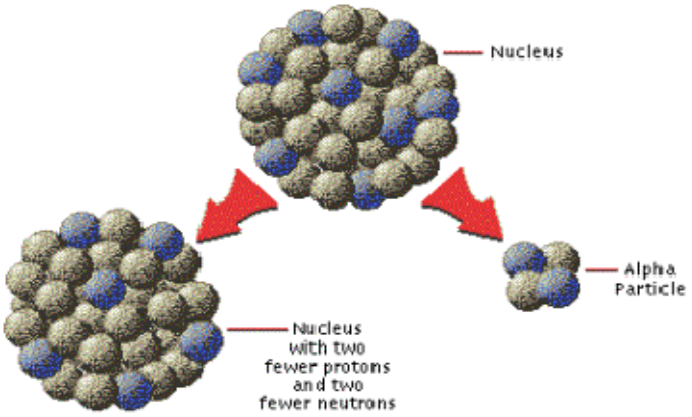
Isotope Revolution:
Determining the Type of Isotope Decay

<u>Teacher instructions</u>

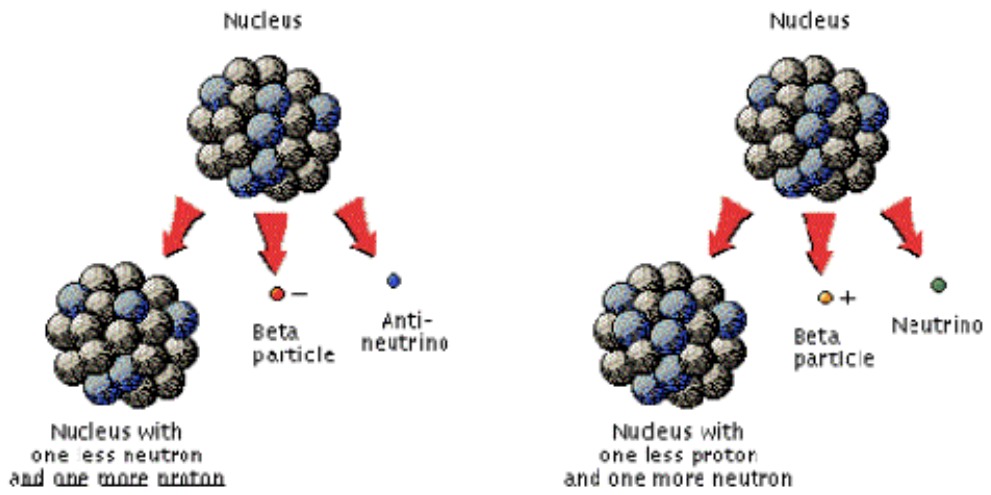
Background Information:

Isotopes that are used by Earth Scientists usually decay in several ways or in a series of decays that involves more than one type of decay. In Alpha decay the atom can be thought of as losing a Helium atom. The nucleus changes by losing two protons and two neutrons. To keep the atom electrically neutral two electrons are also emitted.



Alpha decay. The nucleus breaks down to form an atom with two fewer neutrons and two fewer protons. Also given off is an alpha particle, which is effectively a helium atom.

In Beta decay the nucleus changes by having a neutron evolve into a proton. The atomic number therefore increases by one but the mass number remains the same. A beta particle (electron) is emitted. In Beta capture (or electron capture) a proton changes to a neutron by capturing an electron that is at low energy. In Beta capture the atomic number decreases by one but once again the mass number remains the same.



Beta decay. You can think of the nucleus as losing an electron. Thus a neutron changes to a proton (plus electron . . . β particle). If it loses a positive β particle (β^+), the proton goes to a neutron.

The diagram on the right shows beta decay. The diagram on the left shows (+) beta decay which results in the same nucleus as electron capture.

Activity:

Materials

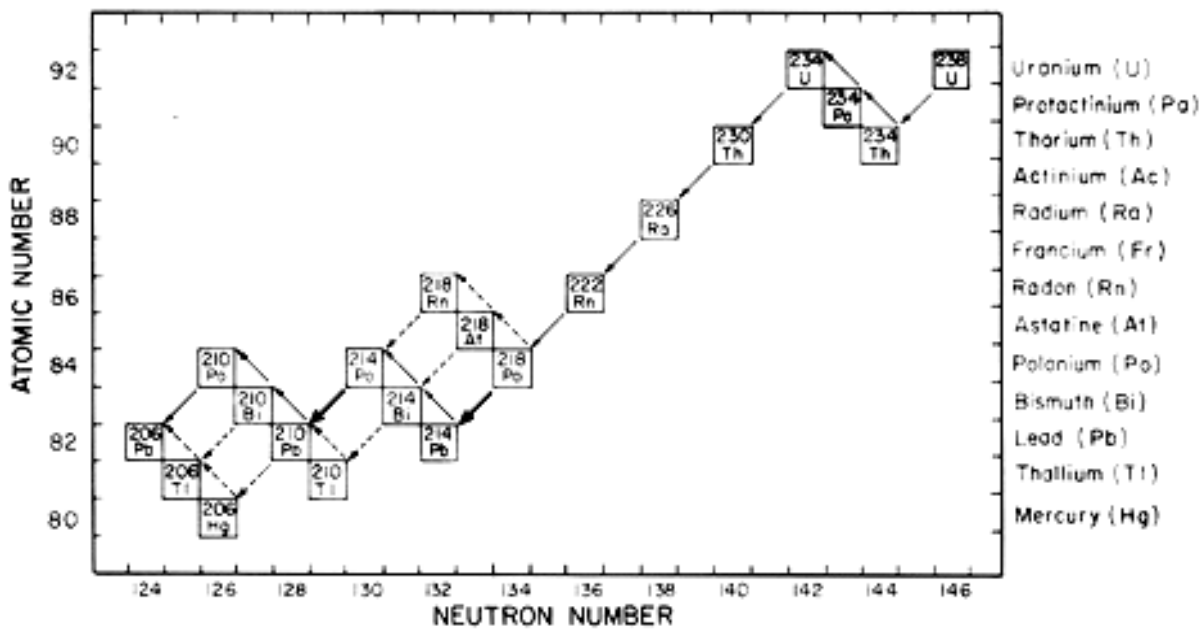
Beads (2 colors)
Zip lock bags

Use one color of bead to represent the protons in the nucleus of the element and the other color to represent the neutrons. Place 19 proton beads and 21 neutron beads in a zip lock bag. In another bag place 18 proton beads and 22 neutron beads. These bags represent the beta decay of potassium-40 to argon-40.

Prepare another pair of bags by putting 19 proton beads and 21 neutron beads and a bag and 20 proton beads and 20 neutron beads in another bag. These bags represent the electron capture decay of potassium-40 to calcium-40. (Potassium-40 decays into both argon and calcium. 12 % of the potassium-40 decays into argon-40 and 88 % decays into calcium-40). A third set of bags will have the 1st bag with 62 proton beads and 85 neutron beads and the 2nd bag will have 60 proton beads and 83 neutron beads. This pair will represent the alpha decay of Samarium147 to neodymium-143.

Indicate to the students which of each pair is the parent and which is the daughter atom. Students will count the number of protons and neutrons and determine which type of decay occurred in each pair.

After students have made their decisions give students a 4th pair of bags. Tell them that this part of the activity is a little more complicated and there may be more than one correct answer. Prepare this pair of bags by putting 92 proton beads and 146 neutron beads in the 1st (parent) bag and 82 proton beads and 124 neutron beads in the 2nd (daughter) bag. Students will now have to devise a pattern of decay that will get them from the parent to the daughter. The following picture is a diagram that shows the real pathways that are taken.



Most stable nuclides usually have qn even number of protons and an even number of neutrons.Certain values for Z and N (Z= the number of protons, N= the number of neutrons) are consistent with stability. These values are called “Magic Numbers”. If either the number of prptons or the number of neutrons or both are magic numbers than the isotope will probably be stable. The magic numbers are 2, 8, 10, 20, 28, 50, 82, and 126. Calcium for example has 5 stable isotopes which have mass numbers of 40, 42, 44, 46, and 48. The number of protons for calcium (20) is a magic number and all of the number of neutrons is even. Calcium-40 is doubly magic because it also has 20 neutrons. Almost 97% of calcium is found as calcium-40.

Teaching tips:

Use students to fill the bags the 1st time. Have them put beads in paper cups before placing them in bags so that the numbers can be rechecked.

Rather than having the students count the beads in the larger atoms you ma y want to give them the numbers. The accuracy of the count may not be very high if students do the counting. This will also save time.

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Student Worksheet:

Data Table

Bag	Proton Beads	Neutron Beads	Element Isotope
A-1			
A-2			
B-1			
B-2			
C-1			
C-2			
D-1			
D-2			

Conclusion

Bag Set	Type of Decay
A	
B	
C	
D	

Discussion Questions:

1. List the ways that alpha, beta, and electron capture decay are the same.

2. List the ways that alpha, beta, and electron capture are different.

3. Research “Magic Numbers” that are used in explaining radioactive decay and show how they apply to each parent daughter pair.

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Student Instructions

Materials:

4 sets of bags with 2 colors of beads

Procedure:

1. Count the beads in the set of bags marked A-1 and A-2. Your teacher will tell you which bead color represents the protons and which bead color represents neutrons.
2. From the information that you teacher has provided you determine which type of radioactive decay has occurred to get from bag 1 to bag 2.
3. Repeat steps one and two with bags marked B and C.
4. Make a data table and record your data. Make another table to record the types of decay that you have concluded will occur in each set of bags.
5. After discussing your conclusions with the class, count the beads in the set of bags marked D. The decay from bag D-1 to bag D-2 occurs in steps. Devise a scheme for this decay.