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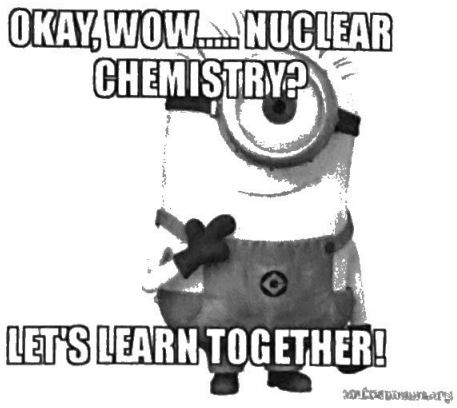
Nuclear Decay Modes

What is nuclear chemistry?

- Nuclear chemistry deals with changes in or transformations of the atomic nucleus
- Four types of decay
  - alpha particle
  - beta particle
  - positron particle
  - gamma rays



Nuclear Reactions vs. Chemical Reactions

Chemical Reactions	Nuclear Reactions
1. Atoms are rearranged by the breaking & formation of bonds	1. Elements are converted from one type to another.
2. Only electrons are involved in the breaking or forming of bonds.	2. Protons, neutrons, electrons, and other subatomic particle are involved are involved.
3. Small amounts of energy are absorbed or released	3. Large amounts of energy are absorbed or released.
4. Rates of reaction are influenced by temperature, concentration , pressure, and catalysts.	4. Rates are NOT affected by temperature, pressure, or catalysts.

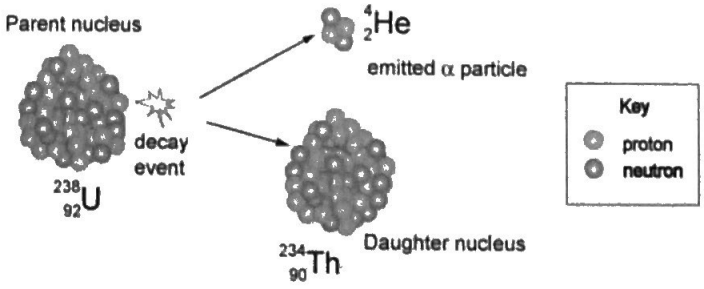
Radioisotopes

- The nuclei of some unstable isotopes, called radioactive isotopes or radioisotopes, split up forming atoms with a different number of protons and releasing radiation.
- This process is called radio active decay.
- Radioactivity is the release of energy and matter that results from changes in the nucleus of an atom

Alpha Radiation

- An alpha particle is a positively charged particle identical to the helium nucleus
- Alpha decay occurs when the nucleus of an atom gives off an alpha particle— two protons and two neutrons.
- Note: when an atom loses an alpha particle, the atomic number is lowered by two and the mass number is lowered by four.

Alpha Decay of a Uranium-238 nucleus



$$^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$$

← atomic mass (#p + #n)

$^{4}_{2}He$

atomic # = # protons (unique to each element)

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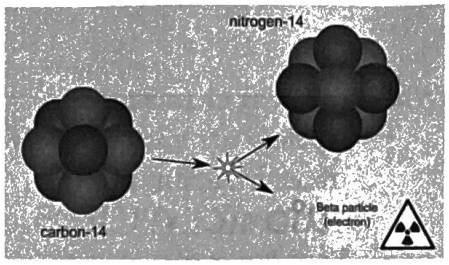
Beta Radiation

- Beta-minus decay occurs when a neutron is converted to a proton, and in the process, emits an electron.
- Beta particles are high-energy electrons whose source is an atomic nucleus
- ${}^{1}_{0}n \rightarrow {}^{1}_{1}H + {}^{0}_{-1}e$
- Neutron Proton electron (beta particle)
- Note: The atomic mass stays the same, and the atomic number (bottom #) increases by one.

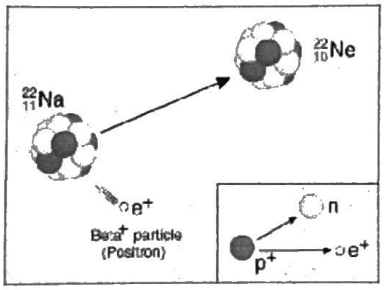


${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e^{-}$

Carbon-14 (radioactive) Nitrogen-14 (stable) beta particle

Positron Radiation

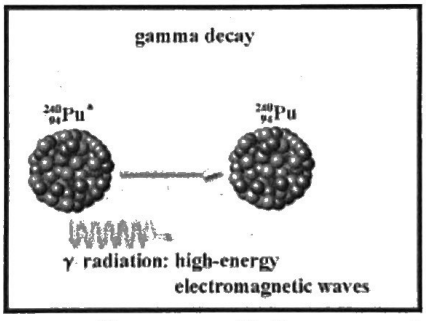
- Beta-plus decay (also called positron emission) occurs when a proton is converted to a neutron, and in the process, emits a positively charged electron (a positron).
- A positron is a particle identical to an electron except that it has a positive charge
- Note: atomic number decreases by one and mass number remains the same



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

Gamma Radiation

- A gamma ray is a high-energy photon emitted by a radioisotope. Often are emitted along with alpha and beta particles.
- Gamma radiation doesn't have a positive or negative charge. Gamma rays are similar to X-rays, but they have even greater energy. Gamma radiation can only be stopped by a thick layer of lead or concrete.

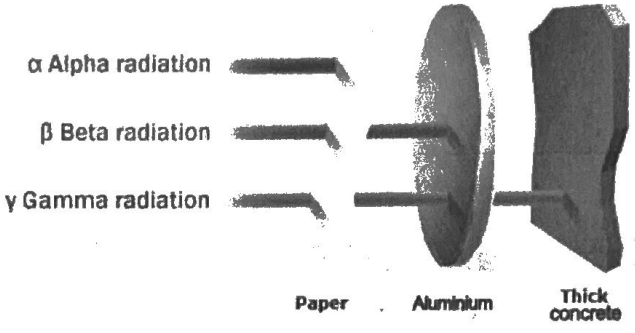


${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha$

${}^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + {}^{0}_{-1}\beta + {}^{0}_{0}\gamma$

${}^{234}_{91}Pa \rightarrow {}^{234}_{92}U + {}^{0}_{-1}\beta + {}^{0}_{0}\gamma$

Penetrating Power



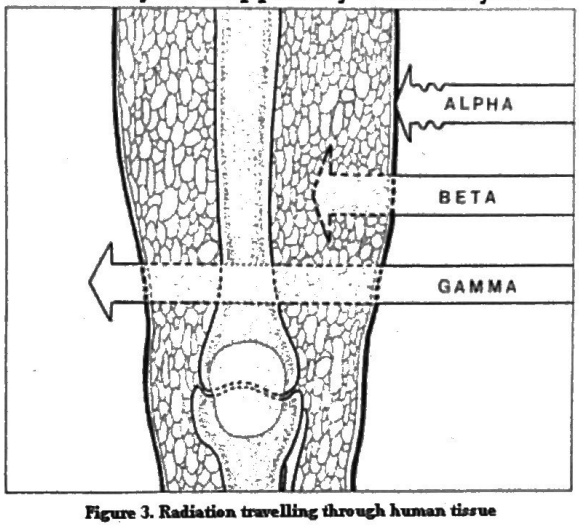


Figure 3. Radiation travelling through human tissue

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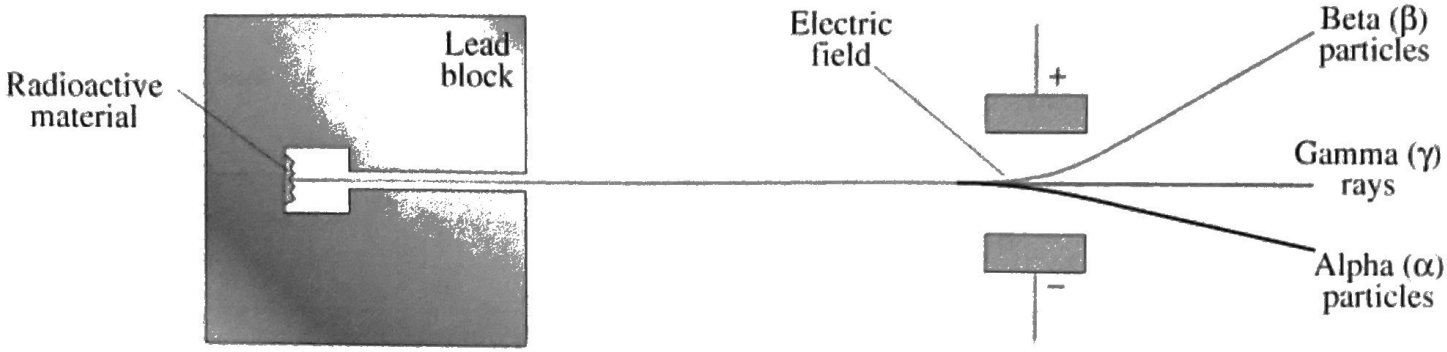
Separating Alpha, Beta, and Gamma Particles



- Alpha and beta particles are deflected in opposite directions- alpha particles toward the negative plate and beta particles toward the positive plate. Gamma rays are undeflected.

Balanacing Nuclear Equations

- What particle is represented by X in the following equation?

$$^{27}_{13}Al + {}^{1}_{0}n \rightarrow {}^{24}_{11}Na + X$$

- Step 1: Label known and unknown
  - Known- charge and mass numbers for Al, neutron, and Na
  - Unknown- X=?
- Step 2: Balance charge on both sides of the equation
  - The sum of the charges on the left is 13; therefore, the sum on the right must also be 13. Na accounts for 11, so X must have a charge of 2.
- Step 3: Balance mass numbers on both sides
  - The sum of mass numbers on the right is 28; therefore, the sum on the left should also be 28. Na accounts for 24, so X must have a mass of 4.
  - X is an alpha particle. It has an atomic number of 2 and a mass number of 4

Practice – Use TABLE O to help you

1. $^{210}_{84}Po \rightarrow$ $^{206}_{82}Pb$ $+ {}^{4}_{2}He$
2. $^{8}_{5}B \rightarrow {}^{8}_{4}Be +$ $^{0}_{+1}\beta$
3. $^{14}_{6}C \rightarrow$ $^{14}_{7}N$ $+ {}^{0}_{-1}e$
4. $^{15}_{8}O \rightarrow {}^{15}_{7}N +$ $^{0}_{+1}\beta$
5. $^{238}_{92}U \rightarrow$ $^{234}_{90}Th$ $+ {}^{4}_{2}He$

$^{4}_{2}He$ or $^{4}_{2}\alpha$ = alpha particle

$^{0}_{+1}\beta$ or $^{0}_{+1}e$ = positron

$^{0}_{-1}e$ or $^{0}_{-1}\beta$ = beta particle

$^{0}_{+1}\beta$ or $^{0}_{+1}e$ = positron

$^{4}_{2}He$ or $^{4}_{2}\alpha$ alpha particle

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Summary

Property	Alpha Radiation	Beta Radiation	Gama Radiation	Positron Radiation
Composition	Alpha particle (helium nucleus)	Beta particle (electron	High-energy electromagnetic radiation	Positron particle
Symbol	$^{4}_{2}He$ and $^{4}_{2}\alpha$	β, $^{0}_{-1}e$	Υ	$^{0}_{+1}e$
Charge	2+	1-	0	1+
Mann (amu)	4	1/1937	0	1/1837
Common Source	Radium-226	Carbon-14	Cobalt-60	
Penetrating Power	Low	Moderate	Very High	Very Low
Shielding	Paper, clothing	Metal foil	Lead, concrete	

Additional Regents Practice – Use Table N and Table O to help you! TABLE N & O

1. A sample of which radioisotope emits particles having the greatest mass

(C)

a. ^{137}Cs $(^{0}_{-1}\beta)$ β^-

b. ^{53}Fe $(^{0}_{+1}\beta)$ β^+

c. ^{220}Fr $(^{4}_{2}\alpha)$ α

d. ^{3}H $(^{0}_{-1}\beta)$ β^-

2. Given the equation representing a nuclear reaction in which *X* represents a nuclide:

$$^{232}_{90}Th \rightarrow {}^{4}_{2}He + X$$

228 88 Ra

(b)

Which nuclide is represented by *X*?

a. ~~$^{236}_{92}Ra$~~ b. $^{228}_{88}Ra$ c. ~~$^{236}_{92}U$~~ d. ~~$^{228}_{88}U$~~

I.D # of element

$^{0}_{+1}\beta$ $^{0}_{-1}\beta$ - Same mass

3. Positrons and beta particles have opposite charge

~~a.~~ The same charge and the same mass

~~b.~~ The same charge and different masses

(C)

(c.) Different charges and the same mass

d. Different charges and different masses

4. Which two radioisotopes have the same decay mode TABLE N

(a)

(a.) ^{37}Ca and ^{53}Fe β^+ β^+

~~b.~~ ^{220}Fr and ^{60}Co α β^-

c. ^{37}K and ^{42}K β^+ β^-

d. ^{99}Tc and ^{19}Ne β^- β^+

5. Which nuclear emission has the greatest penetrating power?

a. Proton

b. Beta particle

(C)

(c.) Gamma radiation

d. Positron