Relationship Between Energy, Momentum, Wavelength

Momentum (p) to classical kinetic energy (E):

$$E = \frac{p^2}{2m}$$

Energy to wavelength (De Broglie) [1]:

$$\lambda = \frac{h}{p}$$

Spherical Harmonics

Due to a spherical shaped electrical force field, we cannot just use sine waves in 1D, but we need the 3D version, spherical harmonics [1]. We see this when we compute quantum energy levels and states for the hydrogen atom [2].

From spherical harmonics, we get three important quantum numbers. n is the principal quantum number representing energy levels. l is the quantum number representing angular momentum. m is the quantum number representing angular momentum projection (or magnetic orbital quantum number) [3].

Energy Transitions and Gamma Decay

As a result of Schrodinger's equation and spherical harmonics, we get that there are fixed energy levels for hydrogen atoms [4]. Even for more complex atoms such as Sodium or Mercury, there are fixed energy levels [4], but they will differ from Hydrogen because the electric force fields differ. In the same way, the strong nuclear force field is much stronger than the electric force field, and the nucleus itself will have energy transitions resulting in release of light energy (gamma radiation). This is the basis of gamma decay [5].

Alpha Decay

The basis of alpha decay is quantum tunneling, from the wave nature of matter. Its probability can be calculated using Schrodinger's equation.

Beta Decay

Beta Decay is special, it is better explained using the Standard Model and the W and Z bosons that mediate the Weak Nuclear force [6].

For Beta Decay, Feynman diagrams are handy in order to visualise what's going on. In lecture (or more correctly, rambling) no.9, i messed up badly because I didn't really know what I was talking about. A more correct explanation can be found in arXiv (pronounced archive) [7]. However, the most useful video conceptually is that from ScienceClic [8]. Rather than take the old wrong video down, I left it up, partly out of convenience, and partly because it's better to learn from mistakes.

Now, there is much to discuss about Feynman diagrams, such as superposition and etc.. However, I only want to use them to visualise weak nuclear force interactions. For that, even my mistakenly drawn Feynman diagrams were somewhat useful.

Important rules for Feynman Diagrams:

1. Arrows in equals arrows out at each vertex
2. Conservation of momentum, energy, spin, charge etc. at each vertex
3. Fermions have arrows w/ straight lines, bosons have squiggly lines/ dashed lines with NO arrows
4. Antimatter fermions (eg. positrons, antineutrinos) arrows flow against the flow of time

Fermions = protons, neutrons, quarks, electrons, neutrinos/antineutrions

Fermions are classified by spin.

Binding Energy

To understand nuclear reactions, it's important to understand binding energy [9].

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