11.4

Binding Energy increases with A for small A because there are more nucleons attracting each other with the strong force.

Pauli exclusion favors equal numbers of protons and neutrons. At large A, the Coulomb repulsion of the protons becomes important.

11.8 which nucleus do you expect will have a larger binding energy, ^3H or ^3He?

^3H - because there is less Coulomb repulsion

^3H

$$E_b = m_p c^2 + 2 m_n c^2 - m_H c^2$$

$$= 0.93827 (GeV) + 2 \cdot 0.93957 (GeV) - 2.8089 (GeV)$$

$$= 8.51 \text{ MeV}$$

^3He

$$E_b = 2 \cdot m_p c^2 + m_n c^2 - m_{He} c^2$$

$$= 2 \cdot 0.93827 (GeV) + 0.93957 (GeV) - 2.8084 (GeV)$$

$$= 7.71$$

11.11

Calculate binding energies of ^{55}Fe, ^{57}Co and ^{58}Ni and compare to weizaecker formula.

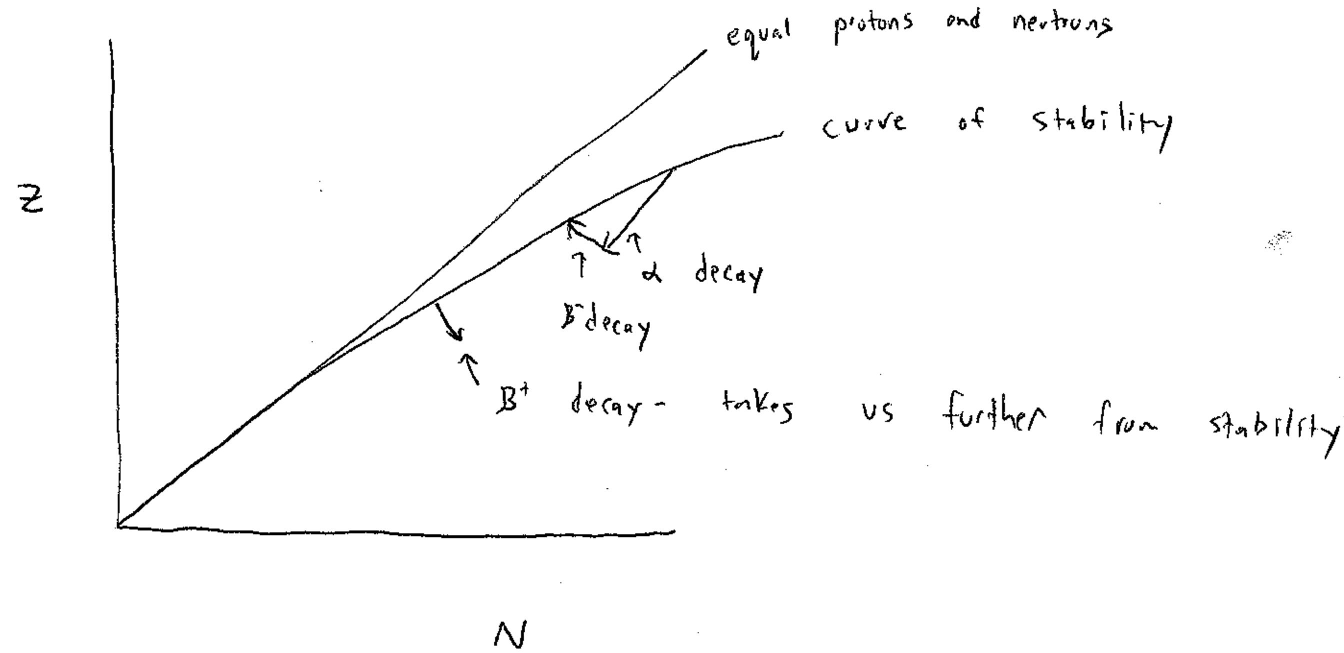
I used a short matlab program to do this. see following pages.

```
%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
```

```
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)
```

11.12

the nucleus favors a higher $\frac{N}{Z}$ ratio as A gets larger. - See 11.4.



11.22

a.) $^{23}Mg \rightarrow e^- + \nu_e + X$

Mg $z = 12$

X has $z = 13$, $A = 23$ $X = {}^{23}Al$

b.) $X \rightarrow {}^{186}Os + \alpha$

Os $z = 76$

X has $z = 78$ $A = 190$ $X = {}^{190}Pt$

c.) $^{11}C \rightarrow e^+ + \nu_e + X$

C has $z = 6$

X has $z = 5$, $A = 11$ $X = {}^{11}B$

d.) $^{12}N \rightarrow {}^{12}C + \nu_e + X$

N $z = 7$

C $z = 6$

$X = \beta^+$

e.) $p + X \rightarrow {}^{2}H + e^+ + \nu_e$

$X = p$

11.35

A person eats 1 mg of radium. Is this Hazardous to the Health? Estimate the radiation dose received in one day.

^{226}Ra is produced in the ^{238}U series

$t_{1/2} = 1.6$ ky

decays by α with $Q = 4.9$ MeV

number of particles in 1 mg

$$N = 10^{-3} g \times \frac{1 \text{ mole}}{226 g} \times \frac{6.02 \times 10^{23}}{\text{mole}} = 2.7 \times 10^{18}$$

$$t_{1/2} = 1.6 \text{ ky} \times \frac{1000 y}{ky} \times \frac{365 \text{ days}}{\text{year}} = 5.84 \times 10^5 \text{ days}$$

activity is

$$R = \frac{N}{\tau} = \frac{N \ln 2}{t_{1/2}} = 3.2 \times 10^{12} \text{ days}^{-1}$$

radiation absorbed dose. mass = 100 Kg

Energy absorbed in 1 day is

$$E = 3.2 \times 10^{12} \times 4.9 \text{ MeV} \times \frac{1 J}{6.24 \times 10^{12} \text{ MeV}}$$
$$= 2.5 J$$

rad is $2.5 J / 100 Kg = 25$ mGy lethal dose is 3 Sv

radiation dose equivalent

$$= 25 \frac{mJ}{Kg} \times 20 = 500 \text{ mSv} = \boxed{0.5 \text{ Sv}}$$

↑ Q factor for α