Hw # 11

1.) $\alpha + {}^{11}B \rightarrow {}^{14}N + n$

Conservation of energy

Assuming ${}^{11}B$ initially at rest

$$\frac{1}{2} m_\alpha v_\alpha^2 + m_\alpha c^2 + m_B c^2 = \frac{1}{2} m_N v_N^2 + m_N c^2 + \frac{1}{2} m_n v_n^2 + m_n c^2$$

conservation of momentum

$$m_\alpha \vec{v}_\alpha = m_N \vec{V}_N + m_n \vec{v}_n$$

Approximation of $m_n \ll m_N$

N has little E_K compared with n

so neglect $\frac{1}{2} m_N v_N^2$

$$m_n c^2 = \frac{\frac{1}{2} m_\alpha v_\alpha^2 + m_\alpha c^2 + m_B c^2 - m_N c^2}{1 + \frac{v_n^2}{2c^2}}$$

no need to measure N velocity.

#2

```
%Calculate for 55Fe
Z=26;
A=55;
M=51.1618; %GeV/c^2
[Eb, Weizaecker]=CalcEb(Z,A,M);
%results:
% binding energy Eb is 480.8 MeV
% This is an even-odd or odd-even nucleus. Weizaecker binding energy is 478.6 MeV
% Wiezaecher is off by  0.46 percent

%Calculate for 57Co
Z=27;
A=57;
M=53.0225; %GeV/c^2
[Eb, Weizaecker]=CalcEb(Z,A,M);
%results:
% binding energy Eb is 497.9 MeV
% This is an even-odd or odd-even nucleus. Weizaecker binding energy is 495.7 MeV
% Wiezaecher is off by  0.44 percent

%Calculate for 58Ni
Z=28;
A=58;
M=53.9526; %GeV/c^2
[Eb, Weizaecker]=CalcEb(Z,A,M);
%results:
% binding energy Eb is 506.1 MeV
% This is an even-even nucleus. Weizaecker binding energy is 502.6 MeV
% Wiezaecher is off by  0.68 percent
```

#2 cont.


```
function [Eb, Weizaecker]=CalcEb(Z,A,M)
%Z: atomic number
%A: atomic mass number
%M: nuclear mass in GeV/c^2

mp=0.93827; %GeV
mn=0.93957; %GeV

N=A-Z;

Eb=(Z*mp+N*mn-M)*1000; %(MeV)
fprintf('binding energy Eb is %5.1f MeV\n',Eb)

Weizaecker_evenodd=15.75*A-17.8*A^(2/3)-.711*Z^2/A^(1/3)-23.7*(A-2*Z)^2/A;

Weizaecker=Weizaecker_evenodd;
%even-even
if (2*round(Z/2)==Z)&(2*round(N/2)==N)
    Weizaecker=Weizaecker+11.18/sqrt(A);
    fprintf('This is an even-even nucleus. Weizaecker binding energy is %5.1f MeV\n',↙
Weizaecker)
end
%odd odd
if (2*round(Z/2)>Z)&(2*round(N/2)>N)
    'odd-odd'
    Weizaecker=Weizaecker+11.18/sqrt(A);
    fprintf('This is an odd-odd nucleus. Weizaecker binding energy is %5.1f MeV\n',↙
Weizaecker)
end
%else its just the even-odd part
if Weizaecker==Weizaecker_evenodd
    fprintf('This is an even-odd or odd-even nucleus. Weizaecker binding energy is %5.1f↙
MeV\n',Weizaecker)
end

err=abs(Eb-Weizaecker)/Eb;
fprintf('Wiezaecher is off by %5.2f percent\n',err*100)
```

3.) $R = (1.07 \text{ fm}) A^{1/3}$

a.) $A = 1$, $R = 1.07$ fm

b.) $A = 56$, $R = 4.1$ fm

c.) $A = 208$, $R = 6.3$ fm.

4.)

$^{232}Th \rightarrow {}^{228}Ra + \alpha$

α decay, $t_{1/2} = 1.4 \times 10^{10}$ years

$$Q = m_{^{232}Th} c^2 - m_{^{228}Ra} c^2 - m_{^4He} c^2$$

$$= (232.038051)(931.49401 \frac{MeV}{c^2})c^2$$

$$- (228.031064)(931.49401 \frac{MeV}{c^2})c^2$$

$$- (4.002602)(931.49401 \frac{MeV}{c^2})c^2$$

$$= 4.085 \text{ MeV}$$

$^{228}Ra \rightarrow {}^{228}Ac + e^- \quad (+ \bar{\nu}_e)$ ← ignore neutrinos in Q calculations

β^- decay, $t_{1/2} = 5.75$ years

$$Q = (228.031064 - 228.031015)(931.49401 \frac{MeV}{c^2})c^2$$

$$= 0.045 \text{ MeV}$$

$^{228}Ac \rightarrow {}^{228}Th + e^- \quad (+ \bar{\nu}_e)$

β^- decay, $t_{1/2} = 6.15$ hours

$$Q = (228.031015 - 228.028716)(931.49401 \frac{MeV}{c^2})c^2$$

$$= 2.142 \text{ MeV}$$

Electron is used to make neutral atom in β^- decay.

5) The strong force competes with Coulomb repulsion. More neutrons gives more strong force interaction, without increasing Coulomb repulsion.