Conservation laws and nuclear reactions at low energies

- Charge
- (energy, momentum) four momentum
- Angular momentum

  (*orbital angular momentum and spin*)
- Parity
- Number of nucleons

  only at low energies: $E < mc^2$

are related, orbital angular momentum of nucleus wave function determines parity

$$P = (-1)^L$$

- Baryon number
- Lepton number

Angular momentum and parity

In general:

$$1 + 2 \longrightarrow 3 + 4$$

$$P_1 \quad P_2 \qquad P_3 \quad P_4$$

$$\underbrace{J_1 \quad J_2}_{L} \qquad \underbrace{J_3 \quad J_4}_{l}$$

Ang. momentum:

$$\vec{J}_1 \oplus \vec{J}_2 \oplus \vec{L} = \vec{J}_3 \oplus \vec{J}_4 \oplus \vec{l}$$

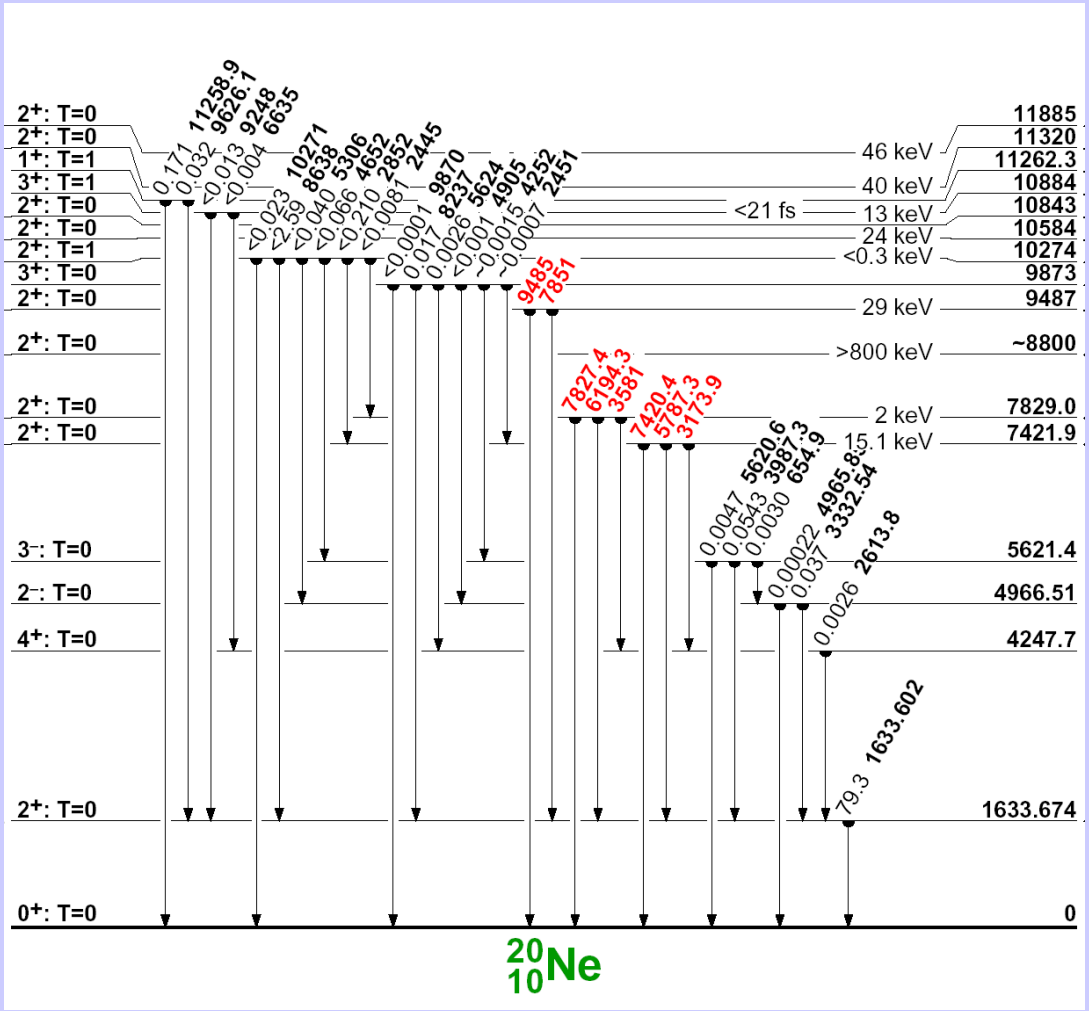
$$\left|\vec{J}_{in}\right| = \left|\vec{J}_{out}\right| \qquad J_{in,z} = J_{out,z}$$

Parity:

$$P_1 P_2 (-1)^L = P_3 P_4 (-1)^l$$

Angular momentum and Parity

example: $\alpha + {}^{16}O \rightarrow {}^{20}Ne^{*} \rightarrow {}^{20}Ne + \gamma$



Angular momentum and Parity

example:

1 $$\alpha + {}^{16}O \rightarrow {}^{20}Ne^{*} \rightarrow {}^{20}Ne + \gamma$$

$$0^{+} \quad 0^{+} \qquad\qquad 0^{+} \quad 1^{-}$$

possible intermediate excited states in ${}^{20}Ne^{*}$

$$J^{P} = 0^{+},\ 1^{-},\ 2^{+},\ \ldots$$

0^{+}

$$L: \quad \mathbf{O} + \mathbf{O} = \mathbf{O} \qquad (\text{no}\,\gamma\,!)$$

$$P: \quad (+1)(+1)(-1)^{L} = (+1)$$

$P = (-1)^{L}$

Rel. angular momentum $L = 0, 2, 4$

s, d, ...

Angular momentum and Parity

1^+

$$L = 1$$

$$0 \oplus 0 \oplus L = \mathbf{1} = 0 \oplus 1$$
$$= 1$$

$$(+1)(+1)(-1) = +1 = (+1)(-1)$$
$$-1 \neq +1 \neq -1$$

Parity violation

1^-

$$0 \oplus 0 \oplus 1 = 1 = 0 \oplus 1$$
$$(+1)(+1)(-1) = -1 = -1$$
$$-1 = -1 = -1$$

Angular momentum and Parity

2^+ ang.: $0 \oplus 0 \oplus 2 = 2 = 0 \oplus 1 \oplus \begin{matrix} 1 \\ 3 \end{matrix}$ *

Par.: $(+1)(+1)(-1)^2 = (+1) = (+1)(-1)(-1)^1$

$(+1) = (+1) = (+1)$

* *γ ray with higher multipolarity carries away angular momentum*

2^- ang.: $0 \oplus 0 \oplus 2 = 2 = 0 \oplus 1 \oplus \begin{matrix} 1 \\ 3 \end{matrix}$ *

Par.: $(+1)(+1)(-1)^2 \neq (-1) \neq (+1)(-1)(-1)^1$

$(+1) \neq (-1) \neq (+1)$

Parity violation

Angular momentum, Parity, Symmetry

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$$\underbrace{p + {}^{7}Li}_{L} \rightarrow \underbrace{\alpha + \alpha}_{l}$$

$$\underbrace{\underset{1/2^+}{} \quad \underset{3/2^-}{}}_{L} \qquad \underbrace{\underset{0^+}{} \quad \underset{0^+}{}}_{l}$$

α-particles (^4He -nuclei) are identical bosons.

$\Rightarrow$ wave function has to be symmetric

$$\psi(1, 2) = \psi(2, 1)$$

$\Rightarrow$ angular momentum l is even

$$P_{\substack{\text{right} \\ side}} = +1$$

$\Rightarrow L$ has to be odd due to parity conservation

Angular momentum, Parity, Symmetry

Angular momentum:

$$1/2 \oplus 3/2 \oplus L = 0 \oplus 0 \oplus l$$

$\rightarrow l$ is even

$$(-1)^l = +1$$

Parity:

$$\underbrace{(+1)(-1)}_{(-1)}\underbrace{(-1)^L}_{(-1)} = (+1)$$

$\rightarrow L$ is odd