Radioactivity = radiation emitted by unstable nuclei

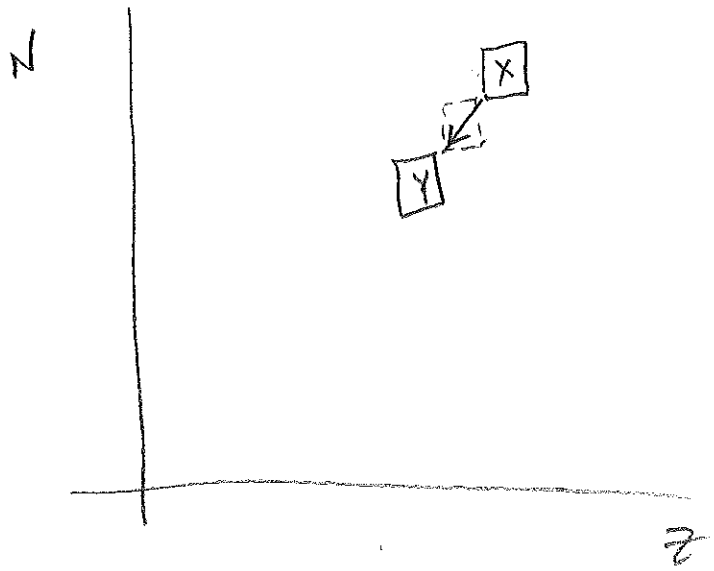
3 types: α, β, γ

α-decay

$$X \longrightarrow Y + \alpha$$

α particle = ${}^{4}_{2}He$

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



α-decay: tunnelling

β-decay

transformation of a neutron into a proton inside a nucleus

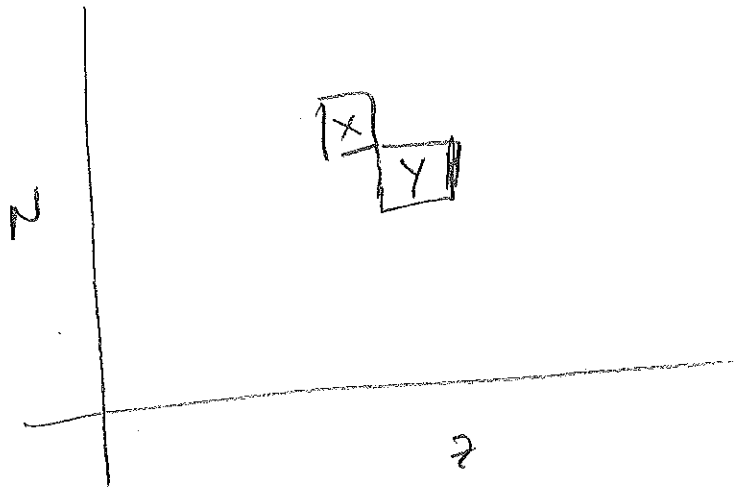
$$n \longrightarrow p + e^- + \bar{\nu}$$

$$^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + e^- + \bar{\nu}$$

↑ β-particle

occurs when energetically possible

ie if $m_X > m_Y + m_e$ $(m_{\bar{\nu}} \cong 0)$



eg $^{14}C \rightarrow {}^{14}N$

$^{60}_{27}Co \rightarrow {}^{60}_{28}Ni$

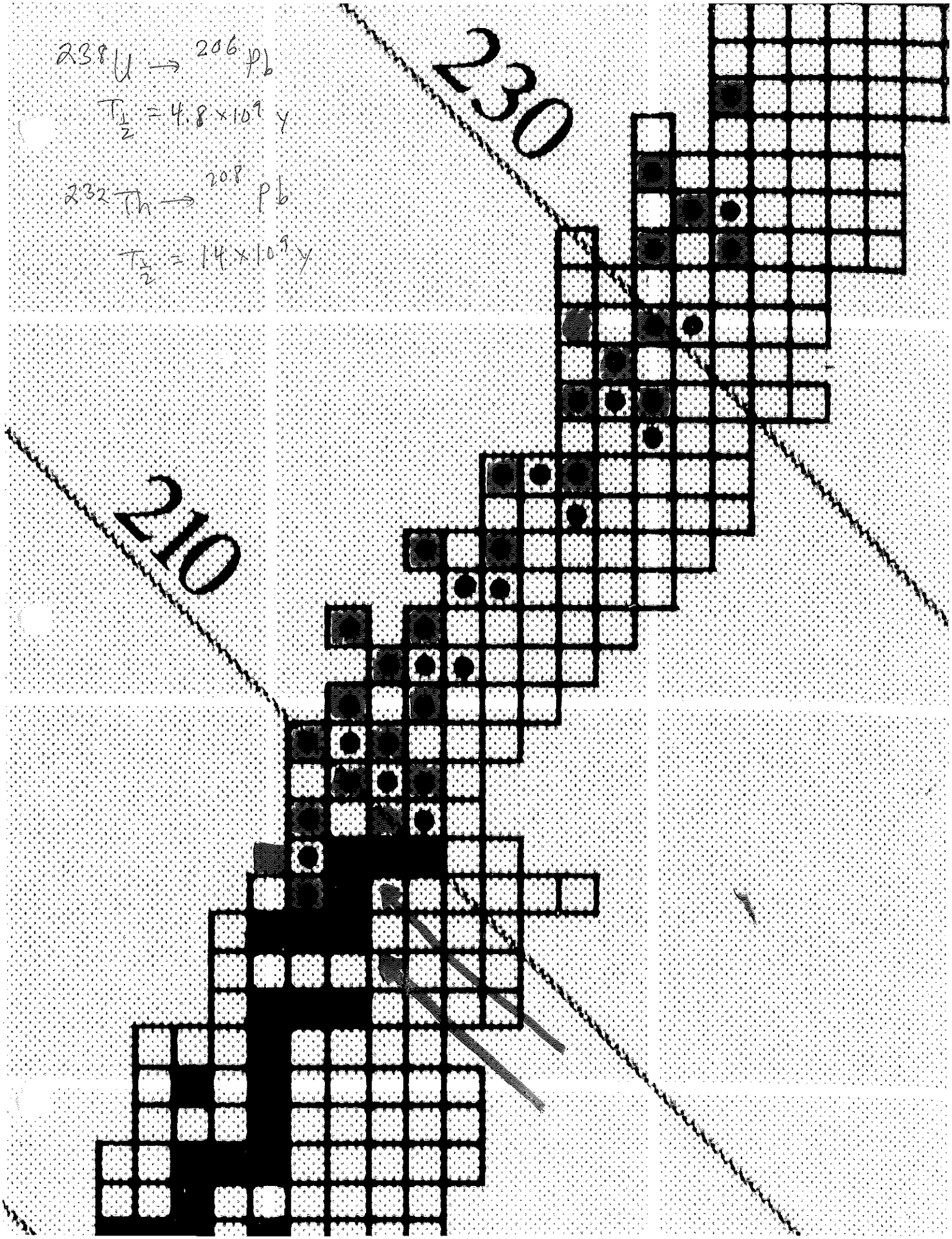
[β^+ decay ?]

$^{238}U \rightarrow {}^{206}Pb$

$T_{\frac{1}{2}} = 4.8 \times 10^9$ y

$^{232}Th \rightarrow {}^{208}Pb$

$T_{\frac{1}{2}} = 14 \times 10^9$ y



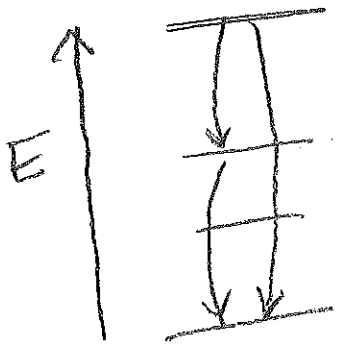
γ-decay

Nuclei have energy levels.

When α or β decay occurs, the final state nucleus is often in an excited state.

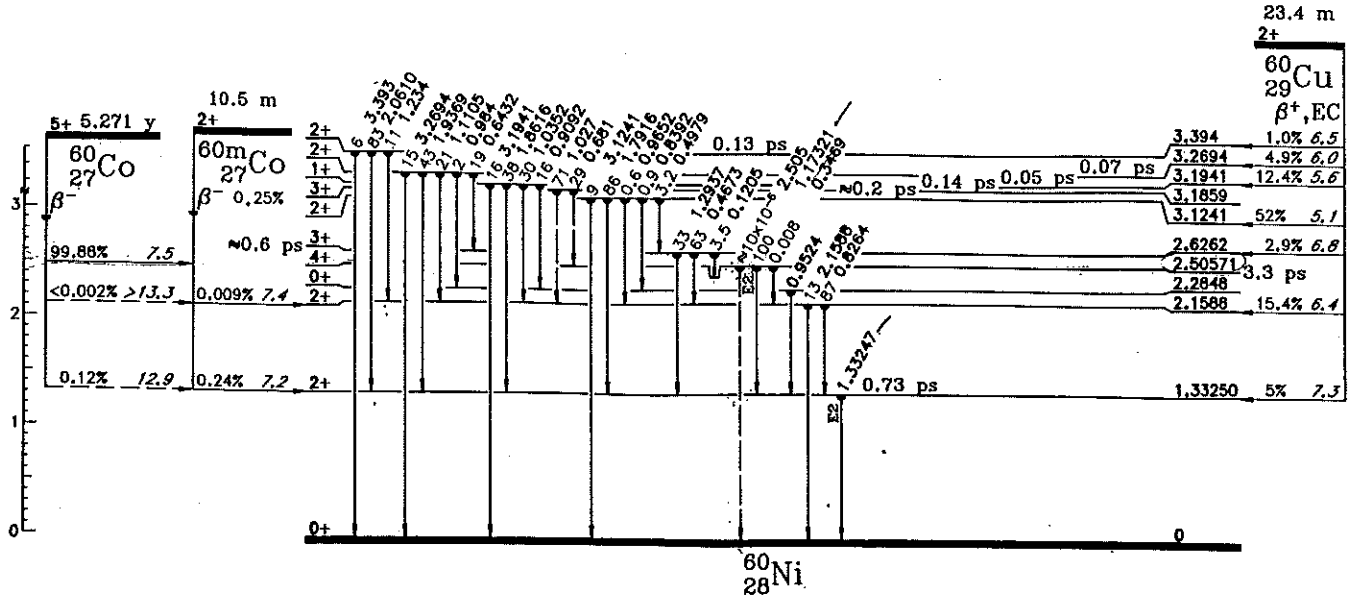
It then decays to ground state by emission of a γ-particle, or a high energy photon

$$X \longrightarrow Y^* \longrightarrow Y + \gamma$$



eg $Co \longrightarrow Ni^* \longrightarrow Ni$

1.17 MeV
1.333 MeV


5+ 5.271 y
60 27 Co
β⁻
99.88% 7.5
<0.002% >13.3
0.12% 12.9
10.5 m
2+
60m 27 Co
β⁻ 0.25%
≈0.6 ps
0.009% 7.4
0.24% 7.2
2+
3+
4+
0+
2+
2+
2+
1+
3+
2+
0+
60 28 Ni
0.13 ps
≈0.2 ps
0.14 ps
0.05 ps
0.07 ps
0.73 ps
3.3 ps
23.4 m
2+
60 29 Cu
β⁺,EC
3.394 1.0% 6.5
3.2694 4.9% 6.0
3.1941 12.4% 5.6
3.1859
3.1241 52% 5.1
2.6262 2.9% 6.8
2.50571
2.2848
2.1586 15.4% 6.4
1.33250 5% 7.3
0

Volume of nucleus $\approx$ A · (volume of 1 nucleon)

since $V = \frac{4}{3}\pi R^3$

radius of nucleus $R \approx A^{1/3} r_0$

where r_0 = radius of nucleon

≈ 1.2 fm $= 1.2 \times 10^{-15}$ m

(fm = femtometer a fermi)

e.g. oxygen nucleus ($A = 16$) $\Rightarrow R \approx 3 \times 10^{-15}$ m

typical size of atom $\sim 3 \times 10^{-10}$ m

$$\frac{R_{nucleus}}{R_{atom}} \sim \frac{3 \times 10^{-15}\ m}{3 \times 10^{-10}\ m} \sim 10^{-5}$$

[if atom filled lecture hall, $R \sim 10$ m
nucleus 10^{-4} m $\approx$ 0.1 mm]