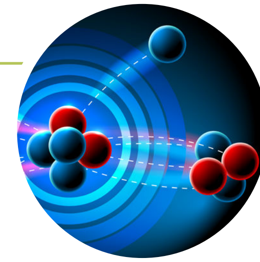
Modeling Alpha and Beta Decay

A Carolina Essentials™ Activity



Student Worksheet

Overview

Maybe you or someone you know has had a **magnetic resonance imaging (MRI)** or **positron emission tomography (PET)** scan to help diagnose a medical problem. Maybe someone close to you has been treated for cancer. These procedures involve radiation produced from radioactive isotopes.

SAFETY REQUIREMENTS

No PPE is required for the activity.

MATERIALS

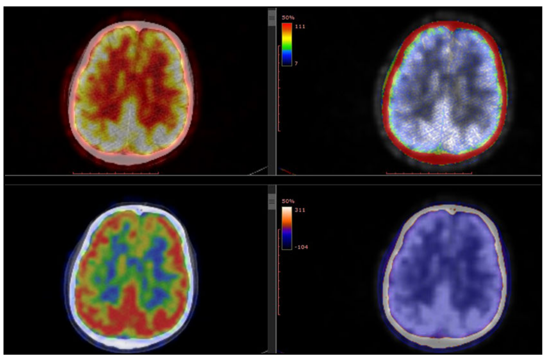
Periodic table

Calculator (optional)

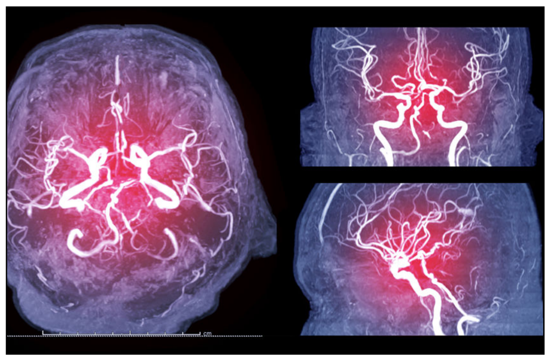
Phenomenon

Nuclear medicine is a branch of medicine that relies on the proper selection of radioactive isotopes to produce scans and to treat many types of cancer.

Look at the brain scans below. Why do you think nuclear decay can be a powerful and useful medical tool?



Positron Emission Tomography (PET) Brain Scan



Magnetic Resonance Imaging (MRI) Brain Scan

All elements have at least one radioactive isotope, and some elements have only radioactive isotopes. Radioactive isotopes decay*,* meaning the nucleus is unstable. The result of nuclear decay is a more stable nucleus, called the **daughter nuclide**, which is often a different element.

Neutron-Proton Ratio

Neutron-proton ratio is an easy way to determine if the nucleus is stable or not:

- For smaller elements, about elements Z = 1 to 15, if the n^0:p^+ ~ 1:1.0, the isotope is likely stable.
- For elements with Z = 16 to 50, if the n^0:p^+ ~ 1:1.6, the isotope is likely stable
- For the heavy elements where Z > 50 and the n^0:p^+ ~ 1:1.8, the nucleus is likely stable.

Smaller and larger neutron-proton ratios within a segment indicate the likelihood of unstable nuclei that will decay. For greater certainty, check the band of stability chart and locate the nuclide to determine its stability. If the nuclide lies on the thick, black center line, it is stable (otherwise it will decay). Nuclear medicine specialists must know if an isotope is stable or if it will decay, and by what process the isotope will decay.

How do nuclear medicine specialists know what isotope will work for diagnostic or treatment purposes? It's important to know what type of radiation the isotope or nuclide emits. Alpha radiation, beta radiation, gamma radiation, and positron emission are types of nuclear changes that produce radiation with accompanying energy changes. This lesson focuses on alpha and beta radiation.

Continued on the next page.

Alpha Radiation

As a nucleus gets large, often with hundreds of neutrons and protons, it becomes unstable, primarily because of its size. To become stable, the nucleus emits an alpha particle, which is a helium nucleus, 2 protons, and 2 neutrons. Alpha particles are the heaviest decay particles.

Alpha radiation is symbolized with α (from the Greek) and written in nuclear equations as $^{4}_{2}\mathbf{He}$. Four indicates the mass of the nucleus, and 2 indicates the number of protons. Alpha radiation is relatively low energy radiation and can be stopped by a sheet of paper.

Beta Radiation

Beta radiation is generated when the ratio of protons to neutrons produces instability. A neutron decays to produce a proton, and a high-speed electron is ejected from the nucleus. The ejected electron is the beta (β) particle. The process:

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

Beta particles are higher in energy than alpha particles and are stopped by an aluminum plate.

In this activity, you'll generate a model to determine whether a nuclide is stable or unstable, and you'll determine the type of radiation emitted by the nucleus to produce a stable nuclide. Nuclear medicine specialists must know this information to select the appropriate isotope for treatment or diagnosis.

Activity Objectives

1. Determine if an isotope is stable or unstable.
2. Construct a model that predicts the type of nuclear decay expected for unstable nuclei.

Activity Procedures

1. Calculate and record the number of neutrons and protons for all isotopes in the data table.

   Protons = atomic number (Z)
   Neutrons = isotope mass – atomic number

2. Calculate the neutron-proton ratio.

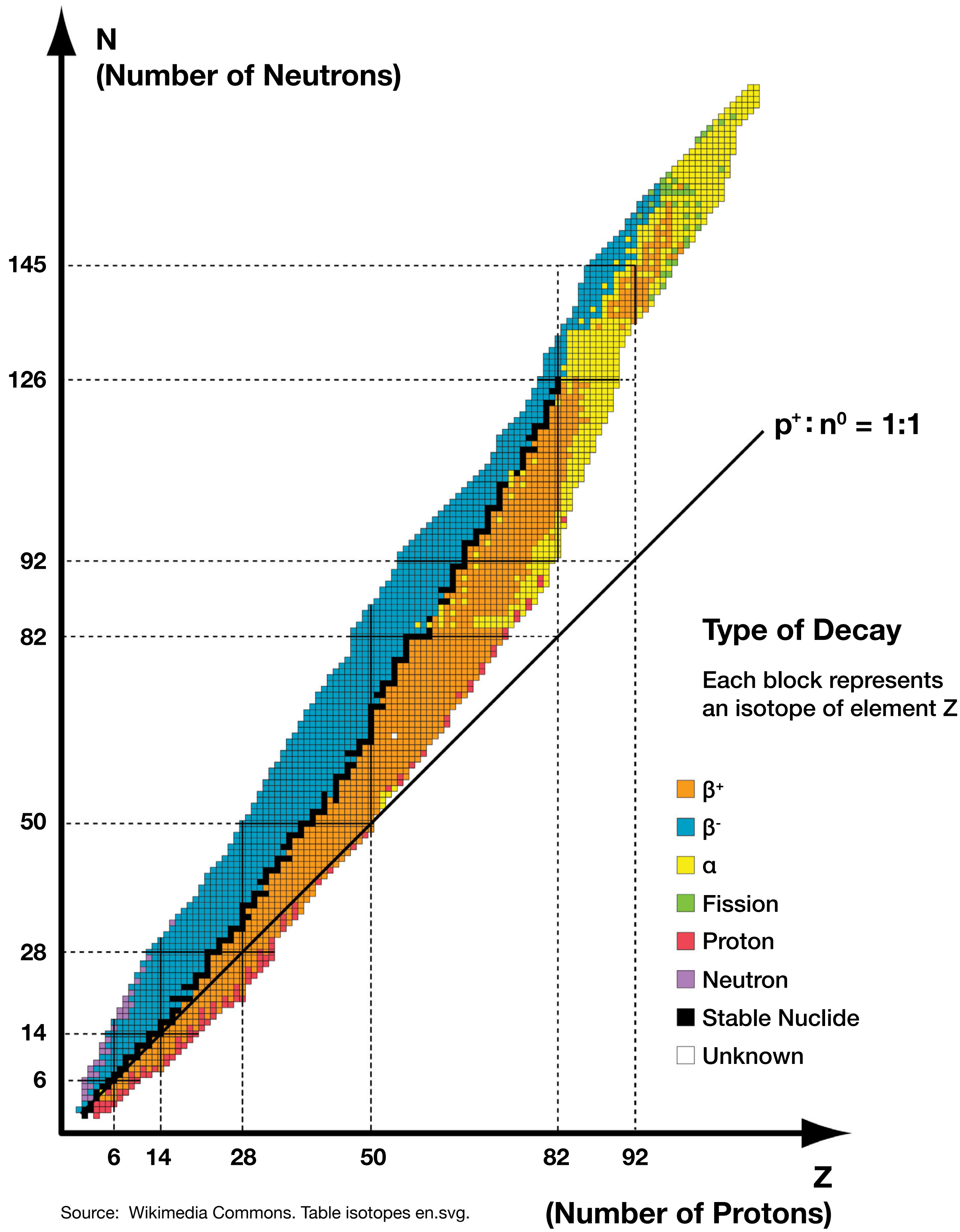
   $\frac{\text{Number of neutrons}}{\text{Number of protons}} = \frac{x.xx}{1}$ or x.xx:1

3. Based on the background information about neutron-proton ratios and nuclear size, highlight the stable isotopes in the data table.
4. Locate each isotope on the band of stability chart to confirm your decision about nuclear stability. For isotopes that decay, identify whether the nucleus decays by alpha or beta decay. Record the decay type in the chart.
5. For the isotopes that decay, write a balanced nuclear reaction.

Isotope	Neutrons	Protons	$n^0:p^+$	Decay Type
Aluminum-27				
Bromine - 82				
Francium-211				
Iron-56				
Lead-214				
Platinum-175				
Iodine-131				
Radium-226				
Silver-108				
Carbon-14				
Thorium- 234				
Uranium-233				

Continued on the next page.

Band of Stability



Source: Wikimedia Commons. Table isotopes en.svg.

Link to: https://commons.wikimedia.org/wiki/File:Table_isotopes_en.svg#/media/File:Table_isotopes_en.svg

Continued on the next page.

Balanced Nuclear Reactions

Analysis and Discussion

1. Construct a process diagram or flow chart that serves as a model for identifying unstable isotopes and the method by which they decay.

2. Your teacher will assign you a medical isotope. Use your model to determine if the isotope is stable or unstable, and if unstable, how it will decay. Write the balanced nuclear equation for the decay of the isotope.