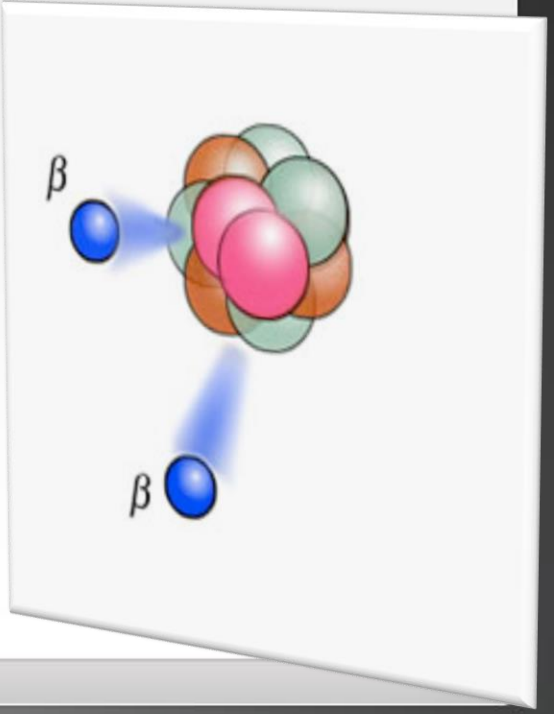
These are pages 22 - 24. The end of the chapter.

EMAIL ME if you have questions.

The Greek letter beta a swoopy capital B.

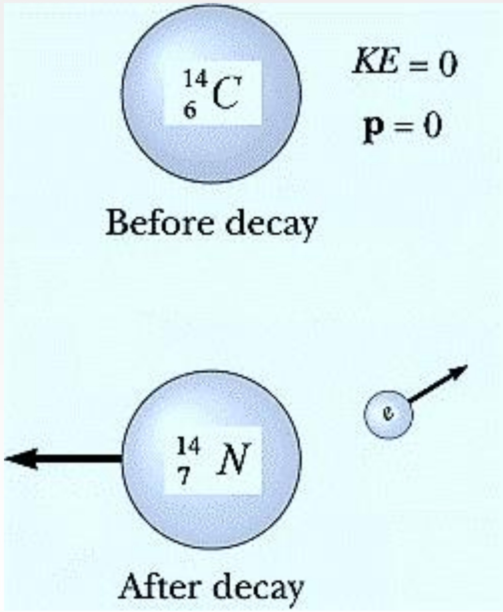
Beta Decay

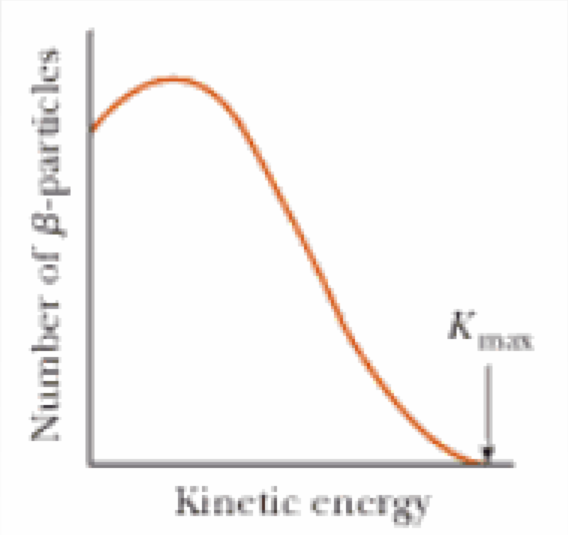
- Beta-minus particle (β^-) – electron, ${}_{-1}^{0}e$
- Beta-plus particle (β^+) – positron, ${}_{+1}^{0}e$



The missing kinetic energy must be going to something else.

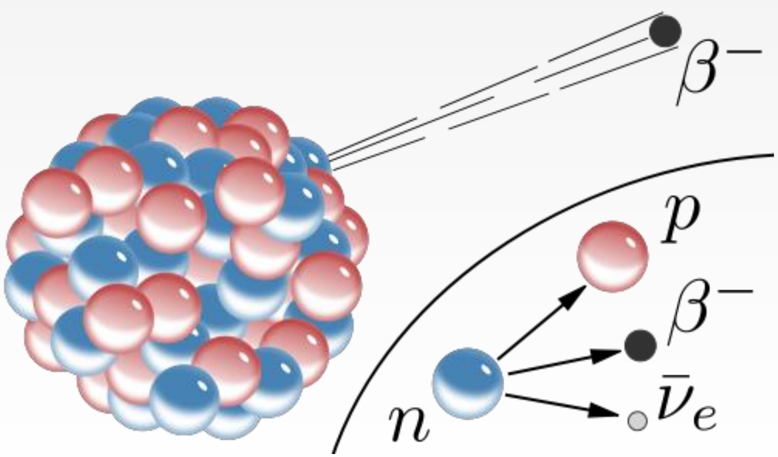
Beta Decay





Beta Decay

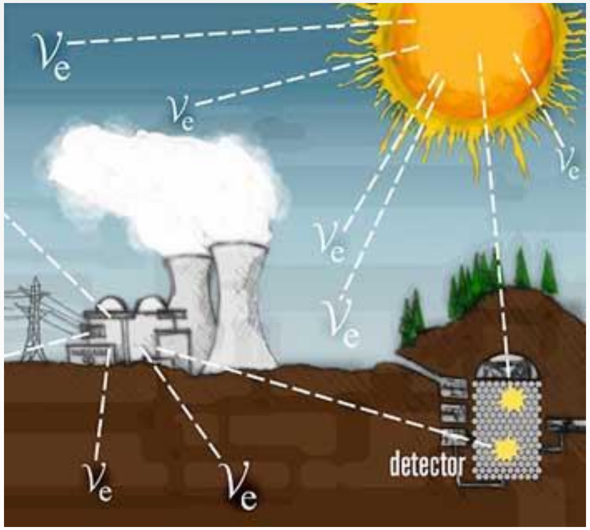
- Conclusion: there is third particle involved with beta decay that carries away some KE and momentum – virtually undetectable



Greek letter nu, swoopy lowercase v.

Beta Decay

- Neutrino and anti-neutrino (ν): fundamental particles - no charge – very small mass

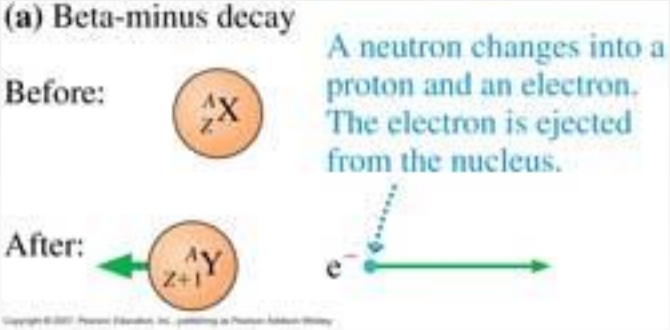


Neutron turns into proton, electron, neutrino, and energy

Beta-minus Decay

- Example reaction:

$$ {}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e + {}^{0}_{0}\overline{n} + energy $$

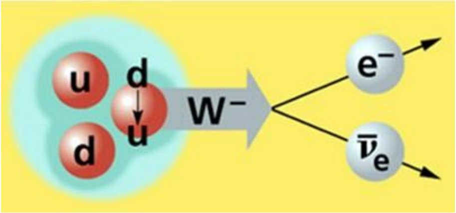


- General equation:

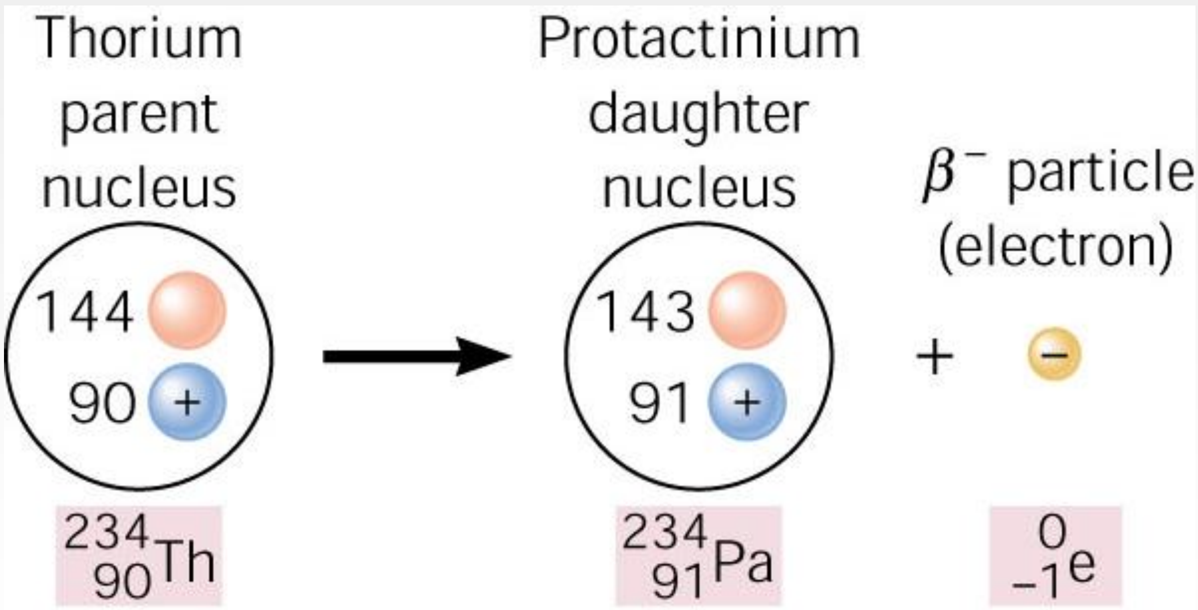
$$ {}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e + {}^{0}_{0}\overline{n} + energy $$

- How does this happen? Weak Force

$$ {}^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e + {}^{0}_{0}\overline{n} + energy $$



Beta-minus Decay



Beta-plus Decay

- Example reaction:

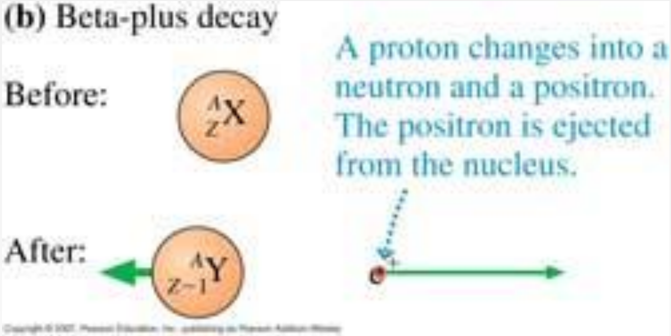
$$ {}^{12}_{7}N \rightarrow {}^{12}_{6}C + {}^{0}_{+1}e + {}^{0}_{0}n + energy $$

- General equation:

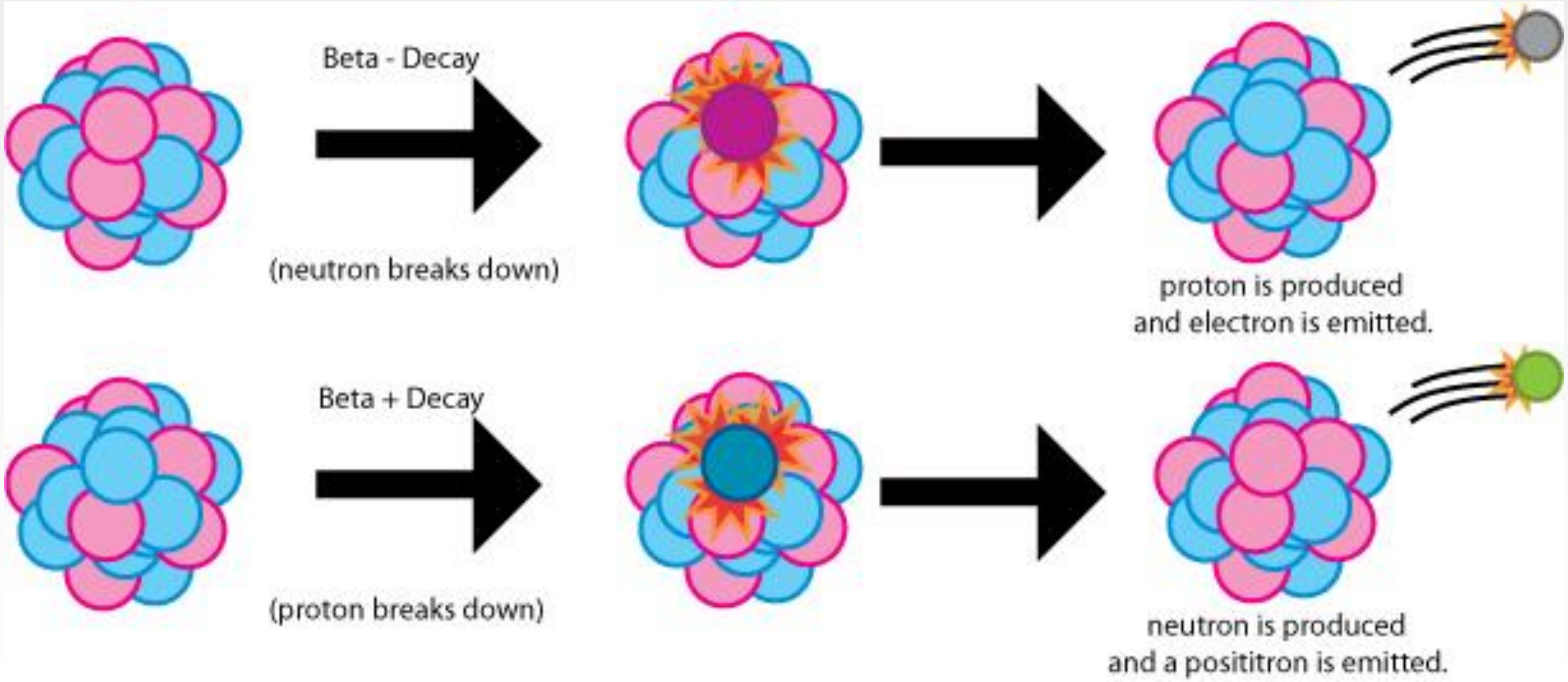
$$ {}^{A}_{Z}X \rightarrow {}^{A}_{Z\text{-}1}Y + {}^{0}_{+1}e + {}^{0}_{0}n + energy $$

- How does this happen? Weak Force

$$ {}^{1}_{1}p \rightarrow {}^{1}_{0}n + {}^{0}_{+1}e + {}^{0}_{0}n + energy $$



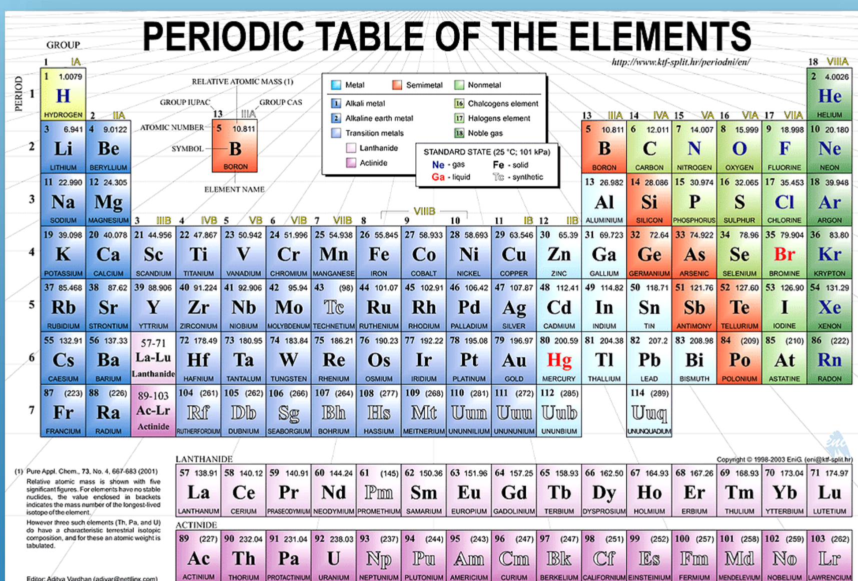
Beta Decay



Beta - Decay
(neutron breaks down)
proton is produced
and electron is emitted.
Beta + Decay
(proton breaks down)
neutron is produced
and a posititron is emitted.

$$^{32}_{15}P \rightarrow ^{32}_{16}S + ?$$

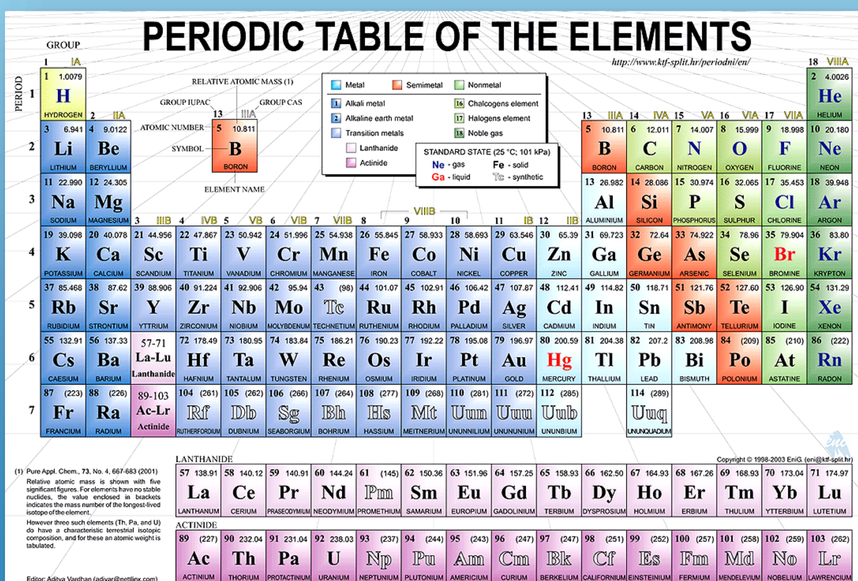
Look at the mass number and atomic number to see if it's beta plus or beta minus



$$^{32}_{15}P \rightarrow\, ^{32}_{16}S + \, ^{0}_{-1}e$$

Beta minus particle

Look at the mass number and atomic number to see if it’s beta plus or beta minus



Energy Levels in Nucleus

The nucleus has quantized energy and consists of discrete energy levels like an atom.

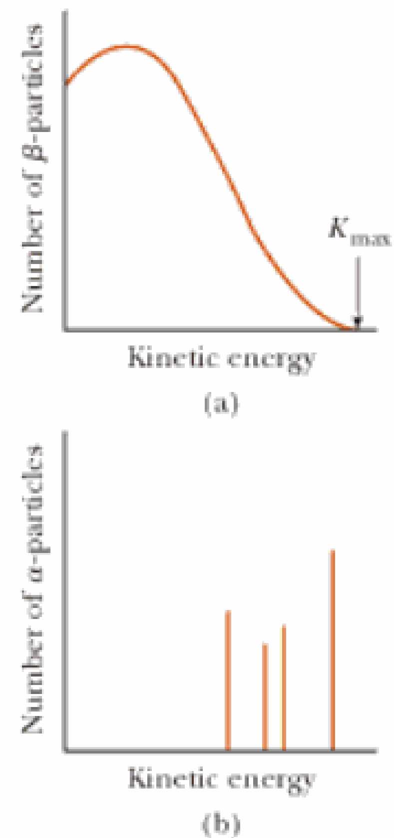
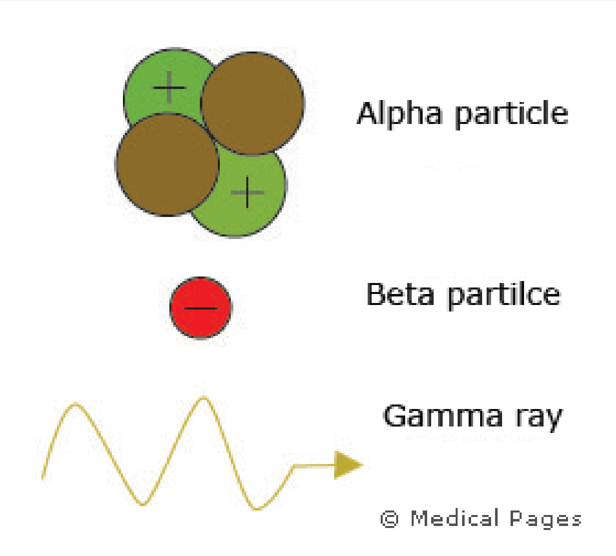


FIGURE 29.8 (a) Distribution of beta particle energies in a typical beta decay. All energies are observed up to a maximum value. (b) In contrast, the energies of alpha particles from an alpha decay are discrete.

Gamma Decay

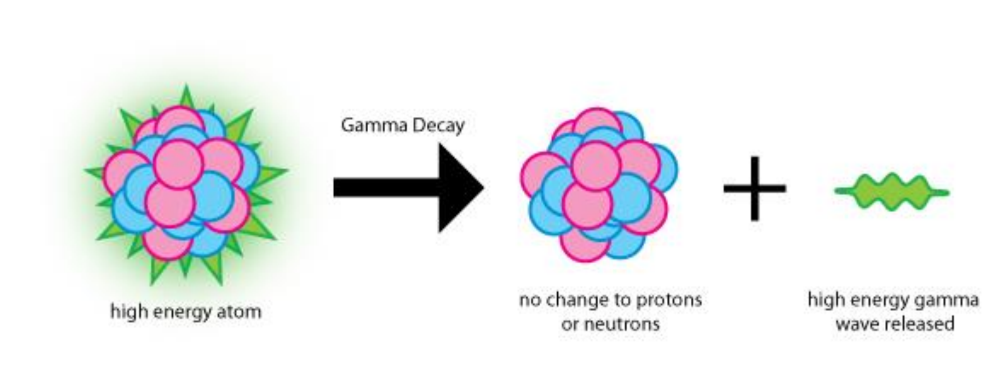
Greek letter gamma, upside down support ribbon
Photons are how EM spectrum deliver its energy – bundle of EM energy

- Gamma particle (γ) – high energy photon



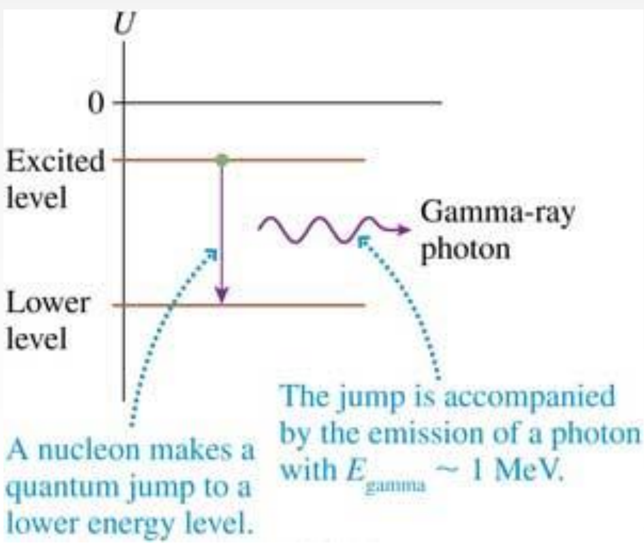
Gamma Decay

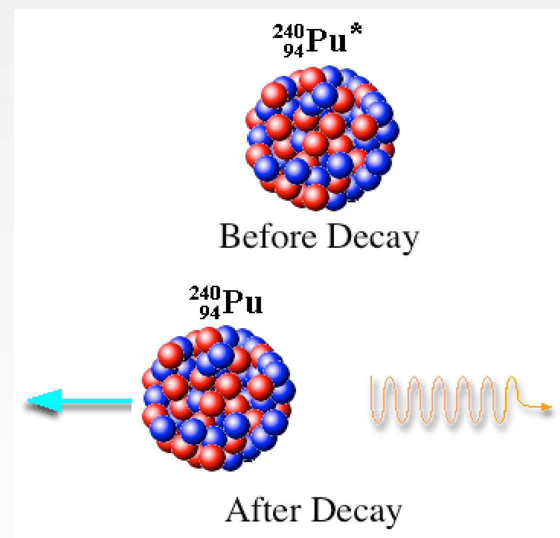
$$ {}^{12}_{6}C^{*} \rightarrow {}^{12}_{6}C + \Upsilon + energy $$



Gamma Decay

$$ {}^{A}_{Z}X^{*} \rightarrow {}^{A}_{Z}X + \Upsilon + energy $$





Where does the photon (energy) come from? Rest mass of nucleons

1. Sodium $^{24}_{11}Na$, whose atomic mass is 23.99 u, emits a gamma ray that has an energy of 0.423 MeV.

1. Sodium ${}^{24}_{11}Na$, whose atomic mass is 23.99 u, emits a gamma ray that has an energy of 0.423 MeV.

a) Calculate the wavelength of the emitted photon.

$$\lambda = \frac{hc}{E} = \frac{1.24 \times 10^{3}\ \text{eV nm}}{0.423 \times 10^{6}\ \text{eV}} = 2.9 \times 10^{-3}\ \text{nm} = 2.9\ \text{pm}$$

b) Calculate the momentum of the emitted photon.

$$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}\ J \bullet s}{2.9 \times 10^{-12}\ m} = 2.3 \times 10^{-22}\ \frac{kg \cdot m}{s}$$

1. Sodium ${}^{24}_{11}Na$, whose atomic mass is 23.99 u, emits a gamma ray that has an energy of 0.423 MeV.

c) Assuming the nucleus was initially at rest, calculate its recoil speed.

$$23.99\text{ u}\left(\frac{1.66 \times 10^{-27}\text{ kg}}{1\text{ u}}\right) = 3.98 \times 10^{-26}\text{ kg}$$

$$p_o = p_f$$

$$0 = p_{nucleus} + p_{photon}$$

$$m_{nucleus}v = -p_{photon}$$

$$v = \frac{-p_{photon}}{m} = \frac{2.3 \times 10^{-22}\text{ kg}\cdot\text{m/s}}{3.98 \times 10^{-26}\text{ kg}} = -5.8 \times 10^{3}\text{ m/s}$$

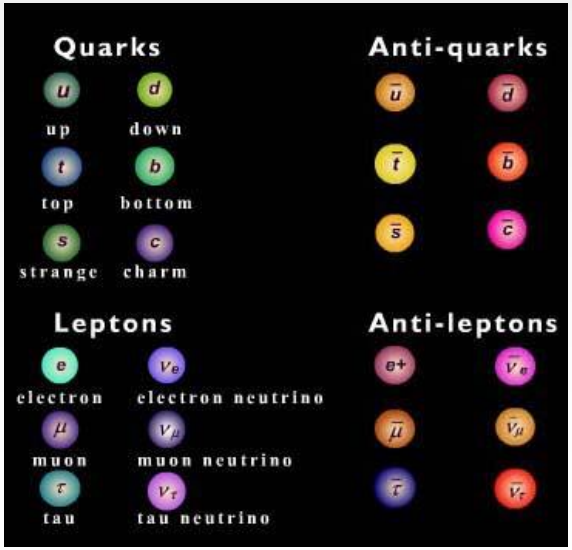
1. Sodium $^{24}_{11}Na$, whose atomic mass is 23.99 u, emits a gamma ray that has an energy of 0.423 MeV.

d) Calculate the kinetic energy of the recoiling nucleus.

$K = 1/2\, mv^2 = 1/2(3.98 \times 10^{-26}\ kg)(5.8 \times 10^3\ m/s)^2 = 6.64 \times 10^{-19}\ J$

Antimatter

- Antimatter (antiparticle): particle with same mass but opposite charge

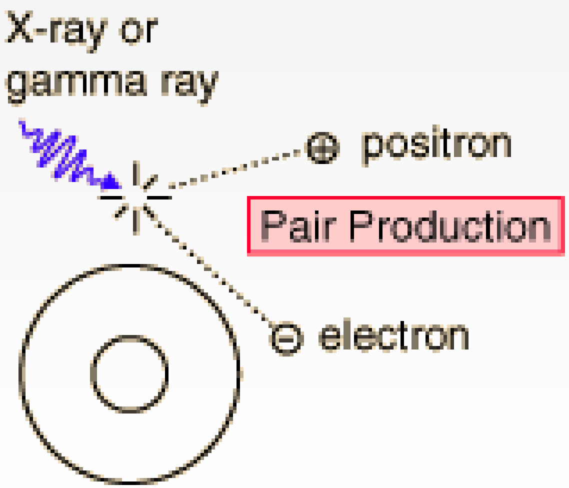


Antimatter

- Electron e^- or e
- Positron (antielectron) e^+ or $\overline{e}$

Pair Production

- Pair Production: high energy photon interacts with nucleus and is converted into a particle and its antiparticle

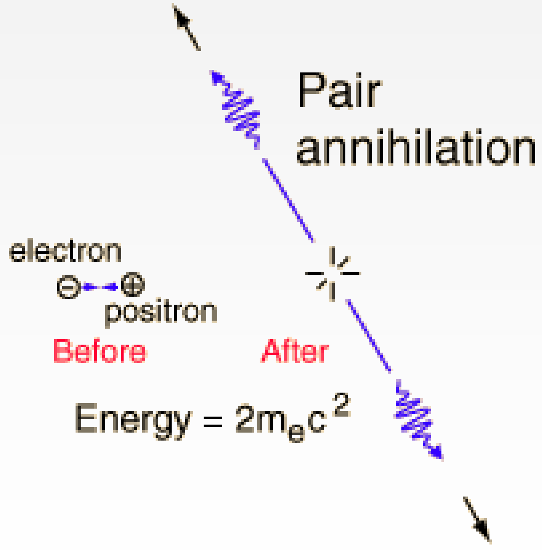


Pair Production

- Example of: conversion of energy into matter
- How much energy does each particle have? Half energy of a photon
- Why must a particle and antiparticle be formed? Why not one particle? To conserve charge

Pair Annihilation

- Pair Annihilation: particle and antiparticle collide and convert to pure energy



Pair Annihilation

- Example of: conversion of matter into energy
- Why two photons in opposite directions? Conservation of momentum and energy
- How much energy does each photon have? Rest mass of one particle

An electron and positron, essentially at rest, annihilate each other to produce two photons of equal energy moving in opposite directions.

An electron and positron, essentially at rest, annihilate each other to produce two photons of equal energy moving in opposite directions.

a. Calculate, in eV, the rest energy of a positron.

$$E = mc^2 = (9.11\times10^{-31}\,kg)(3\times10^{8}\,\tfrac{m}{s})^2 = 8.2\times10^{-14}\,J\left(\frac{1eV}{1.60\times10^{-19}\,J}\right) = 5.12\times10^{5}\,eV$$

An electron and positron, essentially at rest, annihilate each other to produce two photons of equal energy moving in opposite directions.

b. Calculate the wavelength of each created photon.

$$\lambda = \frac{hc}{E} = \frac{1.24 \times 10^3 \text{ eV nm}}{5.12 \times 10^5 \text{ eV}} = 2.42 \times 10^{-3} \text{ nm} = 2.42 \times 10^{-12} \text{ m}$$

$$\lambda = \frac{hc}{E} = \frac{1.99 \times 10^{-25} J \bullet m}{8.2 \times 10^{-14} J} = 2.42 \times 10^{-12} m$$

An electron and positron, essentially at rest, annihilate each other to produce two photons of equal energy moving in opposite directions.

c. Calculate the magnitude of the momentum of each photon.

$$p = \frac{E}{c} = \frac{8.2\times10^{-14}\ J}{3\times10^{8}\ \frac{m}{s}} = 2.7\times10^{-22}\ \frac{kg\cdot m}{s}$$

$$p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}\ J\cdot s}{2.42\times10^{-12}\ m} = 2.7\times10^{-22}\ \frac{kg\cdot m}{s}$$

I wish we were all together for this important moment. I love being able to say:

“The End!”

Seriously, the end. We’re done with notes. It’s all review and project from here on out.