

RADIOACTIVE DECAY

ENTER YOUR ANSWERS AND INFORMATION IN THE LIGHT BLUE FIELDS

Purpose

The purpose of this experiment is to identify the reactants and products of radioactive decay, answer questions about radioactive decay, and answer questions about the rates of radioactive decay.

Theory

Natural Radioactive Decay

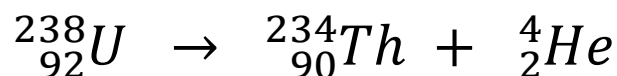
Natural radioactive decay is the process by which the nuclei inside of atoms emit energetic particles or rays. These particles or rays are called nuclear radiation. This type of radiation results in a change in the composition or structure of the nuclei of atoms.

The types of particles that are emitted during radioactive decay are shown on the table below.

Name of Particle	Symbol of Particle
Positron	${}^0_{+1}\beta$
Beta	${}^0_{-1}\beta$
Alpha	${}^4_2\text{He}$
Proton	1_1p
Neutron	1_0n

Nuclear equations can be written to describe radioactive decay where these particles are emitted.

Let's look a reaction involving alpha particle emission. The equation below describes the radioactive decay of a uranium-238 atom where a thorium-234 atom and an alpha particle are formed.



Notice that this equation is balanced. The equation is balanced because the sum of the mass numbers on both sides of the equation are equal, and because the sum of the atomic numbers on both sides of the equation are equal.

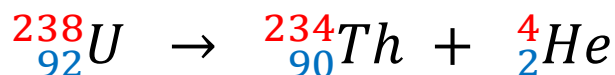
Remember that the **mass numbers** are written superscript to the left of the atomic symbol, and the **atomic numbers** are written subscript to the left to the atomic symbol.

Mass number
Atomic number Atomic symbol

Also remember that:

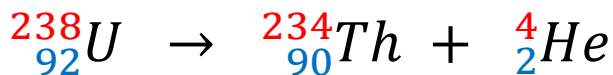
- The **atomic number** of an atom is equal to the number of protons in that atom.
- The **mass number** of an atom is equal to the sum of the number of protons in an atom and the number of neutrons in an atom.

Notice that the sum of the mass numbers on the left side of the nuclear equation and on the right side of the equation is **238**.



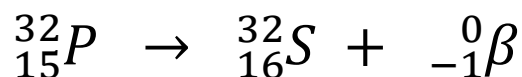
- Left side of the equation: **238**
- Right side of the equation: **234 + 4 = 238**

Also notice that the sum of the atomic numbers on the left side of the equation and on the right side of the equation is **92**.



- Left side of the equation: **92**
- Right side of the equation: **90 + 2 = 92**

Let's look at an example involving beta particle emission. The equation below describes the radioactive decay of a phosphorus-32 atom where a sulfur-32 atom and a beta particle are formed.



Notice that this equation is balanced. The equation is balanced because the sum of the mass numbers on both sides of the equation are equal, and because the sum of the atomic numbers on both sides of the equation are equal.

Notice that the sum of the mass numbers on the left side of the equation and on the right side of the equation is **32**.



- Left side of the equation: **32**
- Right side of the equation: **32 + 0 = 32**

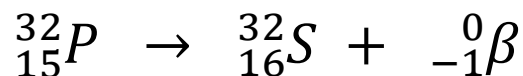
Also notice that the sum of the atomic numbers on the left side of the equation and on the right side of the equation is **15**.



- Left side of the equation: **15**
- Right side of the equation: **16 + (-1) = 15**

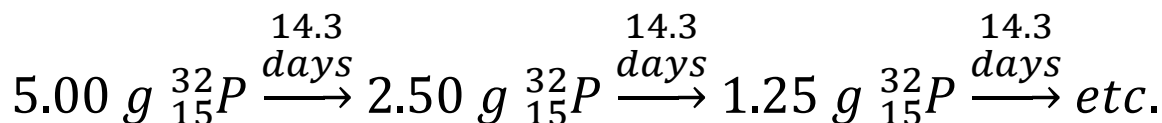
Rates of Radioactive Decay

The rates of radioactive decay are described in terms of half-lives. A half-life is the time required for one-half of the atoms in a radioactive sample to decay. For example, phosphorus-32 undergoes natural radioactive decay to form sulfur-32 atoms and beta particles.



The half-life of phosphorus-32 is **14.3 days**. This means that half a sample of phosphorus-32 will decay to sulfur-32 and beta particles every 14.3 days.

See the image below assuming you start with 5.00-gram sample of phosphorus-32.



- Notice that 5.00 grams of phosphorus-32 decays to 2.50 grams of phosphorus-32 in **14.3 days (one half-life)**.
- Notice that 5.00 grams of phosphorus-32 decays to 1.25 grams of phosphorus-32 in **28.6 days (two half-lives)**.

Name _____

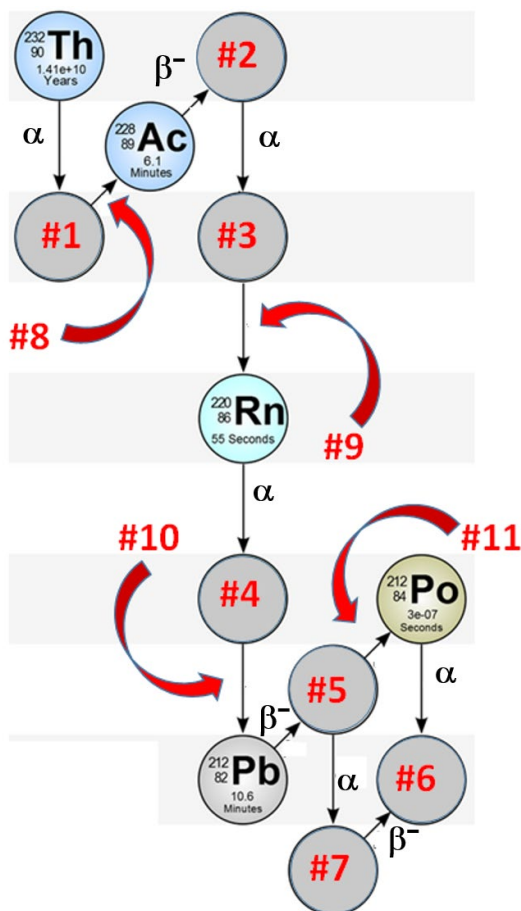
Date _____

RADIOACTIVE DECAY

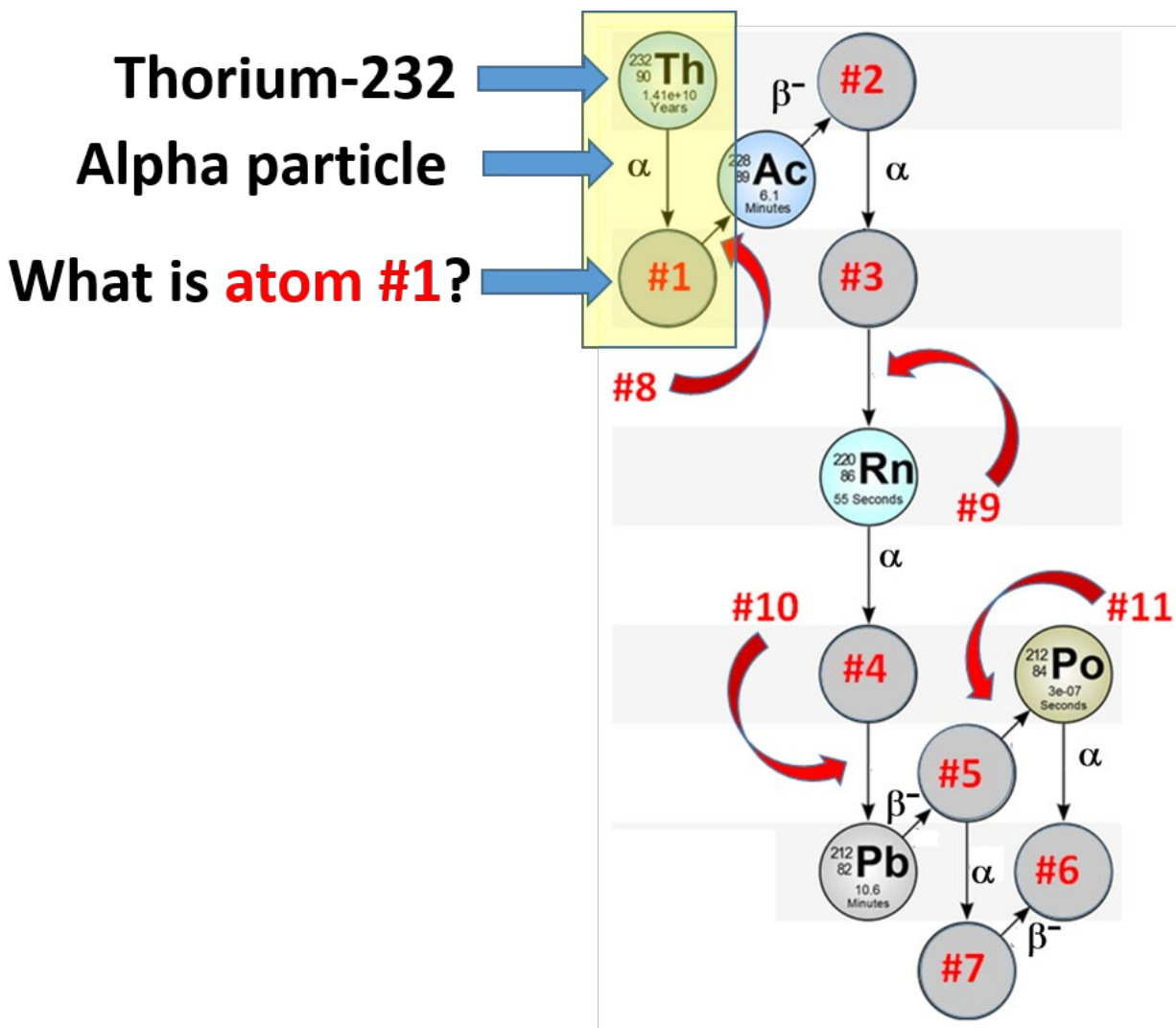
Procedure, Data Sheet and Questions

A. Identifying Reactants and Products of Radioactive Decay

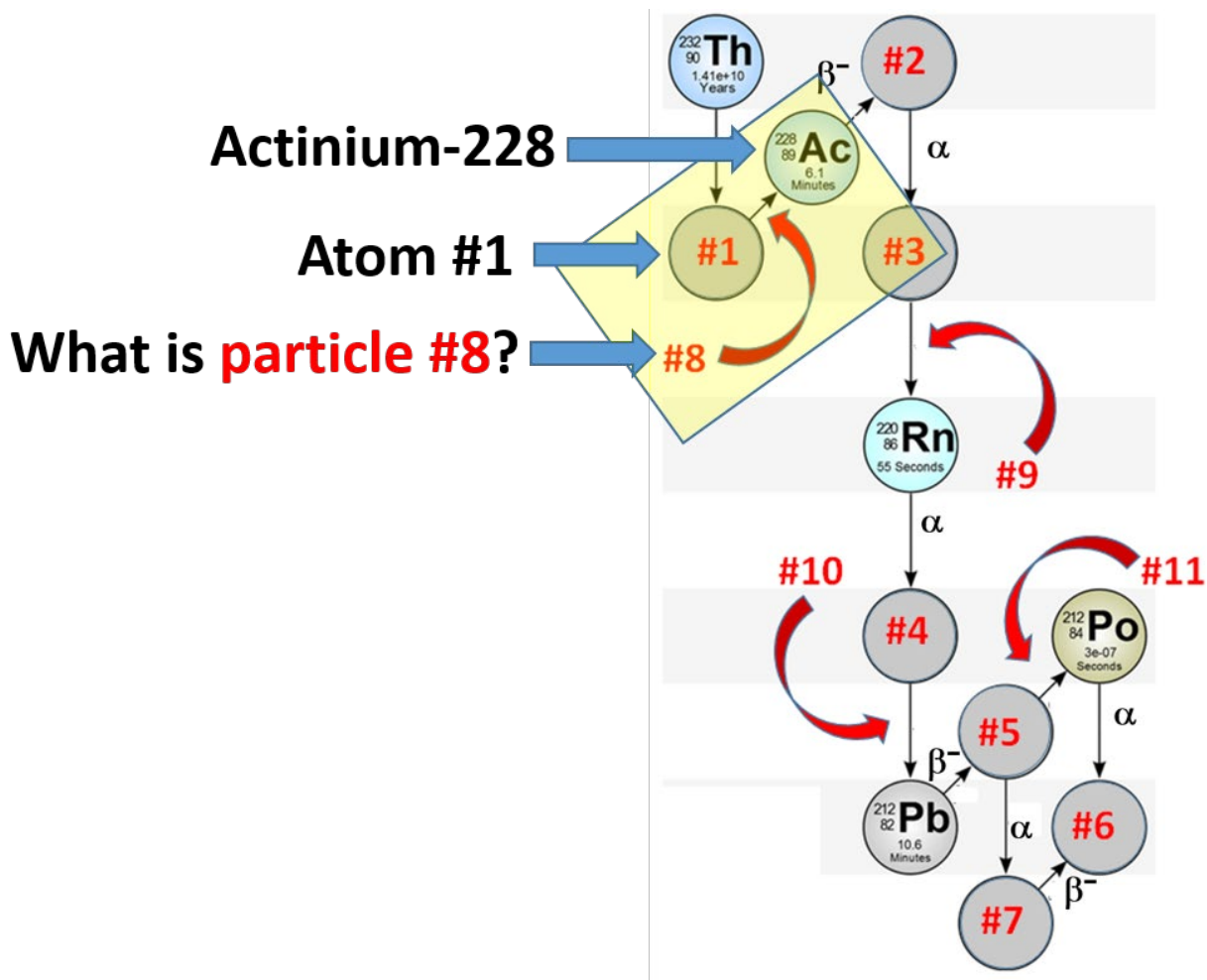
1. The radioactive decay series for thorium-232 is shown below. Notice that this decay series is composed of several radioactive decay reactions, and that some of the reactants and products and the types of particles emitted during the reactions to be identified and are numbered **#1** through **#11**. Your goal will be to determine the missing reactants, products and emitted particles by balancing the nuclear equations describing the radioactive decay reactions.



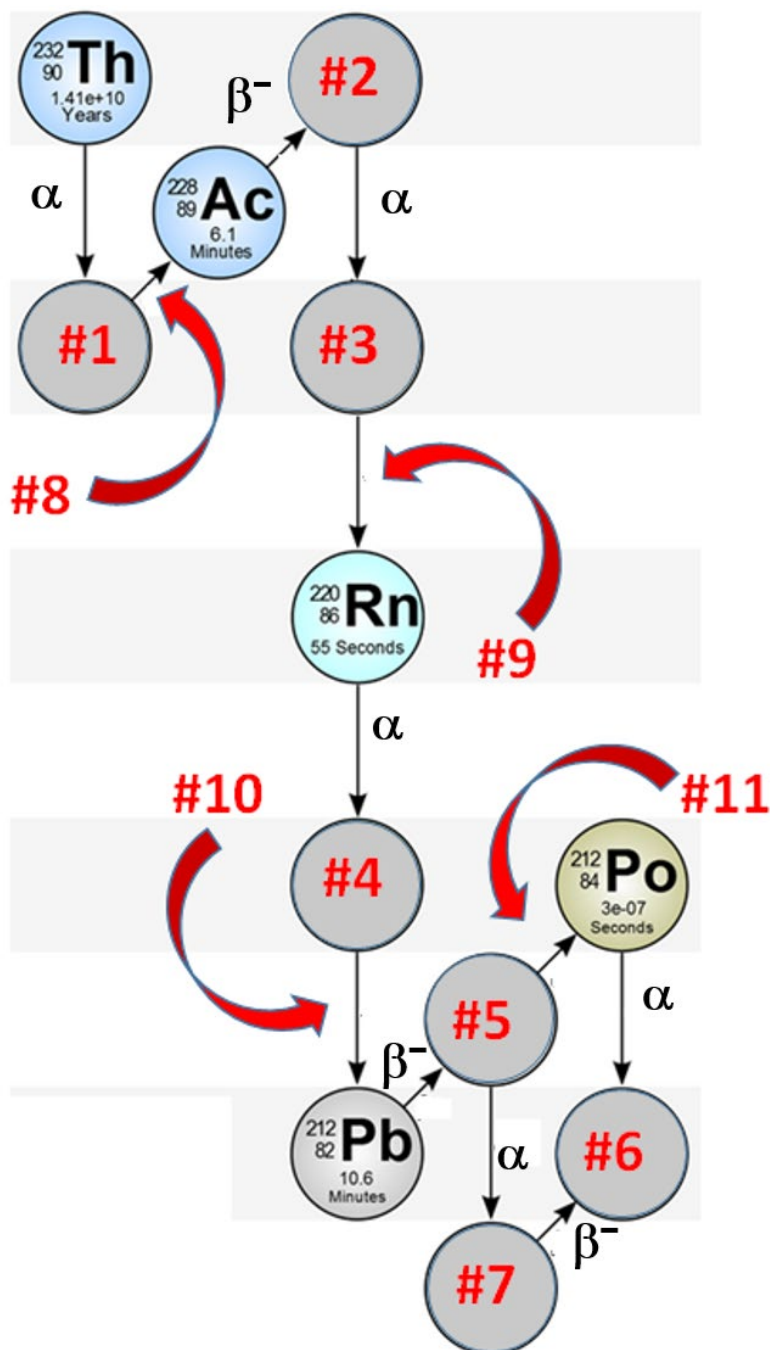
For example, notice at the beginning of the decay series that a thorium–232 atom is emitting an alpha particle (α) to form **atom #1**. You can determine the identity of **atom #1** by balancing the equation. In other words, there is one atom that will allow this equation to balance. What is this atom?



Once you know the identity of **atom #1**, you can determine the particle emitted (**particle #8**) to form actinium-228. You can determine the identity of **particle #8** by balancing the equation. In other words, there is one particle that will allow this equation to balance. What is this particle?



Your goal will be to determine the missing atoms and particles in this decay series. Notice that the missing atoms and particles are numbered **#1** through **#11**. Enter the identities of these atoms and particles on the table on the following page.



Enter the identities of these atoms and particles on the table below.

#1	
#2	
#3	
#4	
#5	
#6	
#7	
#8	
#9	
#10	
#11	

2. Answer the following questions about the thorium-232 decay series.

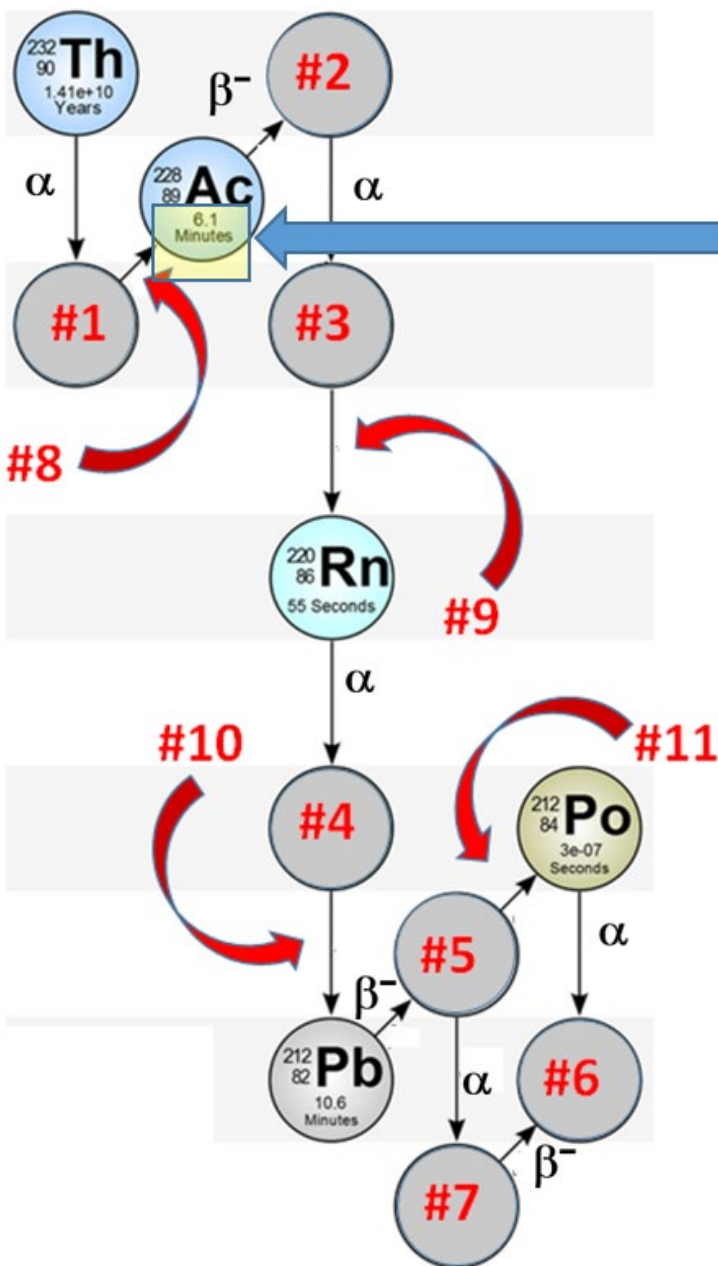
a. The decay series **starts** with thorium-232. What atom does the series **end** with?

b. There are **four elements** that appear in the series more than once. What elements are these?

c. There is one element in the series that is a **noble gas**. What element is this?

B. Rates of Radioactive Decay

Notice that actinium-228 has a half-life of **6.1 minutes**. Answer the questions on the following page about this half-life.



**6.1 minutes:
Half-life of
actinium-228**

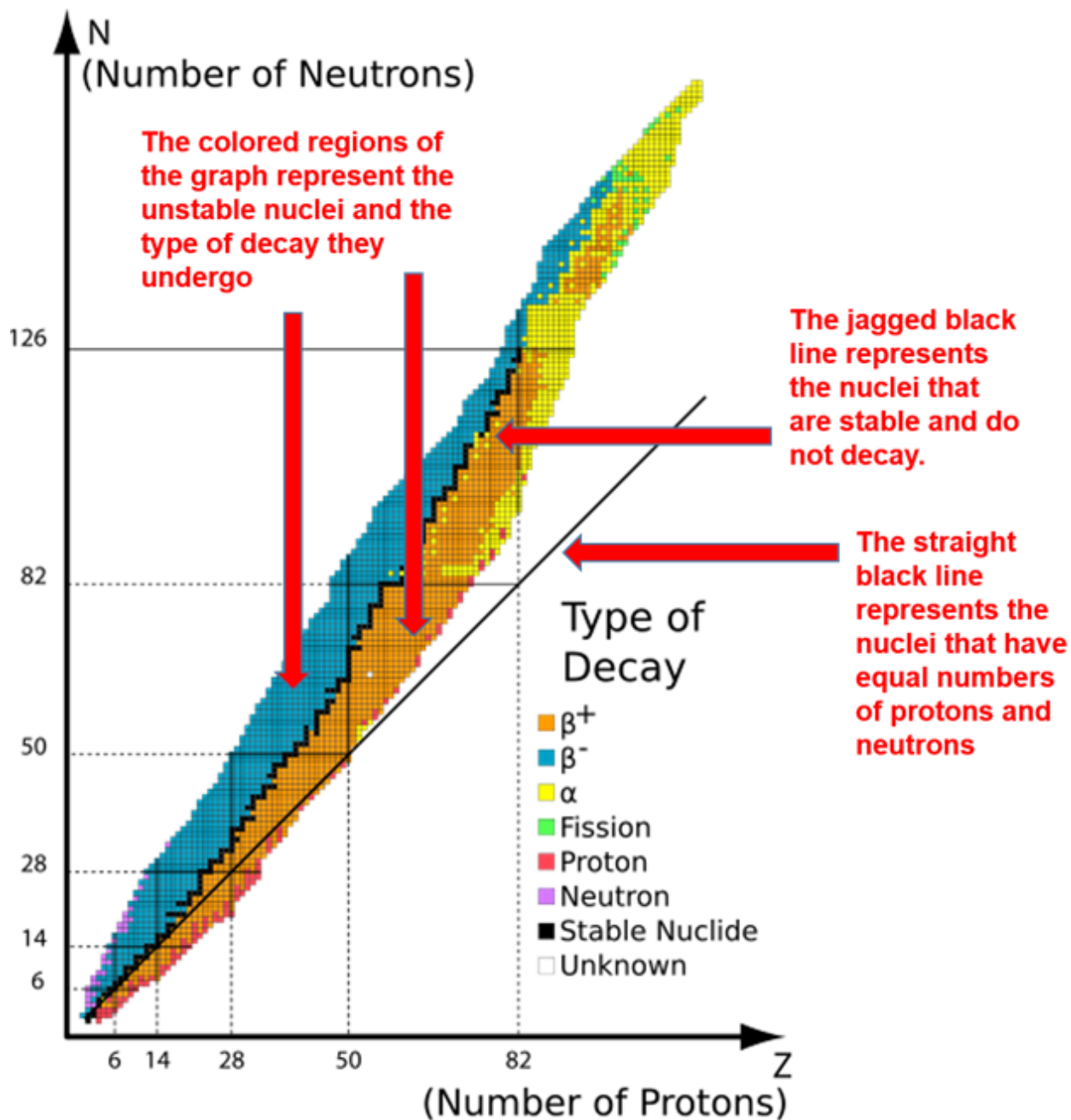
3. a. Suppose you have 3.60 grams of actinium-228. How much actinium-228 remains after 6.1 minutes?

b. Suppose you have 23.80 grams of actinium-228. How much actinium-228 remains after three half-lives?

c. Suppose you start with 68.4 grams of actinium-228, and the sample decays to 4.275 grams of actinium-228. How much time elapsed during this decay?

C. Nuclei Stability

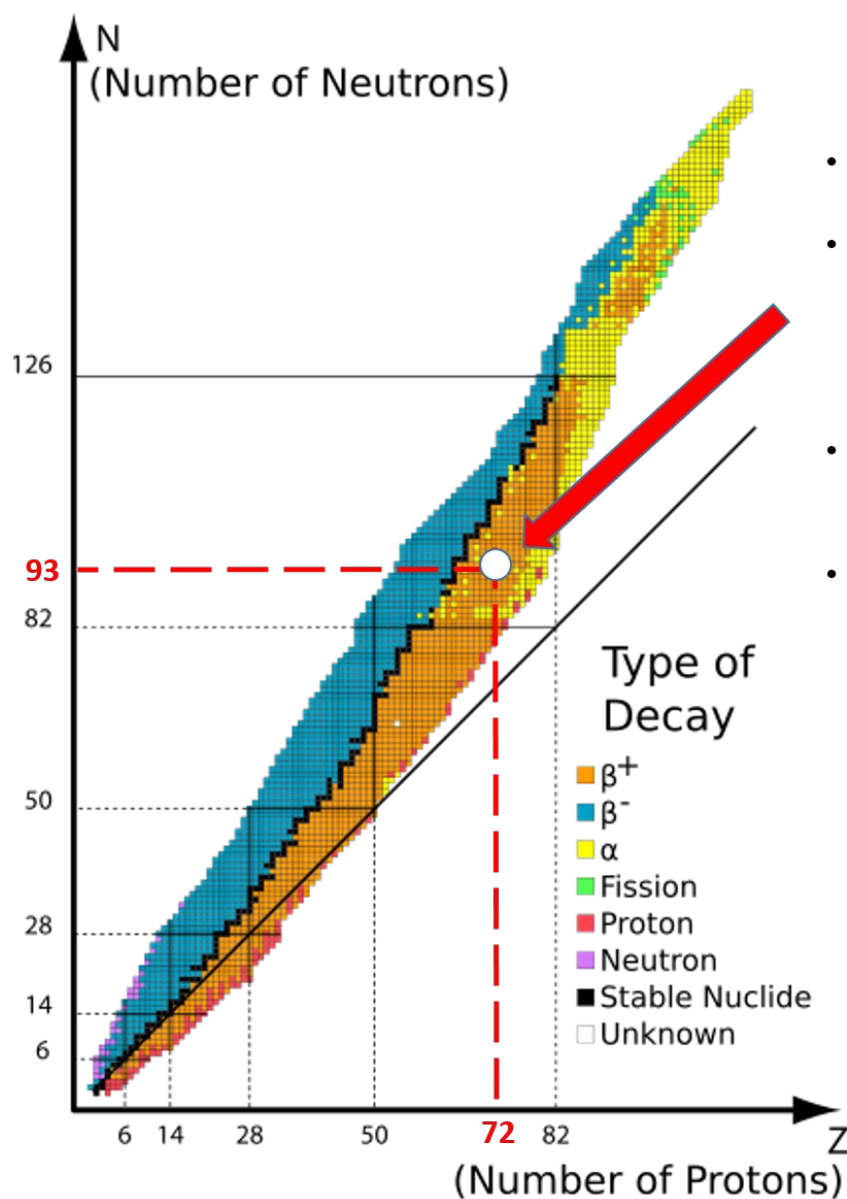
The graph below shows the stable and unstable nuclei, and the type of emission the unstable nuclei undergo.



Remember that:

- The **atomic number** of an atom is equal to the number of protons in that atom.
- The **mass number** of an atom is equal to the sum of the number of protons in an atom and the number of neutrons in an atom.

You can use this information to find specific atoms on the graph. Notice that the number of protons is on the x-axis and the number of neutrons is on the y-axis. The white dot on the graph corresponds to a **hafnium-165 atom**.



- This atom has **72** protons and **93** neutrons.
- This is a hafnium atom because hafnium atoms have 72 protons. Hafnium has an atomic number equal to 72.
- This atom has a mass number equal to 165 (72 + 93).
- So this is a **hafnium-165** atom.

4. Answer the following questions by examining the graph on the previous page.

a. Is a carbon-12 atom stable? (Indicate **Yes** or **No**). If you answered **No**, what type of decay does this atom undergo?

b. Is a tin-100 atom stable? (Indicate **Yes** or **No**). If you answered **No**, what type of decay does this atom undergo?

c. Are all atoms with 14 protons stable? (Indicate **Yes** or **No**)

d. Are there any atoms with 135 neutrons that are stable? (Indicate **Yes** or **No**)

e. Silicon-39 atoms are unstable. What type of radiation is emitted during the decay of this atom? What atom is formed during this decay?