Upcoming topics

- Reactions and cross-sections
- Fission
- Fusion
- Radiation and matter
- Detectors

Nuclear reactions

Bombard nuclei and change their structures. Suppose we have target nucleus X, incoming particle a, resulting in nucleus Y and particle b:

$$\boxed{a + X \rightarrow Y + b.}$$

This is also written

$$X(a, b)Y$$

For example ${}^{7}\mathrm{Li}(p, \alpha)\,{}^{4}\mathrm{He}$ is

$${}^{1}_{1}\mathrm{H} + {}^{7}_{3}\mathrm{Li} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{4}_{2}\mathrm{He}$$

Conservation laws for reactions

Conservation of mass number Nucleons before must equal nucleons after.

Conservation of charge Total $q_{\text{after}} = q_{\text{before}}$.

Conservation of E, $\vec{p}$, and $\vec{L}$.

Reaction energy Q

Total kinetic energy released or absorbed in the reaction.

$$M_X c^2 + K_a + M_a c^2 = M_Y c^2 + K_Y + M_b c^2 + K_b$$

So, solving for the change in K:

$$Q = (K_Y + K_b) - K_a = (M_X + M_a - M_Y - M_b)c^2$$

$Q > 0$ exothermic.

$Q < 0$ endothermic.

For endothermic, more than Q is required to proceed: there must be some excess provided to conserve momentum. The minimum is the threshold energy $K_{th} > |Q|$.

Reaction cross-section

Imagine a beam of particles incident on a thin foil of thickness x. Each target nucleus X has an effective area σ called the **cross-section** for that reaction. Let the foil have area A.

$$R_0 = \text{rate at which particles hit foil.}$$
$$R = \text{rate at which reaction events occur.}$$
$$n = \text{nuclei/volume, each with } \sigma.$$

Total nuclei in foil will be nAx, total area exposed to beam (for the reaction) will be σnAx, so the reaction rate is

$$\frac{R}{R_0} = \frac{\sigma nAx}{A} = \sigma nx.$$

The reaction will remove particles from the beam, so the number remaining after a distance x in the foil will be

$$N = N_0 e^{-n\sigma x}$$

Cross-sections have dimensions of area. The common unit is

$$1 \text{ barn } = 10^{-28} \text{ m}^2.$$

This is of order of the geometric area of a nucleus.

Cross-sections vary with both the specific reaction and with the incident K, and can range from much more to much less than the geometrical area of the target particle.