.03372712351

In [6]:
```
hv_min(cr53, cr52, 53)
```

Out[6]: 8580.162987293754

In [7]:
```
hv_min(pd105, pd104, 105)
```

Out[7]: 7348.52069445043

In [8]:
```
hv_min(w183, w182, 183)
```

Out[8]: 6299.73510083537

In [ ]: