3 Types of Nuclear Decay Processes

Information

- Radioactivity is the spontaneous decay of an unstable nucleus
- The radioactive decay of a nucleus may result from the emission of some 'particle' from the nucleus. The emitted particle may alter the contents of the nucleus.
    - If the number of protons changes, then the element itself changes.
- With exception of H, all nuclei contain both protons and neutrons
    - The isotopes of hydrogen (deuterium and tritium) do have one and two protons, respectively

Critical Thinking Questions

1) What part of the atom can undergo a change if the atom is radioactive?

2) Can the identity (symbol) of an atom change as a result of a radioactive process? Why or why not?

Information

- The nuclide symbol of an atom characterizes the atom by both the atomic number (Z) and the mass number (A).

Model 1: The Nuclide Symbol

In general… ${}^{A}_{Z}X$

For example… ${}^{19}_{9}F$

Critical Thinking Questions

3) Why is the preceding subscript a 9 in the example in Model 1?

4) What does the difference $A - Z$ represent in atomic structure?

5) How many neutrons does the fluorine isotope in Model 1 contain?

6) An isotope of strontium has 38 protons and 52 neutrons. What is the nuclide symbol for this isotope?

Information

- Forces are pushes and pulls that objects can cause on another object. The gravitational, electric and magnetic forces are examples of 'forces at a distance', as they do not work via direct contact of the two objects.
    - Static electricity is often an attractive force, pulling bits of paper to a comb
- According to Coulomb's Law, the electric force between two charged particles is attractive if the charge of the two particles is opposite in sign. Alternatively, a repulsive force is created when two particles with charges of the same sign (+2 and +3, for instance)

Critical Thinking Questions

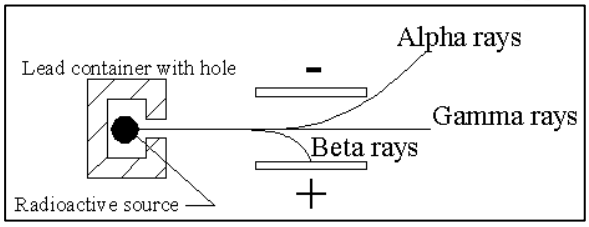
7) Would a negatively charged plate attract a particle with a charge of 0, -1 or +1?

Information

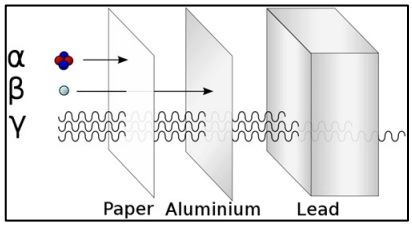
- Though there are others types, we will consider only three of the nuclear decay processes that are the cause of radioactivity. These three types have been termed alpha (α), beta (β), and gamma (γ) emission.
    - By emission, it is meant that each process ejects (or emits) a particle during the decay process.
- When directing each type of particle between to oppositely charged plates, two of the particles are seen to curve due to the presence of an electric field. This is depicted in model 2, below.

Model 2: The deflection of radioactive emissions by an electric field (a) and the relative penetration strengths of radioactive emissions (b)

a)



b)



Critical Thinking Questions

8) Based upon Model 2, which particle carries no charge? α β γ

9) Based upon Model 2, which particle carries a positive charge? α β γ

10) Based upon Model 2, which particle carries a negative charge? α β γ

11) Based upon Model 2, which radioactive particle is least dangerous to humans? Justify your response.

12) Model 3 displays three reactions that represent the alpha emission process

Model 3

$^{19}_{9}F \rightarrow {}^{15}_{7}N + \alpha$

$^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + \alpha$

$^{80}_{34}Se \rightarrow {}^{76}_{32}X + \alpha$

a. For α-emission, does the <u>mass number</u> increase, decrease or stay the same?

b. For α-emission, does the <u>atomic number</u> increase, decrease or stay the same?

c. Why is the right hand side of the first reaction in model 3 showing a nitrogen atom when the atom begins as fluorine? (Hint: what must have changed?)

d. In the third example reaction of model 3, the X represents an unknown. What real atomic symbol should be there? How do you know?

e. Recall that mass is conserved. From this statement and model 3, deduce the mass of the α-particle?

f. Does the α-particle contain any protons? How many? How do you know?

g. Does the α-particle contain any neutrons? How many? How do you know?

h. What is the mass of an alpha particle? How do you know?

i. Complete the following alpha decay reaction

$$^{40}_{19}K \rightarrow \_\_\_\_\_ + \alpha$$

Information

- alpha emission is the emission of a helium nucleus (${}^{4}_{2}He$) or an α-particle.
- The α-emission of fluorine from model 3 can now be written as: ${}^{19}_{9}F \rightarrow {}^{15}_{7}N + {}^{4}_{2}He$
- α-emission is usually seen in atoms with atomic numbers greater than 83.

Critical Thinking Questions

13) Thorium-232 decays by emitting a single alpha particle

a. Does the '232' represent the atomic number or mass number of thorium?

b. Write the nuclear equation using proper nuclide symbols for all species involved in the radioactive decay.

Information

- A beta particle is a *high-speed electron* ejected <u>from the nucleus</u>. Since the nucleus does not contain electrons, β-emission is usually considered the conversion of a neutron to a proton.
- The conversion can be written as ${}^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e$, where ${}^{0}_{-1}e$ represents the electron.
- The neutron is more massive than a proton. In fact, the difference in mass is larger than the actual mass of a single electron. The surplus mass difference is responsible for the high speed (high energy) of the ejected electron.
  - $E = mc^2$!!

Critical Thinking Questions

14) If a β-particle is emitted, does the number of neutrons in the nucleus increase, decrease or stay the same? Justify your response.

15) If a β-particle is emitted, does the number of protons in the nucleus increase, decrease or stay the same?

16) If a nucleus had 432 protons and 831 neutrons,
   a. What is the mass number of this isotope?

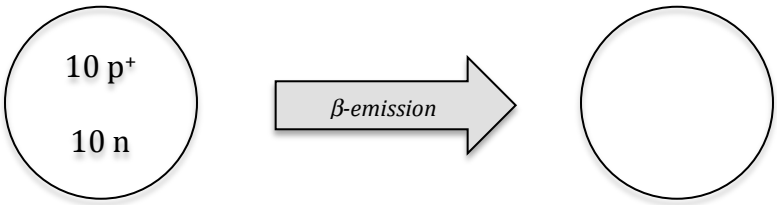
   b. How many protons would the nucleus have after β-emission?

   c. How many neutrons would the nucleus have after β-emission?

   d. What is the mass number of the atom after β-emission?

   e. How does the mass number change during β-emission?

17) Suppose the nucleus on the left of the arrow undergoes β-emission. In the given nucleus, write the number of protons and neutrons?



18)What is the proper nuclide symbol for a β-particle?

19)Suppose fluorine-19 undergoes beta decay. Write the reaction that represents the process using proper nuclide symbols for each particle.

Information

- Both α and β-decay leave the resulting atom with a highly energized nucleus. The excess energy in the nucleus can be emitted as a 'gamma particle' to allow the nucleus to "relax" to a lower energy.
- A gamma particle is actually not a particle at all (more on this later). Instead, it is really a form of light with a very, very large energy.
- The nuclide symbol for the gamma particle is ${}^{0}_{0}\gamma$.

Critical Thinking Questions

20) What is the mass of a gamma particle?

21) How will emitting a gamma particle alter the number of protons in the nucleus?

22) How will emitting a gamma particle alter the number of electrons in the nucleus?

23) How will emitting a gamma particle alter the number of neutrons in the nucleus?

24) Will an atom undergoing γ-decay change its atomic symbol? Why or why not?

25) Suppose fluorine-19 undergoes γ-decay. Write the nuclear reaction using proper nuclide symbols for all species.

Additional Problems:

1. *Thorium-234 can be produced from the alpha decay of which uranium isotope?*
2. *Write the three different radioactive decays for a carbon-14 atoms.*
3. *To the nucleus below, apply all three forms of the radioactive emissions. Draw the resulting nucleus in each case.*