9. Nuclear Physics

9.3 Stability
Valley of Stability
Fusion and Fission
Nuclear Decays

---

Alpha

Beta
Alpha Decay

© Ali Abdulwahab Ridha. All rights reserved. This content is excluded from our Creative Commons license. For more information, see https://ocw.mit.edu/fairuse.
Alpha Decay

Range of lifetimes are 10ns to $10^{17}$ years

\[ V_c = 2(Z-2) \frac{\alpha \hbar c}{r} \]

Both images © Source unknown. All rights reserved. This content is excluded from our Creative Commons license. For more information, see [https://ocw.mit.edu/fairuse](https://ocw.mit.edu/fairuse).
Alpha Decay

---

Energetics

\[ Q_\alpha = B\left(\frac{A-4}{Z-2}X_N'\right) + B\left(^4He\right) - B\left(\frac{A}{Z}X_N\right) = B(A - 4, Z - 2) - B(A, Z) + B\left(^4He\right) \]

\[ Q_\alpha = [B(A - 4, Z - 2) - B(A, Z - 2)] + [B(A, Z - 2) - B(A, Z)] + B\left(^4He\right) \approx -4 \frac{\partial B}{\partial A} - 2 \frac{\partial B}{\partial Z} + B\left(^4He\right) \]

\[ = 28.3 - 4a_v + \frac{8}{3}a_s A^{-1/3} + 4a_c \left(1 - \frac{Z}{3A}\right) \left(\frac{Z}{A^{1/3}}\right) - 4a_{sym} \left(1 - \frac{2Z}{A} + 3a_p A^{-7/4}\right)^2 \]

With \( Z \approx 0.41A \)

\[ Q_\alpha \approx -36.68 + 44.9A^{-1/3} + 1.02A^{2/3} \]
Beta Decay

Beta-minus Decay

Carbon-14 → \( \beta^- \) → Nitrogen-14
- 6 protons
- 8 neutrons
- 7 protons
- 7 neutrons
- Antineutrino
- Electron

Beta-plus Decay

Carbon-10 → \( \beta^+ \) → Boron-10
- 6 protons
- 4 neutrons
- 5 protons
- 5 neutrons
- Neutrino
- Positron

These images are in the public domain.

Image courtesy of Thomas Jefferson National Accelerator Facility - Office of Science Education.
Beta Decay

© Source unknown. All rights reserved. This content is excluded from our Creative Commons license. For more information, see https://ocw.mit.edu/fairuse.
Electron Capture

\[ \frac{A}{Z}X + e^- \rightarrow \frac{A}{Z-1}X' + \nu_e \]

\[ ^{81}_{36}\text{Kr} + e^- \rightarrow ^{81}_{35}\text{Br} + \nu_e \]
Nuclear Decays

© geigercounter.org. All rights reserved. This content is excluded from our Creative Commons license. For more information, see https://ocw.mit.edu/fairuse.
Long Nuclear Decay Chains