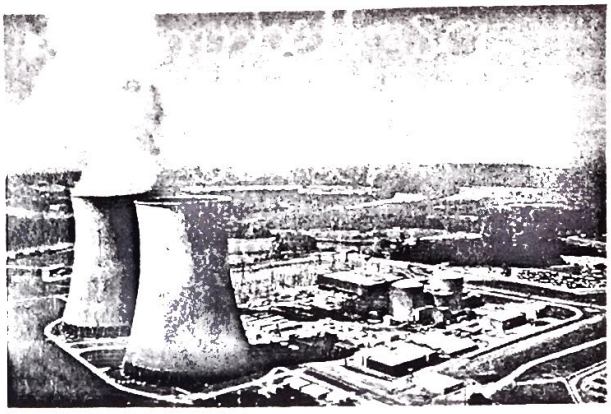
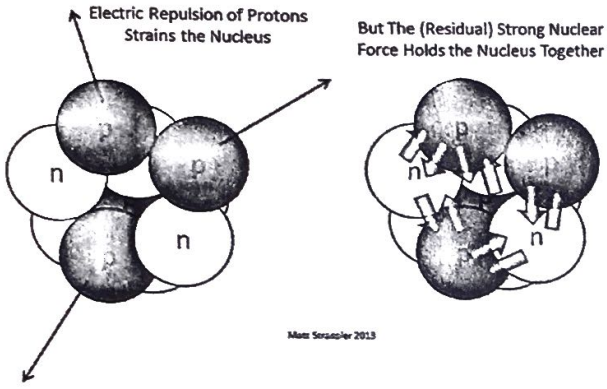
Nuclear Chemistry Key

Phenomenon- How do nuclear power plants produce energy?



Some atoms have nuclei that are stable and do not readily change while other atoms have unstable nuclei. Those atoms with unstable nuclei spontaneous break down into more stable forms by emitting various forms of radiation and/or energy. These elements are said to be radioactive.

What makes an atom unstable?



Inside the nucleus, the positively charged protons repel each other. The neutrons help to hold the protons within the nucleus despite these repulsive forces.

As the # protons atomic # increases, the number of neutrons required to inhibit their repulsive forces increases.

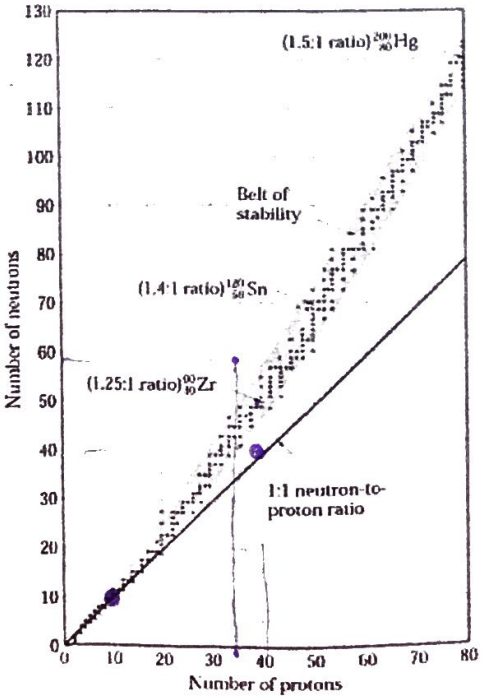
There is a point where the number of protons is so large that no matter how many neutrons are present, the nucleus will not remain stable.

Overall, the ratio of protons to neutrons determines if a nucleus is stable.

A plot can be made of the number of protons and number of neutrons in stable nuclei. The ratios that fall within this range of stability are said to make up the belt of stability

Nuclei that fall within the belt of stability are stable and not radioactive.

Nuclei that fall outside of the "belt of stability" are radioactive and will spontaneously decay in order to achieve a neutron-to-proton ratio that falls within the belt of stability.



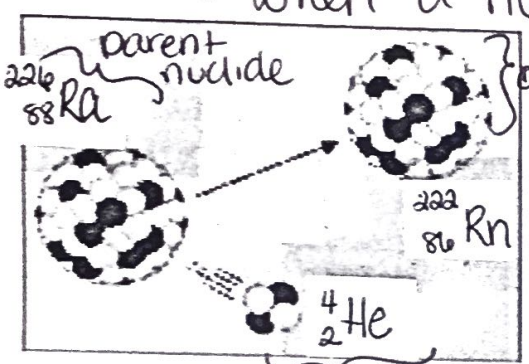
Using the graph to the left, determine if each of the following isotopes are stable or unstable.

1. 10 protons and 10 neutrons — Stable
2. 40 protons and 40 neutrons — not stable (radioactive)
3. Br-94 — mass # (#p+#n); atomic # = #p = 35; #n = 94-35 = 59n — not stable
4. Zr-90 — mass # (#p+#n); atomic # = 40 = #p; #n = 90-40 = 50n — stable

As mentioned earlier, the nuclei of unstable atoms will begin to decay, throwing out particles or radiation until a stable proton:neutron ratio is reached. These particles *radiating* from the nucleus alter the mass and/or charge of the atom. Sometimes, the atom is changed into a completely different element. Such a charge is called a **transmutation**.

Natural transmutations occur spontaneously in nature. There are four types of natural transmutations; alpha decay, beta decay, positron emission and gamma decay. In radioactive decay, the original unstable nucleus is called the parent nuclei. The nucleus formed as a result of the decay is called the daughter nucleus.

Alpha Decay when a nucleus is very large



Parent Nucleus = Ra-226 Daughter Nucleus = Rn-222

Nuclear Equation: $^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$

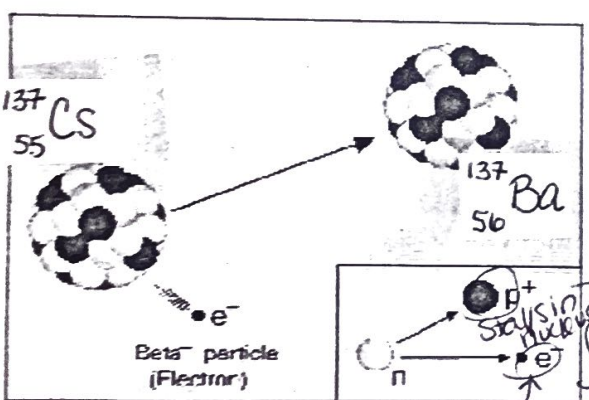
How did the atomic number change when an alpha particle was emitted?

Decreases by 2 (2 protons removed)

How did the mass number change when an alpha particle was emitted?

Decreases by 4 (2 neutrons also removed)

Beta Decay



Parent Nucleus = Cs-137 Daughter Nucleus = Ba-137

Nuclear Equation: $^{137}_{55}Cs \rightarrow {}^{137}_{56}Ba + {}^{0}_{-1}e$

How did the atomic number change when a beta particle was emitted? ~~decreased by one~~ increases by 1

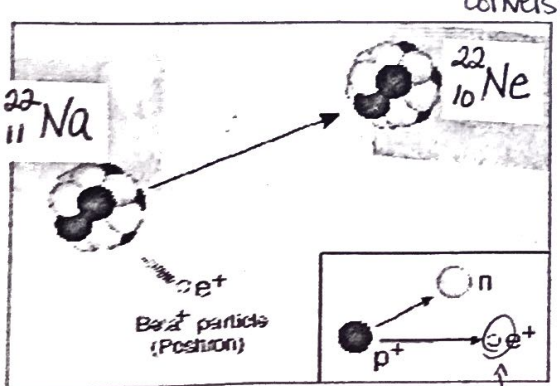
How did the mass number change when a beta particle was emitted? stays the same that

Identify the subatomic particle breaks down during beta decay.

neutron breaks down creating a proton & a beta particle. Proton stays in nucleus. Beta particle is emitted.

beta particle formed by conversion of neutron into a proton

Positron Emission



Parent Nucleus = Na-22 Daughter Nucleus = Ne-10

Nuclear Equation: $^{22}_{11}Na \rightarrow {}^{22}_{10}Ne + {}^{0}_{+1}e$

How did the atomic number change when a positron was emitted? Decreases by 1

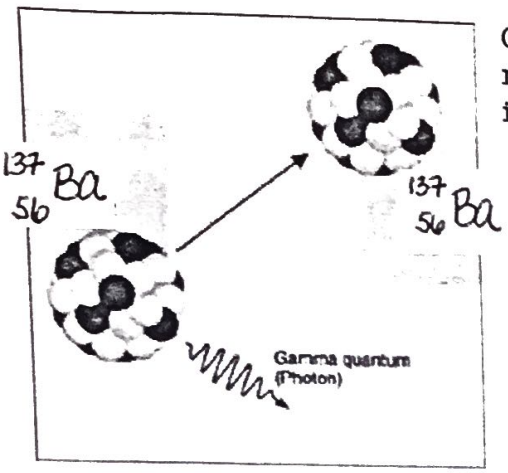
How did the mass number change when a positron was emitted? stays the same

Identify the subatomic particle that breaks down during positron emission.

positron

proton gets broken down into a neutron (stays in nucleus) and a positron (is emitted)

Gamma Radiation

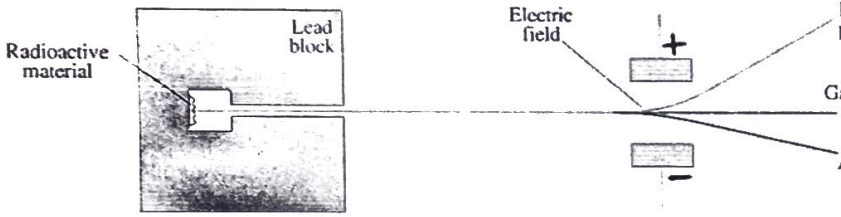


Gamma Radiation is similar to high energy x-rays. This form of radiation does not have a mass or a charge. Gamma radiation is often released along with alpha or beta decay.

- no mass, no charge

Use the diagram below to draw a conclusion regarding the charge (positive, negative, neutral) for each type of radioactive emissions. Justify your classifications.

Stop here pd. 5 5/26/17



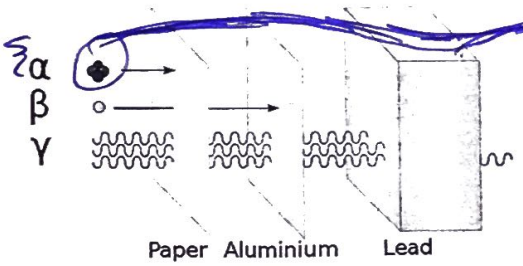
Beta (β) particles } (-) b/c bends toward +

Gamma (γ) rays } neutral (stays in middle)

Alpha (α) particles } (+) b/c bends

Using the diagram below to draw a conclusion regarding the penetrating power of alpha, beta and gamma particles. Which type of radioactive emanation is most dangerous? Justify your response.

weak



- α radiation has weak penetrating power; can be stopped by a piece of paper
- β radiation has moderate penetrating power; can be stopped by a piece of Al foil
- γ radiation is the most dangerous! It can penetrate through lead.

Summary (*) Use Table O

Radiation	Symbol	mass	Charge	Penetrating Power
Alpha Particle	${}^{4}_{2}\alpha$ or ${}^{4}_{2}$	4	+2	weak
Beta Particle	${}^{0}_{-1}\beta$ or ${}^{0}_{-1}e$	0	−1	moderate
Gamma Radiation	${}^{0}_{0}\gamma$	0	0	strong
Positron	${}^{0}_{+1}e$ or ${}^{0}_{+1}\beta$	0	+1	negligible (quickly decomposes)

weakest penetrating ↓

Writing Nuclear Equations:

When elements undergo radioactive decay, they change from one element to another. This process is called a transmutation. Nuclear equations are written to track the changes that occur during a transmutation. When writing nuclear equations both mass and charge must be conserved.

Rules for Writing Nuclear Equations

1. The mass on each side of the equation must be equal
2. The charges on each side of the equation must be equal.
3. The nuclear charge is the atomic number and can be used to determine the identity of the new element.

The type of emission given off by a radioactive nuclei is listed on ***Table N*** of the Reference Tables.

Sample Problem: Write a nuclear equation for the spontaneous decay of Rn-222.

Step 1: Determine the emission from Table N
It is an alpha emission

Step 2: Look up the atomic number of the known element.
$^{222}_{86}Rn \rightarrow {}^{4}_{2}He + X$

Step 3: Determine the mass number and atomic number of the daughter nuclei so that mass and charge is conserved.
$^{222}_{86}Rn \rightarrow {}^{4}_{2}He + {}^{218}_{84}X$

Step 4: Identify the new element using the nuclear charge (or atomic number).
$^{222}_{86}Rn \rightarrow {}^{4}_{2}He + {}^{218}_{84}Po$
*Use the Periodic Table!

Your turn....Using the information above, your reference table and the your knowledge of chemistry, write a complete nuclear equation for each transmutation below.

1. What is the daughter nuclei that forms when carbon-14 decays? ← mass # (on top) B- decay ($^{0}_{-1}\beta$ or $^{0}_{-1}e$)

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

2. What forms when iron-53 decays? positron B+ decay

$^{53}_{26}Fe \rightarrow {}^{0}_{+1}\beta + {}^{53}_{25}Mn$

3. Write the balanced nuclear equation for the decay of francium-220. mass # (top) α-decay

$^{220}_{87}Fr \rightarrow {}^{4}_{2}\alpha + {}^{216}_{85}At$

4. From what radioactive element does fluorine-19 form as a result of positron emission? $^{0}_{+1}\beta$

$X \rightarrow {}^{19}_{9}F + {}^{0}_{+1}\beta$

$^{19}_{10}Ne$

Apply your knowledge

5. Which radioactive emanations have a charge of 2+?
   a. Alpha particles ^4_2He or $^4_2\alpha$
   b. Beta particles
   c. Gamma rays
   d. Neutrons

6. In the following equation, which particle is represented by the letter X?
   $^{14}_{6}C \rightarrow {}^{14}_{7}N + X$ $^0_{-1}\beta$
   a. An alpha particle
   b. A beta particle
   c. A neutron
   d. A proton

7. In the reaction $^{238}_{92}U \rightarrow {}^{4}_{2}He + X$, the particle represented by X is
   a. $^{234}_{90}Th$
   b. $^{234}_{92}U$
   c. $^{238}_{93}Np$
   d. $^{242}_{94}Pu$

8. Thorium-229 is used to increase the lifetime of fluorescent bulbs. What type of decay occurs when thorium-229 decays to form radium-225?

$^{229}_{90}Th \rightarrow {}^{225}_{88}Ra + {}^{4}_{2}He$ alpha decay

9. Write a balanced nuclear equation for the beta decay of Si-35.

$^{35}_{14}Si \rightarrow {}^{0}_{-1}B + {}^{35}_{15}P$

Regents Example

Base your answers to questions 70 through 74 on the article below, the *Reference Tables for Physical Setting/Chemistry*, and your knowledge of chemistry.

In the 1920s, paint used to inscribe the numbers on watch dials was composed of a luminescent (glow-in-the-dark) mixture. The powdered-paint base was a mixture of radium salts and zinc sulfide. As the paint was mixed, the powdered base became airborne and drifted throughout the workroom causing the contents of the workroom, including the painters' clothes and bodies, to glow in the dark.

The paint is luminescent because radiation from the radium salts strikes a scintillator. A scintillator is a material that emits visible light in response to ionizing radiation. In watch-dial paint, zinc sulfide acts as the scintillator.

Radium present in the radium salts decomposes spontaneously, emitting alpha particles. These particles can cause damage to the body when they enter human tissue. Alpha particles are especially harmful to the blood, liver, lungs, and spleen because they can alter genetic information in the cells. Radium can be deposited in the bones because it substitutes for calcium.

70 Write the notation for the alpha particles emitted by radium in the radium salts. [1]

^4_2He or $^4_2\alpha$

71 How can particles emitted from radioactive nuclei damage human tissue? [1]

they can alter genetic info. in the cells

72 Why does radium substitute for calcium in bones? [1]

Ra & Ca are in the same group, so have similar chemical properties.

73 Explain why zinc sulfide is used in luminescent paint. [1]

Acts as a scintillator that emits visible light in response to ionizing radiation.

74 Based on Reference Table F, describe the solubility of zinc sulfide in water. [1]

ZnS insoluble