Particle Interactions

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Collisions

Collisions are one of two ways particles can interact, producing different particles.

e.g.

$$\mathrm{p} + \mathrm{p} \longrightarrow \mathrm{p} + \mathrm{n} + \pi^{+}$$

Some of the kinetic energy of the protons goes into producing the extra mass of the neutron and pion.

Decays

Most particles are unstable, and can decay into other particles (so long as certain rules are followed).
e.g.

$$\pi^+ \longrightarrow \mu^+ + \nu_\mu$$

mass of $\pi^+ = 2.5 \times 10^{-28}$ kg
mass of $\mu^+ = 1.9 \times 10^{-28}$ kg
mass of ν_μ is almost zero ($< 3.4 \times 10^{-34}$ kg)
All unstable particles have a characteristic lifetime, which is the average time that it will take for that particle to decay.

Conservation laws 1

$$p + p \longrightarrow p + p + \pi^0$$

$$p + n \longrightarrow p + p + \pi^-$$

$$\pi^- + p \longrightarrow n + \pi^0$$

$$p + p \neq p + p + \pi^-$$

Conservation laws 2

$$\pi^+ + \mathrm{n} \longrightarrow \Lambda^0 + \mathrm{K}^+$$

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$$\mathrm{p} + \mathrm{n} \longrightarrow \Lambda^0 + \mathrm{K}^+ + \mathrm{n}$$

But now

$$\mathrm{p} + \mathrm{n} \neq \Lambda^0 + \mathrm{K}^+$$

A new particle, X^-, has been found. What is its B?

$$\mathrm{p} + \mathrm{n} \longrightarrow \mathrm{p} + \mathrm{p} + \mathrm{n} + X^-$$

Researchers announce that the new particle went on to give the following interaction:

$$X^- + \mathsf{p} \longrightarrow \mathsf{p} + \mathsf{p} + \pi^- + \pi^-$$

Are you happy with this?

Conservation laws 4

Only kidding! What the X^- really did do was:

$$X^- + \mathrm{p} \longrightarrow \pi^- + \pi^- + \pi^+ + \pi^+ + \pi^0$$

In fact, $X^- = \overline{\mathrm{p}}$

Conservation laws 5

Why does the following reaction **not** occur (consider charge and strangeness to start with)?

	K^+	$+$	n	$\neq$	π^+	Λ^0
Q						
B						

Why does the following reaction **not** occur (consider charge and strangeness to start with)?

	K^+	$+$	n	$\not\to$	π^+	Λ^0
Q	$+1$		0	$\to$	$+1$	0
B	0		$+1$	$\to$	0	$+1$
S	$+1$		0	$\to$	0	-1

Conservation laws 6

In every interaction:

1. mass/energy must be conserved
2. momentum must be conserved
3. charge Q must be conserved
4. baryon number B must be conserved
5. lepton number L must be conserved
6. strangeness S
   1. is conserved in collisions
   2. changes by ± 1 in a weak decay

Example 1

Is the following interaction possible?

	n	$\longrightarrow$	p	+	e^-	+	$\bar{\nu}_e$
Q	0	$\rightarrow$	+1		−1		0
B	+1	$\rightarrow$	+1		0		0
L	0	$\rightarrow$	0		+1		−1
S	0	$\rightarrow$	0		0		0

All of the quantities are conserved, so this β decay is possible.

Example 2

Is the following interaction possible?

	Λ^0	$\longrightarrow$	p	+	π^-
Q	0	$\rightarrow$	$+1$		-1
B	$+1$	$\rightarrow$	$+1$		0
L	0	$\rightarrow$	0		0
S	-1	$\rightarrow$	0		0

Q, B and L are conserved, and the strangeness changes by $+1$ in this weak decay.

Example 3

Identify particle X:

	p	$+$	π^-	$\longrightarrow$	n	$+$	π^0	$+$	π_-	$+$	X
Q	$+1$		-1	$\rightarrow$	0		0		-1		$+1$
B	$+1$		0	$\rightarrow$	$+1$		0		0		0
L	0		0	$\rightarrow$	0		0		0		0
S	0		0	$\rightarrow$	0		0		0		0

From its properties, the particle X must be a π^+.