Nuclear Chemistry

Nuclear Chemistry - the study of the composition and changes of the atomic nucleus.

The nucleus of an atom is very small (a baseball compared to the metrodome).

Inside the nucleus are protons and neutrons.

Protons are positively charged.

Positively charged particles repel each other.

The positively charged protons in the very small nucleus should (and do) repel each other.

Nuclear Changes

In some atoms the neutrons and gluons are able to hold the nucleus together.

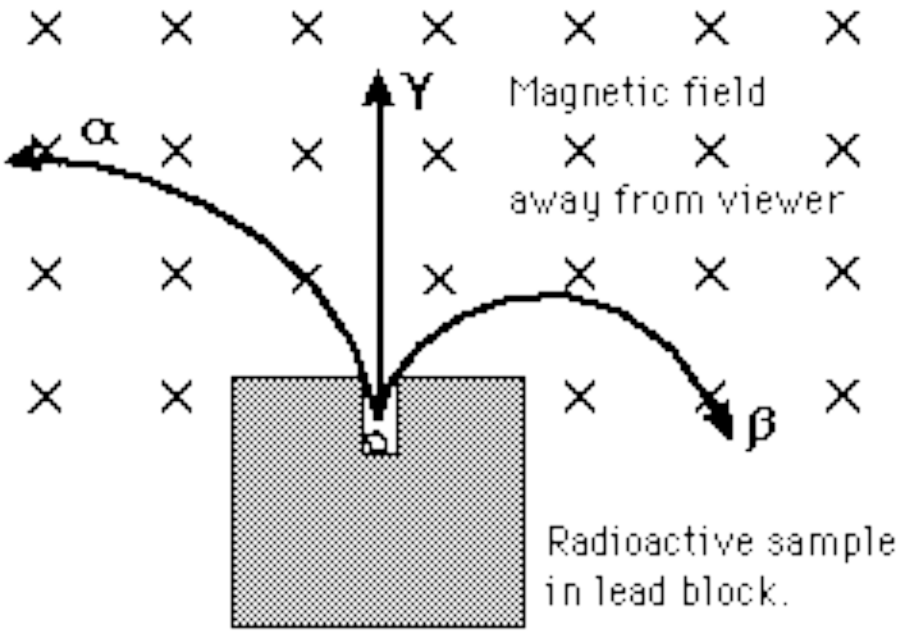
In some atoms the repulsion of the proton causes the nucleus to break apart - we call this decay (sometimes radioactive decay because of the kinds of energy associated with the process).

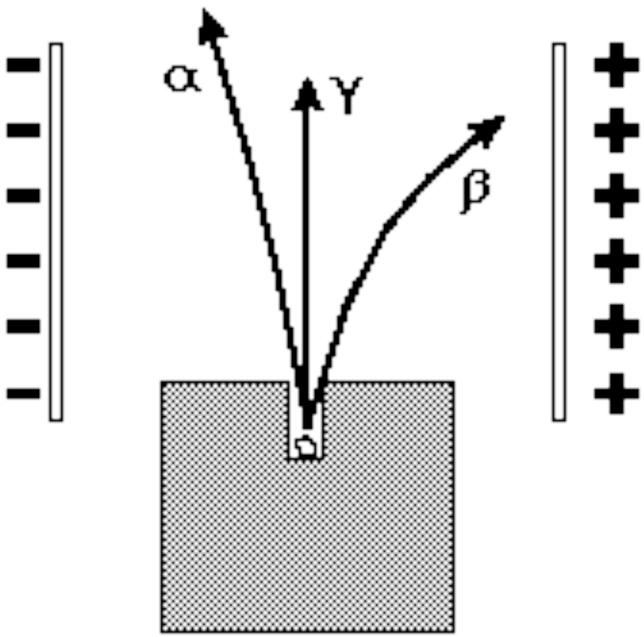
Radioactive Decay

Radioactive decay was first discovered by Marie Currie. While working with an ore called pitchblende she noticed that photographic plates (now we use film) were “exposed” even though they had not been in the light.

Ernest Rutherford discovered 3 different types of radioactive decay and called them alpha, beta and gamma for the first 3 letters of the Greek alphabet.

Radioactive Particles





Radioactive Particles

Alpha (α) particle - The α particle has the most mass (it doesn't change direction easily) and must have a positive charge.

It was later discovered that the α particle is the same as a helium nucleus ^{4}He

Beta (β) particle - The β particle has less mass (it changes direction easily) and has a negative charge.

It was later discovered that the β is identical to an electron.

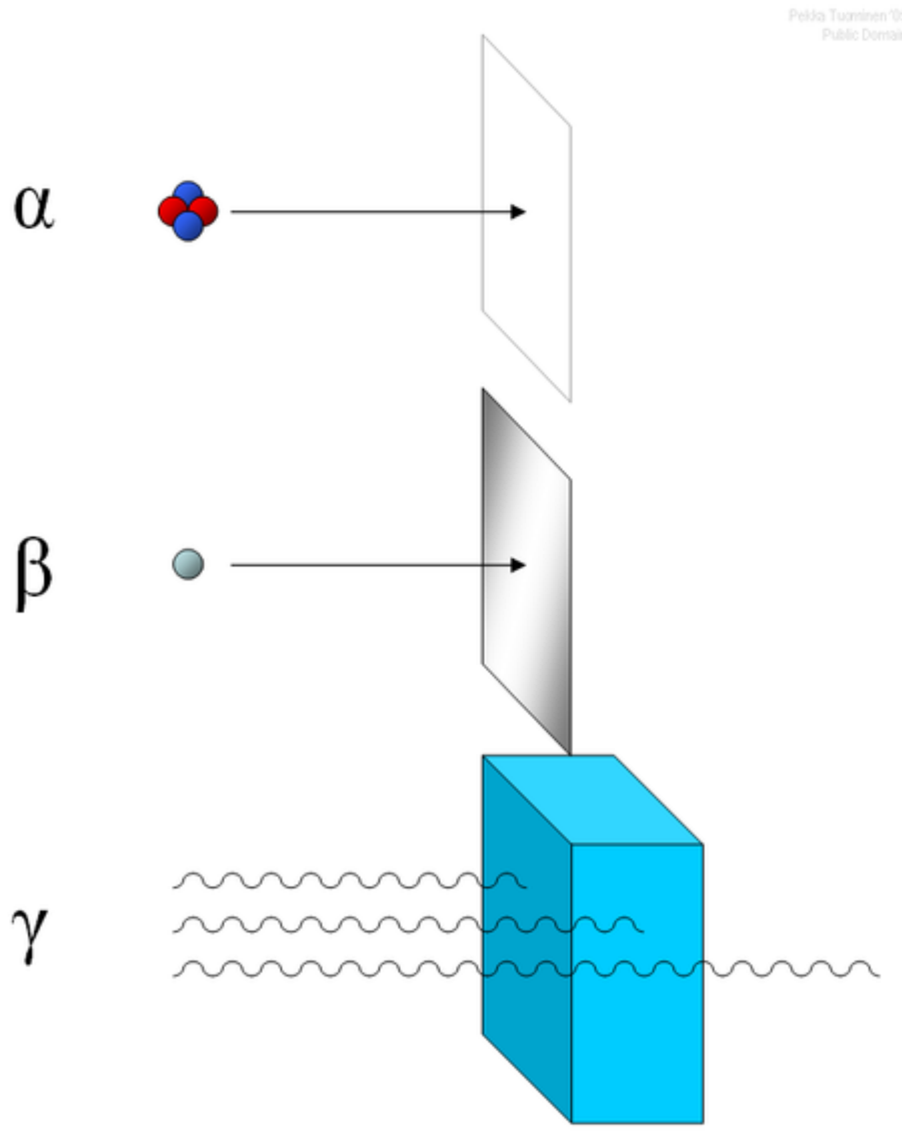
Particles

β type particles were later found to also have a positive charge but in every other way were identical to the electrons.

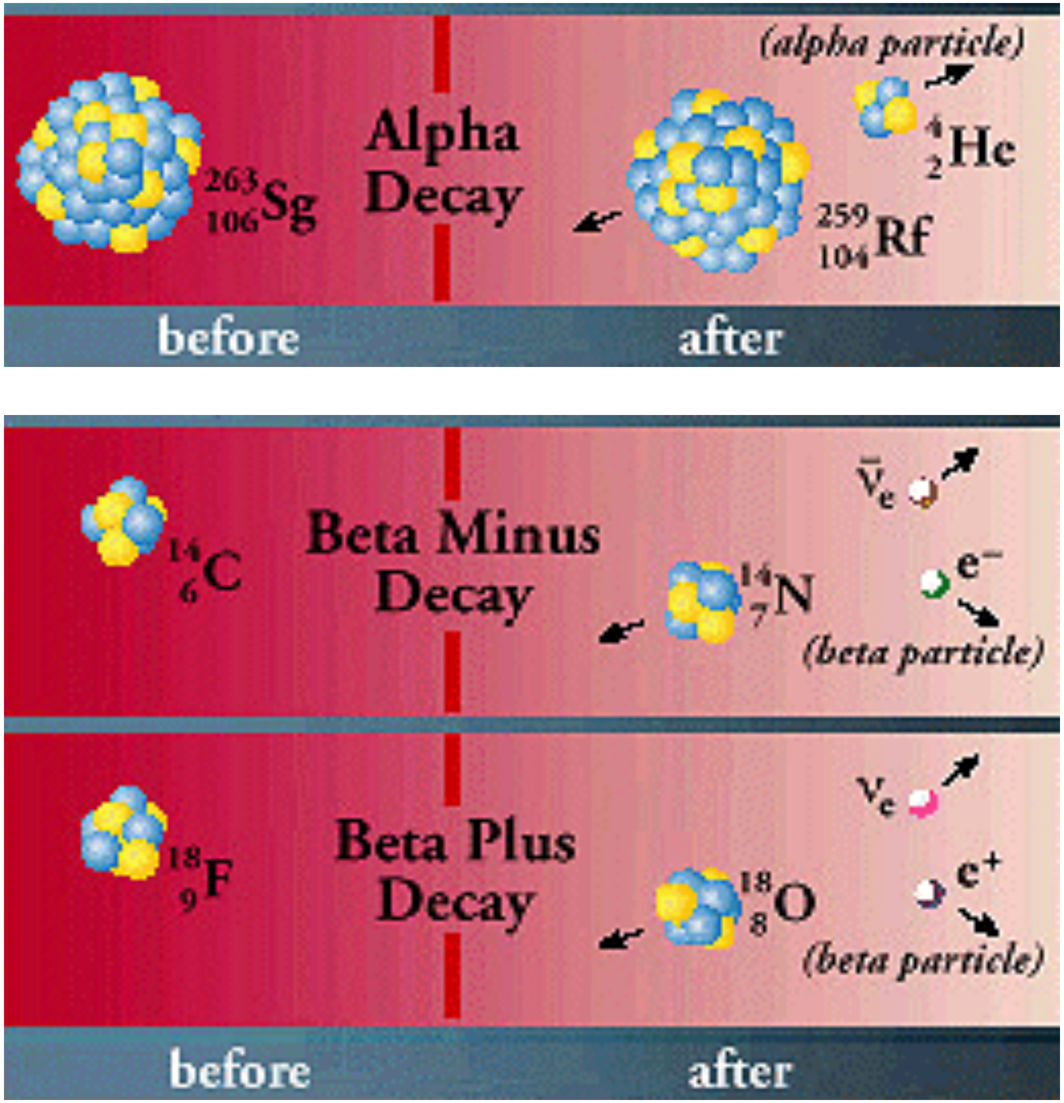
The negatively charged β particles are now referred to as β^- and the positively charged β particles are referred to as β^+ or positrons.

Gamma (γ) ray - The gamma "particles" were later discovered to be very high energy light rays and not particles at all.

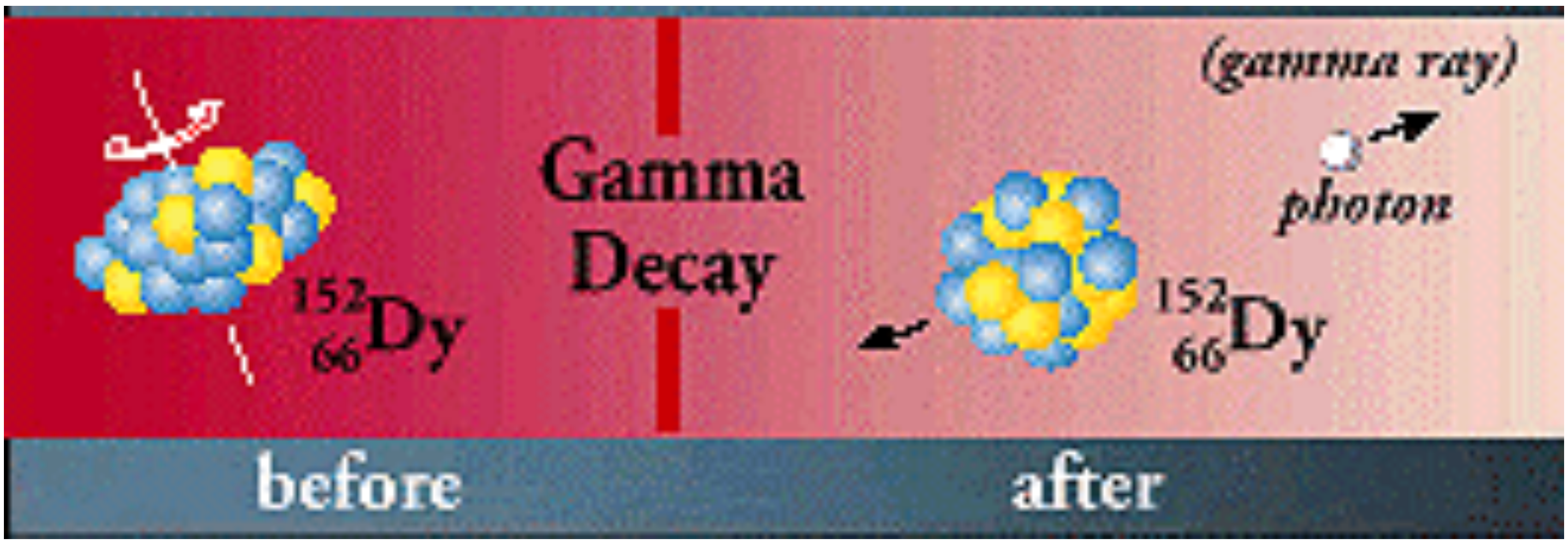
Particle Penetration Ability



Radioactive Decay



Radioactive Decay



Other Nuclear Reactions

When it was discovered that the nucleus of an atom can also capture one of these particles new vocabulary was developed to describe the new observations.

Radioactive decay (or just decay), emission and fission all mean the same - one particle breaks into two or more.

Nuclear capture (or just capture) and fusion mean the same - two (or sometimes more) particles become one.

Example Nuclear Reactions

alpha decay of uranium-235

$$^{235}_{92}U \xrightarrow{\alpha} {}^{4}_{2}He + {}^{231}_{90}Th$$

beta minus decay of carbon-14

$$^{14}_{6}C \xrightarrow{\beta^-} {}^{0}_{-1}e + {}^{14}_{7}N$$

positron (beta plus) emission by oxygen-15

$$^{15}_{8}O \xrightarrow{\beta^+} {}^{0}_{+1}e + {}^{15}_{7}N$$

Example Nuclear Reactions

neutron capture of cobalt-59

$$^{59}_{27}\text{Co} + ^{1}_{0}\text{n} \rightarrow ^{60}_{27}\text{Co}$$

fusion of two helium-3 atoms forming two hydrogen-1 and one helium-4 atoms

$$2\,^{3}_{2}\text{He} \rightarrow 2\,^{1}_{1}\text{H} + ^{4}_{2}\text{He}$$

Rates of Radioactive Decay

All of the radioactive material does not decay at one time. It decays slowly at a very regular rate.

The rate of decay is described as a half life.

One half life is the **time** it takes for one half of the element to decay. (Of course it doesn't just disappear, it forms something else.)

Half Life Calculations

If you start with 128 grams of radon-222 how long will it take until only 2.0 grams remain?

(The half life of radon-222 is 3.82 days).

The "grunt" technique:

128 g → 64 g 3.82 days
64 g → 32 g 3.82 days
32 g → 16 g 3.82 days
16 g → 8.0 g 3.82 days
8.0g → 4.0 g 3.82 days
4.0g → 2.0 g 3.82 days

22.92 days

Using the binary method

$A = A_o / 2^n$

$A =$ amount at the end

$A_o =$ original amount

$n =$ number of half lives

$2.0 \text{ g} = 128 \text{ g}/2^n$

solve for n (you need to use logs or trial and error), n=6.

6 half lives x 3.82 days/half life = 22.92 days

Even More Logs

The math method used by professional scientists.

$A = A_o e^{-kt}$

A = amount at the end

A_o = original amount

k = the decay constant - depends on the half life

t = time