Z atomic number (P) or (e) if the atom is neutral

N number of the neutrons

A mass number $(N + P)$

$${}^{A}_{Z}X_{N} \longrightarrow \text{or } {}^{A}_{Z}X$$

$$N \rightarrow A - Z$$

Z same, different N $\Longrightarrow$ isotopes

Z different, same N $\Longrightarrow$ isotones

same A $\Longrightarrow$ isobars — isomers

different Z, different N

$1u = 1.66\,0540 \times 10^{-27}\ Kg \approx$ mass of p or n

atomic mass unit (a.m.u)

$$1u = 931.4943\ MeV/c^2$$

$$m_{atom} \equiv m_{nucleus} \pm \frac{1}{2000}$$ for e

$$r = r_0 A^{1/3} = 1.3\, A^{1/3}\ fm$$

$r_0 \to 1.2 \to 1.3$

* all nuclei have nearly the same ρ

$\rho = 2.3 \times 10^{17}\ Kg/m^3 \longrightarrow$ constant

Nuclear Stability

ns will reduce the repulsive force in the Ps

$n \longleftrightarrow n$

$n \longleftrightarrow p$

$\boxed{\text{charge independent}}$

inside the shell $\Rightarrow$ nuclear force = Short range

outside " " $\Rightarrow$ coulomb

for Light nuclei $Z = N$ Stable

adding n for Light nuclei make reactive

less n = more n

Heavy nuclei $\Longrightarrow$ $N > Z$ for stable

$$\frac{N}{Z} = \frac{3}{2} \sim 2$$

in average the force is attractive in the nuclei

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nucleon → p
nucleon → n

the stability has a limit up to

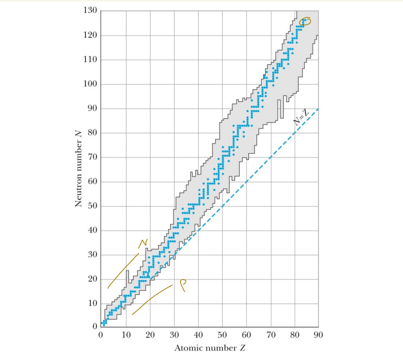


Figure 13.4 A plot of neutron number N versus atomic number Z for the stable nuclei (solid points). The dashed line, corresponding to the condition $N = Z$, is called the *line of stability*. The shaded area shows radioactive nuclei.

Bi $Z = 83$

Nuclear spin

$= \frac{1}{2}, \frac{3}{2}, \frac{5}{2} \ldots$

P and n $\Longrightarrow$ $\vec{I} = \vec{J}_p + \vec{J}_N$

p: all, N: all

$\rightarrow$ half integer: even-odd, odd-even

$\rightarrow$ integer: even 2, even N; odd 2, odd N $= 0, 1$

$$|\vec{I}| = \hbar \sqrt{I(I+1)}$$

$m_I = \ldots$

the p are in a motion

$$\mu_n = \frac{e\hbar}{2 m_p} = 5.05 \times 10^{-27}\ J/T$$

free p has $\mu = 2.7928\ \mu_n$

$n = -1.9135\ \mu_n$

Binding Energy 13.2

13.6 eV

p ... e →

e ionization

free > bound

Energy Energy

Particle	kg	u	MeV/c^2
		Mass	
Proton	$1.672\,623 \times 10^{-27}$	1.007 276	938.272 3
Neutron	$1.674\,929 \times 10^{-27}$	1.008 665	939.565 6
Electron	$9.109\,390 \times 10^{-31}$	$5.48\,579\,9 \times 10^{-4}$	0.510 999 1

total mass

mass of p

mass of n

$$E_b\,(MeV) = \left[\underbrace{Z}_{\text{number of p}} \cdot M(H) + \underbrace{N}_{\text{number of n}}\, m_n - M_A\right] \cdot 931.494\ \frac{MeV}{u}$$

in u

in u

$$E_b\,(MeV) = \left[Z\, m_p + N\, m_n - M_A\right] \cdot 931.494\ \frac{MeV}{u}$$

in u

$\frac{B}{A} \approx$ constant after carbon $\approx 7 \sim 8$ MeV

high $\frac{B}{A} \Longrightarrow$ stable

4 Major things that affects the B.E.

① Volume effect

B depends on A

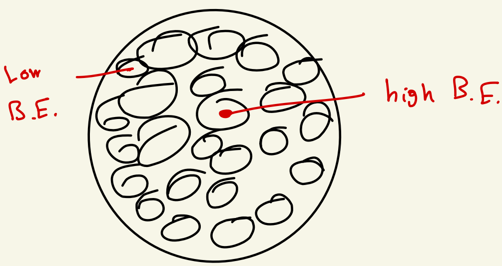
increases the B.E.

$r = r_0 A^{1/3}$

$V = \frac{4}{3} \pi r_0^3 A$

② the surfac effect

decreases the B.E.



$A = 4\pi r^2$

$A = 4\pi r_0 A^{2/3}$

$B - - A^{2/3}$

(3) Coulomb repulsion effect decreases the B.E.

$$U = \frac{k\, Ze(Z-1)e}{r = r_0\, A^{1/3}}$$

$$B \sim -C_3 \frac{Z(Z-1)}{A^{1/3}}$$

(4) Symmetry Effect

$Z = N$ = increasing B.E

$N > Z$ or $N < Z$ decreases B.E

$$B \sim -C_4 \frac{(N-Z)^2}{A}$$

adding those effect $\boxed{A > 15}$

$$\overset{V}{E_b = C_1 A} - \overset{S}{C_2 A^{2/3}} - \overset{C}{C_3 \frac{Z(Z-1)}{A^{1/3}}} - \overset{Symm}{C_4 \frac{(N-Z)^2}{A}}$$

$C_1 = 15.7$ MeV	$C_2 = 17.8$ MeV
$C_3 = 0.71$ MeV	$C_4 = 23.6$ MeV

Adding these contributions, we get as the total binding energy

$$E_b = C_1 A - C_2 A^{2/3} - C_3 \frac{Z(Z-1)}{A^{1/3}} - C_4 \frac{(N-Z)^2}{A} \qquad (13.7)$$

This equation is often referred to as the **Weizsächer semiempirical binding energy formula,** because it has some theoretical justification but contains four constants that are adjusted to fit this expression to experimental data. For

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Independent - particle Model.
(Single particle shell Model)

odd - even
even - odd

the p will cancel each other if they are even

$^{23}_{\cancel{10}}Ne_{13}$ ✓
p L s j

$I = \frac{5}{2}$

last (N, P)
then find I

$\boxed{\text{نوصف البناء}}$

Collective Model

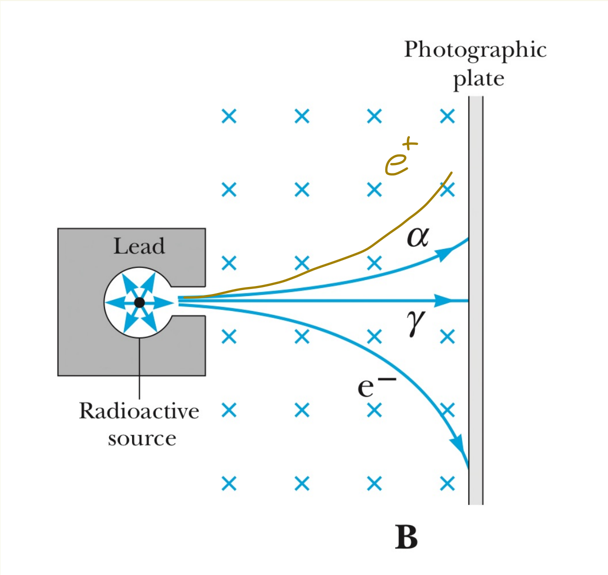
Radioactivity 134

3 types of radiation by nature

1. alpha (α), the emitted particles are ${}^4_2He_2$ nuclei

2. Beta β, in which the emitted particles are either electrons or positrons m_e $q = \pm e$

3. gamma γ, high energy rays
   you will see γ after β or α



$$\frac{dN}{dt} = -\lambda N$$

decay constant is the pobablity for decay

number of the nuclei decresing

$$\int_{N_0}^{N} \frac{dN}{N} = \int_{0}^{t} -\lambda \, dt$$

$$\ln N \Big|_{N_0}^{N} = -\lambda t$$

$$\ln \frac{N}{N_0} = -\lambda t$$

$$\boxed{N = N_0 e^{-\lambda t}}$$

what lefts in the sample

# of radioactive nuclei ~~decreases~~ with time

maximum Nuclei at $t = 0$

$N = N_0 e^{-\lambda t}$

$R_0 = N_0 \lambda$

the rate $\quad R = \left| \frac{dN}{dt} \right| = N_0 \lambda \, e^{-\lambda t}$

activity

number of decays per time

$R = R_0 \, e^{-\lambda t}$

initial activity

$$\boxed{R = R_0 \, e^{-\lambda t} = N_0 \lambda \, e^{-\lambda t}} \checkmark$$

$5T_{1/2} \quad N = \frac{N_0}{32}$

half time

$t: \; N_0 \longrightarrow \frac{N_0}{2}$

$N = N_0 e^{-\lambda t}$

$$\frac{N_0}{2} = N_0 \, e^{-\lambda T_{1/2}}$$

$$\ln 2 = \lambda T_{1/2}$$

$$\boxed{T_{1/2} = \frac{\ln 2}{\lambda}}$$

half time for N is when half of my sample go

$T_{1/2}$ for R is the half for Radioactivity

$1\,Bq = 1$ decay/s

$1\,Ci = 3.7 \times 10^{10}$ decay/s

$\lambda = 5\,s^{-1}$

$\parallel$

in one second it will emitt 5 particle

Alpha decay

$$^{A}_{Z}X \longrightarrow \, ^{A-4}_{Z-2}Y + \, ^{4}_{2}\alpha$$

Parent

daugters

$931\,494 \; \frac{MeV}{u}$

disintegration value

$$Q = (M_x - M_y - M_\alpha)\,c^2 > 0$$

Spontoneous

the amount realeased of energy after spliting

$$Q = K_\alpha + K_y$$

$$\vec{p}_\alpha + \vec{p}_y = 0$$

$$p_\alpha = p_y$$

$$Q = \frac{P_\alpha^2}{2M_\alpha} + \frac{P_y^2}{2M_y}$$

$$= \frac{P_\alpha^2}{2}\left(\frac{1}{M_\alpha} + \frac{1}{M_y}\right)$$

$$= \underbrace{\frac{P_\alpha^2}{2M_\alpha}}_{= K_\alpha}\left(\frac{M_\alpha + M_y}{M_y}\right)$$

$$K_\alpha = \frac{M_y}{M_\alpha + M_y} Q$$

98% of Q will go to α

Beta decay

A is the Same, but Z is changed by 1

electron emission

$${}^{A}_{Z}X_{N} \longrightarrow {}^{A}_{Z+1}Y_{N-1} + e^{-} + \bar{\nu}$$

antineutrino

β^{-} decay

$n \longrightarrow p^{+} + e^{-} + \bar{\nu}$

will be emitted

positron emission

$${}^{A}_{Z}X_{N} \longrightarrow {}^{A}_{Z-1}Y_{N+1} + e^{+} + \nu$$

neutrino

β^{-} decay

$p^{+} \longrightarrow n + e^{+} + \nu$

electron capture

$${}^{A}_{Z}X_{N} + e^{-} \longrightarrow {}^{A}_{Z-1}Y_{N+1} + \nu$$

neutrino

$p^{+} + e^{-} \longrightarrow n + \nu$

$\hookrightarrow$ X- rays

e^+, e^- will have a range of energies! $K_e : [0 \to K_{max}]$

ν do not interact with matter

$$\beta^- \qquad Q = [M_x - M_y]\,c^2$$

$$\beta^+ \qquad Q = [M_x - M_y - 2m_e]\,c^2$$

$$\varepsilon \qquad Q = [M_x - M_y]\,c^2$$

$$\boxed{Q > 0}$$

$c^2 = 931.494$ MeV

$$\frac{{}^{14}C}{{}^{12}C} = 1.3 \times 10^{-12}$$

this ration will decrease because ${}^{14}C$ decreases

but ${}^{12}C$ is constant.

Gamma decay   it follows after α or β