Chem 1151 Lab 5 - Nuclear Chemistry

## Learning Objectives:

1) Understand the concept of radioactive decay
2) Know the change associated with an alpha, beta or gamma decay of a nucleus
3) Write the product of a nuclear reaction involving alpha, beta or gamma emission
4) Understand the concept of half-lives and do simple half-life calculations

3 Types of Nuclear Decay Processes

Information

■ Radioactivity is the spontaneous decay of an unstable atomic nucleus.

■ The decay of the nucleus is usually in the form of some emitted particle. The loss of this particle may alter the contents of the nucleus, potentially changing the atomic number and, thus, the symbol representing the atom.

■ With the exception of Hydrogen ($_1^1H$), each nucleus contains both protons and neutrons.

■ The nuclide symbol of an atom characterizes the atom by its atomic number and mass number, as shown in model 1.

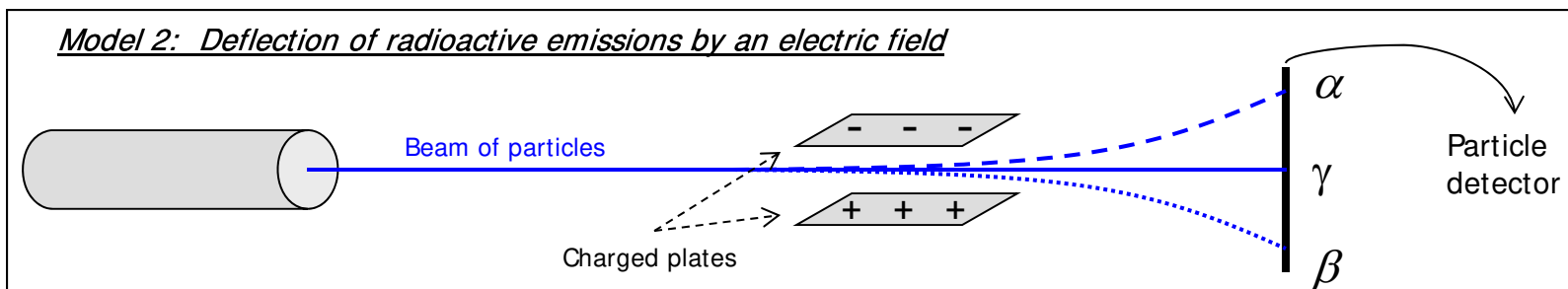   ■ The nuclide symbol for hydrogen is shown in parenthesis, above.

Critical Thinking Questions

Model 1: The Nuclide Symbol

Mass number ⟶ A
$_Z X$
Atomic number ⟶ Z
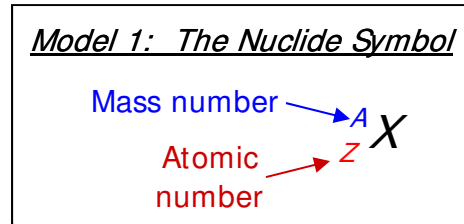
1) Using the nuclide symbol, how do you determine the number of neutrons in an atom?

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

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 (α, β or γ) 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: Deflection of radioactive emissions by an electric field

Beam of particles

− − −

+ + +

Charged plates

α

γ

β

Particle detector

3 Types of Nuclear Decay Processes

Critical Thinking Questions

3) Based upon the experiment in model 2, which particle has no charge? α β γ

4) Based upon the experiment in model 2, which particle has a positive charge? α β γ

5) Based upon the experiment in model 2, which particle has a negative charge? α β γ

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

> **Model 3: Sample alpha decays**
>
> $$^{19}_{9}F \rightarrow {}^{15}_{7}N + \alpha$$
>
> $$^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + \alpha$$
>
> $$^{80}_{34}Se \rightarrow {}^{76}_{32}X + \alpha$$

     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 the atom as being nitrogen, when the reactant atom is fluorine?
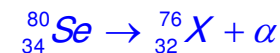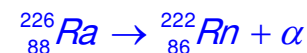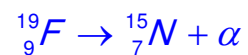
     d) Does the alpha particle contain any protons from the nucleus of the radioactive element? Justify your response.

     e) Does the alpha particle contain any neutrons from the nucleus of the radioactive element? Justify your response.

     f) All alpha particles are composed of the same number of protons and neutrons? How many of each?

     g) Based upon what you've deduced, what is the actual element symbol for "X" in the third reaction of model 3?

3 Types of Nuclear Decay Processes

Information

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

Critical Thinking Question

7) Thorium-232 decays by emitting a single alpha particle. Write the nuclear equation for the decay of Thorium-232.
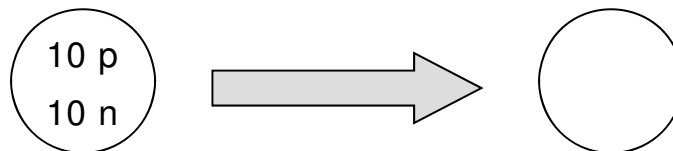
Information

- 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 equivalent to the conversion of a neutron to a proton.

- This conversion can be written as: $_{0}^{1}n \rightarrow\ _{1}^{1}p +\ _{-1}^{0}e$
  - Here, the subscript is the charge of the particle and the superscript is the mass of the particle.

Critical Thinking Questions

8) What is the symbol used to display the β-particle?

9) How will emitting a beta particle alter the number of protons in an atom?

10 How will emitting a beta particle alter the number of electrons in an atom?

11) How will emitting a beta particle alter the number of neutrons in an atom?

3 Types of Nuclear Decay Processes

12) How would the nucleus to the right look after undergoing beta emission?

(10 p / 10 n) ⟶ ( )

13) Suppose the generic atom X ($^A_Z X$) undergoes β-emission.
To the right, complete the reaction that represents this process.

14) Suppose fluorine-19 undergoes beta decay. Write the reaction that represents this process.

$$^A_Z X \rightarrow$$
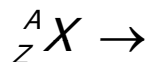
Information

■ Both α and β decay often leave the resulting atom with an energetic or excited nucleus. This excess energy can be given off, lowering the nucleus to a lower, and more stable, energy state.

■ A **gamma particle** is actually not a 'particle' at all. Instead, a gamma particle represents the emission of a high energy form of light (electromagnetic radiation) from the excited nucleus.

■ What is the symbol for the gamma particle in nuclear reactions?

Critical Thinking Questions:

15) How will emitting a gamma particle alter the number of protons in an atom?

16) How will emitting a gamma particle alter the number of electrons in an atom?

17) How will emitting a gamma particle alter the number of neutrons in an atom?

3 Types of Nuclear Decay Processes

18) What is the mass of a gamma particle? What is its charge?

19) In alpha decay, the atom undergoing the decay changed to a different atom. Will the same thing happen to an atom that undergoes gamma decay? Explain.

20) Suppose the generic atom X ($_Z^A X$) undergoes γ-emission.
To the right, complete the reaction that represents this process

21) Suppose fluorine-19 undergoes gamma decay. Write the nuclear equation that represents this process.
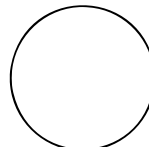
$$_Z^A X \rightarrow$$
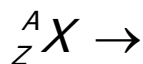
22) Apply each of the three radioactive emissions discussed in this activity to the given nucleus (on the left). Fill in the respective nuclei to the right with the proper number and type of subatomic particle.
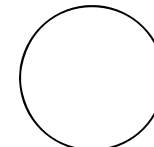Give the elemental symbol for the reactant and products.

	α decay	β decay	γ decay

84 p
125 n

_____   _____   _____   _____
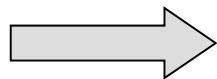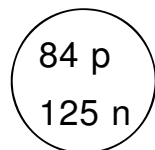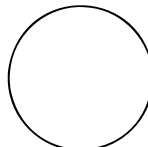
Half-Life of a Radioisotope

Information

- The half-life of a radioisotope is the amount of time it takes for one-half of a sample to decay.
- Each radioisotope has a characteristic half-life that depends on the stability of the nucleus

- Activity: Modeling Half-Lives
    - Get a piece of graph paper and a licorice stick.
    - Draw a vertical and horizontal axis on the paper
        - Label the vertical axis as radioactive atoms
        - Label the horizontal axis as minutes
    - Place the licorice stick against the vertical axis and mark its full height at 0 minutes
    - At the end of 1 minute tear the stick in half and record the new height
    - Repeat after 1 minute intervals (tearing the stick in half) until you cannot divide the licorice stick any further
    - Connect the points

- Question?
    - How long is the half life of the "radioactive" licorice? _____
    - Suppose you ate 20.0 grams of "radioactive" licorice.
      How many grams of "radioactive" licorice remain after 3 minutes? _____

- Grams: _____ → 1 half-life → _____ → 1 half-life → _____ → 1 half-life → _____
         0 min.   1 min.   2 min.   3 min.