Measure of radioactivity

The radioactive decay is a random process!!!

- **Activity** = the strength of a radioactive source ~ rate at which the isotope decays.
- The amount of radioactive material that decay and emit radiation in one second (the volume of radiation produced in a certain time period):
  - 1 Curie (Ci) = 3.7×10^{10} disintegration (transformation) per second
  - 1 Becquerel (Bq) = 1 disintegration per second
Basic types of radiation-matter interaction

- **Reflection** interaction; $\Delta E = 0$
- **Absorption** interaction; $\Delta E > 0$
- **Transmission** no interaction; $\Delta E = 0$
- **Scattering** interaction
  - Elastic collision ($\Delta E = 0$)
  - Non-elastic collision ($\Delta E \neq 0$)

Interactions between radiation and matter

<table>
<thead>
<tr>
<th>alpha radiation ($\text{He}^{2+}$)</th>
<th>beta radiation ($\text{e}^-$ or $\text{e}^+$)</th>
<th>gamma radiation (photon)</th>
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<tr>
<td>ionization</td>
<td>ionization</td>
<td>photo-ionization</td>
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<td>x-ray production</td>
<td>Compton scattering</td>
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<tr>
<td>annihilation</td>
<td>pair production</td>
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</tbody>
</table>
Absorption of gamma and beta radiation

**Lambert's absorption law**

\[ I = I_0 e^{-\mu x} \]

- \( \mu \): linear absorption coefficient [m\(^{-1}\)]
- \( x \): thickness of absorber [m]

**\( X_{1/2} \): half-value layer**

- the width of absorber that can reduce the original intensity by one half

\[ X_{1/2} = \frac{\ln 2}{\mu} = \frac{0.693}{\mu} \text{[m]} \]

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**Photoionization (total absorption)**

- orbital electron
- atomic nucleus
- \( \gamma \)-ray (photon)
- ejected electron
Photo-electric effect (Einstein–1905)

\[ h\nu = \varphi + E_{\text{kinetic}} \]

Electromagnetic radiation (light)

\[ h\nu - \varphi = E_{\text{kinetic}} \]

\[ E_{\text{kinetic}} = h\nu - \varphi \]

\( \varphi \) (work function) = y intercept
\( \varphi \) : the minimum work needed to remove an electron from an atomic orbit.
Compton-scattering

\[ \lambda_{\text{incident}} < \lambda_{\text{scattered}} \]
\[ E_{\text{incident}} > E_{\text{scattered}} \]

Pair production (\(\leftarrow\)annihilation)

\[ h\nu = E^- + E^+ = (m_0c^2 + E^-_{\text{kinetic}}) + (m_0c^2 + E^+_{\text{kinetic}}) = 2 \cdot m_0c^2 + E^-_{\text{kinetic}} + E^+_{\text{kinetic}} \]
\[ h\nu = E^- + E^+ = (m_0c^2 + E_{\text{kinetic}}^-) + (m_0c^2 + E_{\text{kinetic}}^+) = 2 \times m_0c^2 + E_{\text{kinetic}}^- + E_{\text{kinetic}}^+ \]

\[ m_0c^2 = 0.511 \text{ MeV (rest mass energy of the e}^- \text{ and e}^+) \]

\[ 2 \times m_0c^2 = 1.02 \text{ MeV (threshold energy for pair production)} \]

1.02 MeV – 0.012 Å → gamma-ray (< 0.01 Å) or x-ray (< 10 Å))

**Pair annihilation (total destruction)**

\[ E_{\gamma\text{photon}} = m_0c^2 + E_{\text{kinetic}} \]

\[ E_{\gamma\text{photon}} = 0.511 \text{ MeV} + E_{\text{kinetic}} \]
The end!