Ch. 30 Part 2
Radioactivity

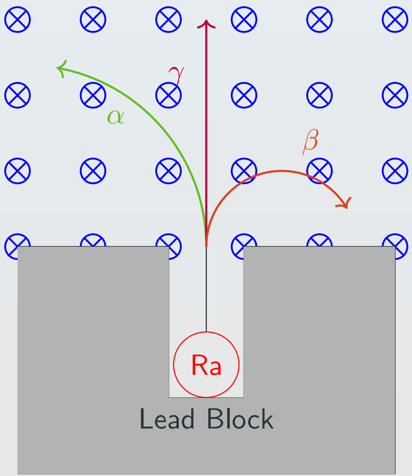
30.4: Radioactivity

We sometimes observe a nucleus emit something without any external stimulus. The nucleus is unresponsive to ordinary human-scale elements of pressure, chemistry, and temperature.

Radioactivity: disintegration or decay of an unstable nucleus.

Observe three basic types, distinguished by their behavior in a magnetic field and their interaction with matter. Call them α, β, and γ.

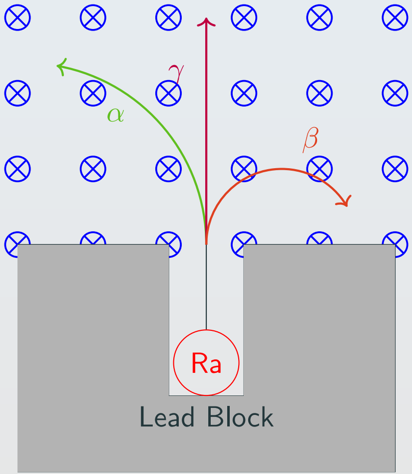
30.4: Radioactivity



Recall we found for charged particles moving in a magnetic field that

$$qvB = m\frac{v^2}{r} \implies r = \frac{mv}{qB}$$

30.4: Radioactivity



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We now understand that these are:

- α: A ${}^{4}_{2}$He nucleus, *i.e.* 2 protons and 2 neutrons.
- β: An electron (e^-)
- γ: A photon.

Alpha Decay

- charge $= +2e$
- mass $= 4.0015\,\mathrm{u}$, or using $(1\,\mathrm{u})c^2 = 931.5\,\mathrm{MeV}$, the energy equivalent is $3727.4\,\mathrm{MeV}$
- The α particle also carries away kinetic energy
- Reaction: ${}^{A}_{Z}\mathrm{X} \rightarrow {}^{A-4}_{Z-2}\mathrm{Y} + {}^{4}_{2}\alpha$

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- *e.g.* ${}^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\alpha$

Alpha Decay

Energy released (usually shows up as the kinetic energy of the α particle.)

- ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^{4}_{2}\alpha$

Initial mass	m_{Ra}	$=$	$226.025\,409\ \text{u}$

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Initial mass	m_{Ra}	$=$	226.025 409 u
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Energy difference:

$$\Delta E = (0.006\,326\ \mathrm{u}) \times c^2 = (0.006\,326) \times (1\ \mathrm{u}c^2)$$

$$\Delta E = (0.006\,326) \times (931.5\ \mathrm{MeV}) = 5.893\ \mathrm{MeV}$$

Beta Decay

- charge $= -e$
- mass $= 9.11 \times 10^{-31}$ kg; the energy equivalent is 0.511 00 MeV
- Reaction: ${}^{\mathrm{A}}_{\mathrm{Z}}\mathrm{X} \rightarrow {}^{\mathrm{A}}_{\mathrm{Z+1}}\mathrm{Y} + \mathrm{e}^{-}$
- *e.g.* ${}^{35}_{16}\mathrm{S} \rightarrow {}^{35}_{17}\mathrm{Cl} + \mathrm{e}^{-} + \bar{\nu}_e$
- Neutron decay: $n \rightarrow \mathrm{p} + \mathrm{e}^{-} + \bar{\nu}_e$
- The $\bar{\nu}_e$ is a neutral nearly massless particle known as an anti-neutrino of the electron type. It plays an important role in conserving momentum in this reaction. We will ignore it.

Reverse Beta Decay

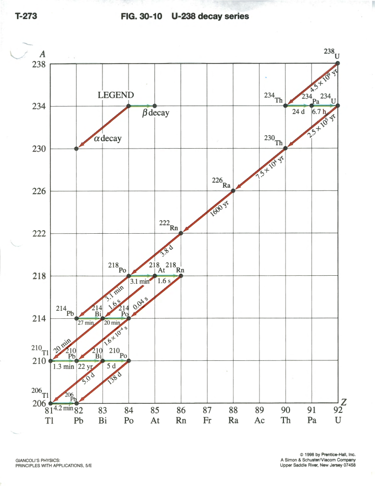
The reverse reaction is also possible—electron capture:

- Reaction: ${}^{A}_{Z}\mathrm{X} + \mathrm{e}^{-} \rightarrow {}^{A}_{Z-1}\mathrm{Y}$
- *e.g.* ${}^{59}_{28}\mathrm{Ni} + \mathrm{e}^{-} \rightarrow {}^{59}_{27}\mathrm{Co} + \nu_e$
- The ν_e is a neutral nearly massless particle known as a neutrino of the electron type. It plays an important role in conserving momentum in this reaction. We will ignore it.

Gamma Decay γ

- An excited nuclear state (indicated by *) emits a photon
- The photon carries away energy $E = \dfrac{hc}{\lambda}$
- Reaction: ${}^{\mathrm{A}}_{\mathrm{Z}}\mathrm{X}^\star \rightarrow {}^{\mathrm{A}}_{\mathrm{Z}}\mathrm{X} + \gamma$
- *e.g.* ${}^{137}_{55}\mathrm{Cs}^\star \rightarrow {}^{137}_{55}\mathrm{Cs} + \gamma$

Decay Chains



Nuclear Radiation Is a Form of Ionizing Radiation

This is useful to read, but will not be on the final.

What's Next?

- Nuclear Decay and Half-Lives
- Examples and Applications
- Final Review