The Band of Stability

- *Students know* how to relate the position of an element in the periodic table to its atomic number and atomic mass.
- *Students know* protons and neutrons in the nucleus are held together by nuclear forces that overcome the electromagnetic repulsion between the protons.
- *Students know* some naturally occurring isotopes of elements are radioactive, as are isotopes formed in nuclear reactions.
- *Students know* the three most common forms of radioactive decay (alpha, beta, and gamma) and know how the nucleus changes in each type of decay.

Introduction

Radioactive decay changes the nature of an atom's nucleus, and it happens for a reason. Each element from hydrogen (atomic number 1) to lead (atomic number 82) has stable isotopes in which the tendency of protons to repel one another is overcome by attractive nuclear forces. These attractive nuclear forces require ideal distances between the protons. The neutrons help create these ideal distances. If there are too few neutrons, or too many neutrons, the nucleus becomes unstable.

If an atom has more than 82 protons in the nucleus, there is no arrangement of neutrons that can produce more attractive forces than repulsive forces. Therefore, all isotopes of elements beyond lead are radioactive. Their only route to stability is to first reduce the overall size of the nucleus by losing large particles called "alpha particles."

Example:

$$^{210}_{84}Po \; + \; \rightarrow {}^{206}_{82}Pb \; + \; ^{4}_{2}He$$

Atoms that have fewer than 82 protons will undergo decay that alters the proton/neutron ratio. Neutrons may be converted to protons by losing a beta particle (essentially an electron).

Example:

$$^{1}_{0}n \;\rightarrow\; ^{1}_{1}p \; + \; ^{0}_{-1}\beta$$

Protons may be converted to electrons by positron emission. A positron is the anti-particle of the electron.

Example:

$$^{1}_{1}p \;\rightarrow\; ^{1}_{0}n \; + \; ^{0}_{+1}\beta$$

Protons may also be converted to neutrons through the process of electron capture.

Example:

$$^{1}_{1}p \; + \; ^{0}_{-1}e \rightarrow \; ^{1}_{0}n$$

Radioactive decay also often has associated with it the release of gamma radiation (γ). Gamma radiation is pure energy, of very short wavelength and very high energy. Since it does not have mass, it does not on its own change the nature of the nucleus. For this reason, it is often omitted from equations where is should appear. An example is the first equation on this sheet:

Example:

$$^{210}_{84}Po \; + \; \rightarrow {}^{206}_{82}Pb \; + \; ^{4}_{2}He + \, ^{0}_{0}\gamma$$

Part 1 – Create a "Band of Stability"

You will be graphing the proton and neutron numbers for some isotopes that are known to be stable.

1. Using an entire side of a piece of graph paper, draw a vertical "y" axis and label it "Neutrons." Draw a horizontal "x" axis and label it "Protons". (1 point each)
2. Scale the y-axis so that it goes from 0 to 150. (1 point)
3. Scale the x-axis so that it goes from 0 to 100. (1 point)
4. On a piece of binder paper, complete the following table (2 points):

Stable Isotope	***Atomic Number***	***Protons (X axis)***	***Neutrons (Y axis)***
Helium – 4			
Carbon – 12			
Silicon – 28			
Scandium – 45			
Iron – 56			
Silver – 109			
Xenon – 131			
Gadolinium – 160			
Tungsten – 184			
Lead – 206			

Note that this is only a small part of the list of stable isotopes. From hydrogen to lead, there are currently *243* isotopes identified as stable.

5. Plot the points that result from the table above, in the form (x,y), on your graph. (2 points)
6. Draw a bold curve through the points, creating as smooth a curve as possible. (1 point)

Part 2 – Unstable Isotopes

1. On a piece of binder paper, complete the following table (2 points):

Unstable Isotope	***Atomic Number***	***Protons (X axis)***	***Neutrons (Y axis)***
Carbon – 14			
Silicon – 32			
Iron – 52			
Xenon – 135			
Lead - 214			
Radium – 226			

Note that this is only a small part of the list of unstable isotopes. There are about *70 naturally occurring* isotopes identified as unstable, and MANY more that are the result of processes such as nuclear fission.

2. Plot the points that result from the table above, in the form (x,y), on your graph. Label each point with the identity of the isotope that it represents. (2 points)
3. On your binder paper:
   a) For each isotope in the table above, identify a type of decay that could begin to move the isotope toward the band of stability (1 point each)
   b) Write a nuclear decay equation for each isotope undergoing the type of decay that you have indicated. If you ask nicely, your instructor may help you with this ☺. (1 point each)
4. Your paper will be turned in with your name, date and period on top of the binder paper, and the graph paper attached to the back of it.