Introduction:

Isotopes are atoms of the same element that differ in their numbers of neutrons. The neutrons are contained in the nucleus of the atom along with protons. By definition, two isotopes of the same element must contain the same number of protons in their nuclei. Only the neutrons differ. Protons and neutrons, each with a mass of approximately 1 atomic mass unit (amu), are much more massive than electrons. The mass number of the atom is defined as the number of protons plus the number of neutrons. Electrons are not accounted for because they have so little mass. Isotopes must have different mass numbers and therefore also different masses because of the different numbers of neutrons. For example, there are three different isotopes of carbon atoms: carbon-12, carbon-13, and carbon-14. Each type has 6 protons, but the numbers of neutrons are 6, 7, and 8 respectively. Their masses also differ, and are approximately 12 amu, 13 amu, and 14 amu. It is important to understand that despite the difference in mass, all isotopes of a single element are chemically alike! The number of protons and electrons are the same, and it is the number of electrons that primarily determine the chemical behavior of the elements.

Most chemical elements consist of mixtures of isotopes. The atomic mass values recorded on the Periodic Table are derived by using the concept of weighted averages. In this experiment, you will simulate one way that scientists can determine the relative amounts of different isotopes present in a sample of an element.

On April 2, 1792, Congress established the United States Mint and began to produce copper pennies. In 1982, with inflation, the copper in the penny cost more than a penny was worth. So the United States Mint began to produce pennies that contained a zinc core. Now there are two “isotopes” of pennies in circulation, each having a different mass but still considered a penny. With imagination, you can consider the US penny as a new “element” – “pennium.” For our imaginary element “pennium” we will use a mixture of pennies from pre-1982 and post-1982. These pennies have different compositions, and therefore different masses. These will represent the two isotopes of “pennium” in our mixture.

When the atomic mass of an element is reported, it is actually an average of all the isotopes that exist for that element. Similarly, a mixture of pre-1982 and post-1982 pennies must have an average mass in between the mass of either type of penny. Exactly what the mass is will depend on the relative amounts of the isotopes. Some isotopes are more common in nature and are said to have a higher “natural abundance”. When the amount of one isotope is expressed as a percent of the total atoms of that type, it is known as a “percent abundance.” In this lab you will work “backwards.” You will measure the mass of a sample of a mixture of ten of the pennies, but you will not be able to look at them. From this
Percent Abundance Lab: Isotopes of Pennium

mass, you will estimate and/or calculate the abundance (how many) of each penny is in your sample. You will take a sealed container containing a mixture of pre-1982 and post-1982 pennies. Your container could contain any combination of the two "isotopes." Your task is to determine the isotope composition of the element pennium without opening the sealed container.

The relationships can be represented mathematically by the following equality.

- The container will contain 10 pennies of an unknown mixture.
- Let \( x \) = the number of pre-1982 pennies in the container.
- Then, \( 10 - x \) = number of post-1982 pennies in the container.

We can write the relationship as:

\[
\text{Total mass of mixture of pennies} = \ (x)(\text{average mass of pre-82 penny}) + (10 - x)(\text{average mass of post-82 penny})
\]

**Purpose:**

To determine the percent abundance of an element “pennium.”
To become familiar with the ideas of isotopes and relative abundance.
To understand how an average atomic mass can be used to determine relative abundance.

**Materials:**

- Container with pennies
- Electronic Balance
- 5 pre-1982 pennies
- 5 post-1982 pennies

**Procedure:**

1. Determine the mass of 5 pre-’82 pennies. Record the mass.
2. Determine the mass of 5 post-’82 pennies and record the mass.
3. Obtain a sample of the element “pennium” from your instructor. Be sure the container is kept closed during the experiment! Record the mass of the container.
4. Determine the mass of the container and your sample of the “element.” Record the mass in the data table.
Percent Abundance Lab: Isotopes of Pennium

Data Table:

<table>
<thead>
<tr>
<th>Title of Data: _____________________________________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown container # ____________________</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Items Measured</th>
<th>Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of 5 pre-'82 pennies</td>
<td></td>
</tr>
<tr>
<td>Mass of 5 post-'82 pennies</td>
<td></td>
</tr>
<tr>
<td>Mass of container</td>
<td></td>
</tr>
<tr>
<td>Mass of container + “pennium”</td>
<td></td>
</tr>
</tbody>
</table>

Calculations:

1. Find the total mass of the pennies in the container by subtracting the mass of the empty container.

2. Find the average mass of a pre 1982 penny and a post 1982 penny.

<table>
<thead>
<tr>
<th>Calculated Values</th>
<th>Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average mass of pre-'82 penny</td>
<td></td>
</tr>
<tr>
<td>Average mass of post-'82 penny</td>
<td></td>
</tr>
<tr>
<td>Mass of Pennium in container</td>
<td></td>
</tr>
</tbody>
</table>

3. Calculate the value of \( x \) (the number of pre-1982 pennies) and \( 10 - x \) (the number of post-1982 pennies). Use the formula given in the introduction. Remember, do the multiplication, combine like terms, and solve for \( x \).

Because we are using rounded numbers, the answer will not be a whole number. Remember that like atoms, we are using whole pennies, so round your answers for \( x \) and \( 10 - x \) to the nearest whole number.
Percent Abundance Lab: Isotopes of Pennium

Pre-Lab Requirements: Read the lab handout carefully. The following items are needed in your composition notebook.

Title of Lab
Summary of introduction
Purpose
Summary of procedure
Data Tables copied into notebook

And answer the following Pre-lab questions. Answer in complete sentences where appropriate.

1. What measurable property distinguishes a pre-’82 penny from a post-’82 penny?

2. Why is the element “pennium” a good analogy for actual element isotopes?

3. How will you determine the mass of each “isotope?”

Post lab Questions:
1. How many pre-’82 pennies are in your container? How many post-’82 pennies are present?

2. What is the average atomic mass of your pennium? (Divide the mass of the your ten pennies by 10). The average atomic mass is always closest to the more abundant isotope. Does this value agree with the results that you found?

3. Use the mass of carbon found on the Periodic Table to help you answer this question. Which isotope of carbon is most abundant in nature, carbon-12, carbon-13, or carbon-14? How do you know?