TRANSMUTATIONS

(Key)

HC

Some atoms have nuclei that are stable and do not readily change while other atoms have ***unstable nuclei*** that ***spontaneously convert into more stable nuclei*** by emitting various forms of radiation.

Radioisotope: an unstable isotope that spontaneously decays (breaks down)

Unstable nuclei that spontaneously change to form more stable nuclei undergo **natural transmutations**.

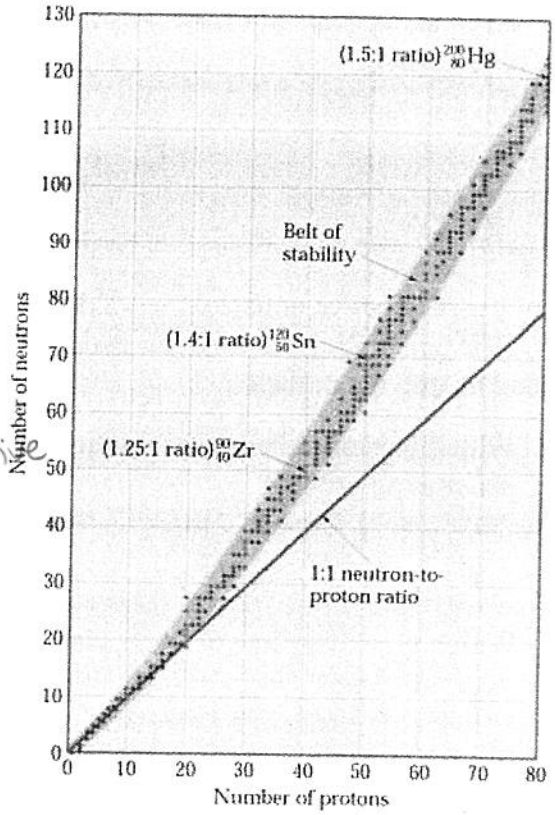
Transmutation: The formation of new elements when a radioisotope decays

The ratio of protons to neutrons is used to determine if a nuclei is stable.

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 — unstable - radioactive
3. Br-94 — mass # (p+n) - atomic # = 35 = p; n = 94 - 35 = 59 — unstable
4. Zr-90 — atomic # = 40 = p; n = 90 - 40 = 50 — stable

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

The position of a nuclei relative to the belt of stability determines the type of decay that occurs. If an unstable nuclei …..

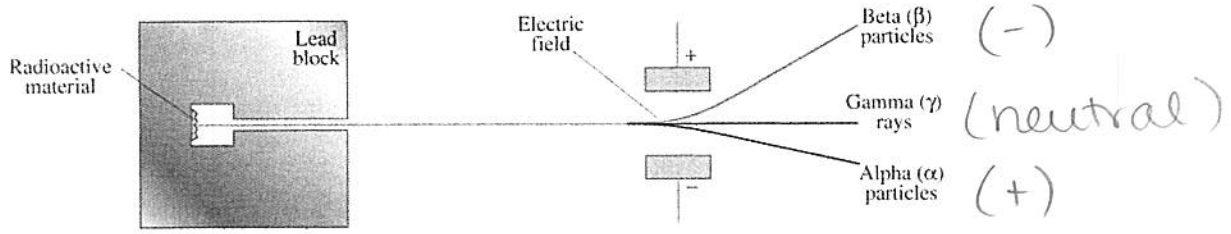
a. has too many neutrons in the nucleus , the isotope undergoes beta decay — Why? To create a beta particle, a neutron breaks down

b. is very large , the isotope undergoes alpha decay — Why? An alpha particle is made of 2 protons & 2 neutrons so releases a lot of mass from the nucleus.

c. has too many protons in the nucleus , the isotope undergoes positron emission or B+ decay

Charges of nuclear emissions

The particles released by a nucleus during radioactive decay have different charges. The diagram below represents the paths taken by three different radioactive emissions when subjected to an electric field.



(−) (neutral) (+)

5. Label each of the emissions above as positive, negative or neutral. Explain how you know made this determination.

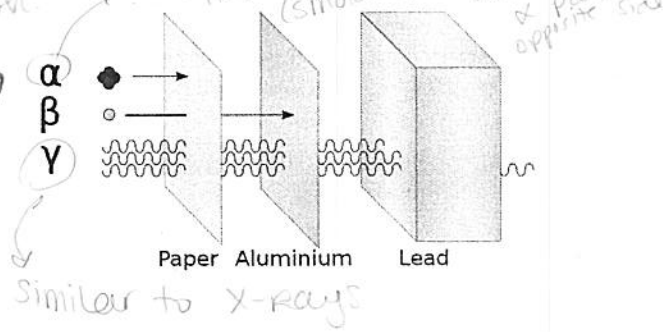
6. Explain, in terms of charged particles, why the gamma rays move through the electric field undeflected.

Gamma Rays are neutral so are unaffected by an electric field.

Penetrating Power of Radioactive Emission

what the particle can go through

Each of the radioactive emissions has a different penetrating power. The penetrating power of an emission relates to what is needed to stop the particle.



smoke detectors emit these - how they detect smoke (smoke blocks the sensor which detects & particles

Similar to X-rays

7. Which type of radioactive emission has the weakest penetrating power?

α (alpha)

8. Which type of radioactive emission has the greatest penetrating power?

γ (gamma)

9. Which form of radioactive emission would be the most dangerous for human exposure? Why?

γ (gamma)

10. Which type of radioactive emission would be the most dangerous when ingested? Why?

(from reading) alpha – although low penetrating power, it has high ionizing power.

⊗ inverse relationship between penetrating & ionizing power

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 for 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).

$^{222}_{86}Rn \rightarrow {}^{4}_{2}He + {}^{218}_{84}Po$

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

11. What is the daughter nuclei that forms when carbon-14 decays?

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

12. What forms when iron-53 decays?

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

13. Write the balanced nuclear equation for the decay of francium-220.

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

14. From what radioactive element does fluorine-19 form as a result of positron emission?

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

$^{19}_{10}Ne$

Practice and apply your knowledge

15. Samples of elements that are radioactive must contain atoms
    a. With stable nuclei
    b. With unstable nuclei
    c. In the excited state
    d. In the ground state

daughter nuclei are more stable than Parent nuclei

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

17. Atoms of I-131 spontaneously decay when the
    a. Stable nuclei emit alpha particles
    b. Stable nuclei emit beta particles
    c. Unstable nuclei emit alpha particles
    d. Unstable nuclei emit beta particles

Table N

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

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

alpha decay

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

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

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]

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

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

can alter genetic info in cells

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

same group, similar chemical properties

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

Acts as a scintillator that emits visible light

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

ZnS - insoluble

NATURAL AND ARTIFICIAL TRANSMUTATIONS

NATURAL TRANSMUTATION	ARTIFICIAL TRANSMUTATION
EXAMPLES $^{38}_{92}U \rightarrow {}^{4}_{2}He + {}^{234}_{90}Th$ $^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$ $^{226}_{88}Ra \rightarrow {}^{4}_{2}He + {}^{222}_{86}Rn$	**EXAMPLES** $^{27}_{13}Al + {}^{4}_{2}He \rightarrow {}^{30}_{15}P + {}^{1}_{0}n$ $^{238}_{92}U + {}^{1}_{0}n \rightarrow {}^{239}_{94}Pu + 2\,{}^{0}_{-1}e$ $^{239}_{94}Pu + {}^{1}_{0}n \rightarrow {}^{147}_{56}Ba + {}^{90}_{38}Sr + 3\,{}^{1}_{0}n$
What do you notice about the examples? - one parent - one reactant	What do you notice about the examples? - two parents - two reactants
The spontaneous decay of an unstable radioisotope into more stable daughter nuclei	- Bombards a nucleus w/ a high energy particle to force a nonspontaneous change in the nucleus to occur.

PRACTICE *Identify whether the following reactions is a natural transmutation or an artificial transmutation.*

$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$	N
$^{87}_{37}Rb \rightarrow {}^{0}_{-1}e + {}^{87}_{38}Sr$	N
$^{227}_{92}U \rightarrow {}^{223}_{90}Th + {}^{4}_{2}He$	N
$^{27}_{13}Al + {}^{4}_{2}He \rightarrow {}^{30}_{15}P + {}^{1}_{0}n$	A
$^{11}_{6}C \rightarrow {}^{0}_{+1}e + {}^{11}_{5}B$	N
$^{238}_{92}U + {}^{1}_{0}n \rightarrow {}^{239}_{94}Pu + 2\,{}^{0}_{-1}e$	A
$^{239}_{94}Pu + {}^{1}_{0}n \rightarrow {}^{147}_{56}Ba + {}^{90}_{38}Sr + 3\,{}^{1}_{0}n$	A

Completing the equations for an artificial transmutation is the same as that for a natural transmutation; the sum of the mass numbers on the left side of the equation must equal the sum of the mass numbers on the right and the sum of the protons on the left side must equal the sum of the protons on the right.

1. $^{48}_{22}Ti + {}^{4}_{2}He \rightarrow {}^{1}_{1}H +$ $^{51}_{23}V$
2. $^{63}_{29}Cu + {}^{1}_{0}n \rightarrow {}^{60}_{27}Co +$ $^{4}_{2}He$
3. $^{44}_{20}Ca +$ $^{4}_{2}He$ $\rightarrow {}^{47}_{21}Sc + {}^{1}_{1}H$
4. $^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{17}_{8}O +$ $^{1}_{1}H$

Directions: *Answer the following using your knowledge of Chemistry.*

1. Which nuclear equation represents a natural transmutation?

   (1) ${}^{9}_{4}\mathrm{Be} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{6}_{3}\mathrm{Li} + {}^{4}_{2}\mathrm{He}$

   (2) ${}^{27}_{13}\mathrm{Al} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{30}_{15}\mathrm{P} + {}^{1}_{0}\mathrm{n}$

   (3) ${}^{14}_{7}\mathrm{N} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{17}_{8}\mathrm{O} + {}^{1}_{1}\mathrm{H}$

   (4) ${}^{235}_{92}\mathrm{U} \rightarrow {}^{231}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$

2. Given the nuclear equation:

   $${}^{1}_{1}\mathrm{H} + X \rightarrow {}^{6}_{3}\mathrm{Li} + {}^{4}_{2}\mathrm{He}$$

   The particle represented by X is

   (1) ${}^{9}_{4}\mathrm{Li}$ (3) ${}^{10}_{5}\mathrm{Be}$

   (2) ${}^{9}_{4}\mathrm{Be}$ (4) ${}^{10}_{6}\mathrm{C}$

3. Which reaction is an example of natural transmutation?

   (1) ${}^{239}_{94}\mathrm{Pu} \rightarrow {}^{235}_{92}\mathrm{U} + {}^{4}_{2}\mathrm{He}$

   (2) ${}^{27}_{13}\mathrm{Al} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{30}_{15}\mathrm{P} + {}^{1}_{0}\mathrm{n}$

   (3) ${}^{238}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{239}_{94}\mathrm{Pu} + 2\,{}^{0}_{-1}\mathrm{e}$

   (4) ${}^{239}_{94}\mathrm{Pu} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{147}_{56}\mathrm{Ba} + {}^{90}_{38}\mathrm{Sr} + 3{}^{1}_{0}\mathrm{n}$

4. Radioactive cobalt-60 is used in radiation therapy treatment. Cobalt-60 undergoes beta decay. This type of nuclear reaction is called

   (1) natural transmutation (2) artificial transmutation

   (3) nuclear fusion (4) nuclear fission

5. Which equation is an example of artificial transmutation?

   (1) ${}^{9}_{4}\mathrm{Be} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{12}_{6}\mathrm{C} + {}^{1}_{0}\mathrm{n}$

   (2) $\mathrm{U} + 3\,\mathrm{F_2} \rightarrow \mathrm{UF_6}$

   (3) $\mathrm{Mg(OH)_2} + 2\,\mathrm{HCl} \rightarrow 2\,\mathrm{H_2O} + \mathrm{MgCl_2}$

   (4) $\mathrm{Ca} + 2\,\mathrm{H_2O} \rightarrow \mathrm{Ca(OH)_2} + \mathrm{H_2}$

6. Given the following nuclear equation, which particle is represented by **X**?

   $${}^{253}_{99}\mathrm{Es} + X \rightarrow {}^{1}_{0}\mathrm{n} + {}^{256}_{101}\mathrm{Md}$$

7. The change that is undergone by an atom of an element made radioactive by bombardment with high-energy protons is called

   (1) natural transmutation (2) artificial transmutation

   (3) natural decay (4) radioactive decay

HC did not do (post as extra practice?)