Lab 03.3a
Isotopes & Atomic Mass

Chemistry I/H

BACKGROUND

Measuring the mass of elements is a process complicated by the fact that most elements are composed of multiple isotopes of the element. For example, zinc exists as five separate isotopes: zinc-64, zinc-66, zinc-67, zinc-68, and zinc-70. The numbers attached to these names are the mass numbers (protons + neutrons) of each individual isotope. Mass numbers represented this way are not the precise mass of the isotope but are usually pretty close. Electrons don't significantly impact the mass of the isotope and are usually excluded in determining isotopic mass (mass number).

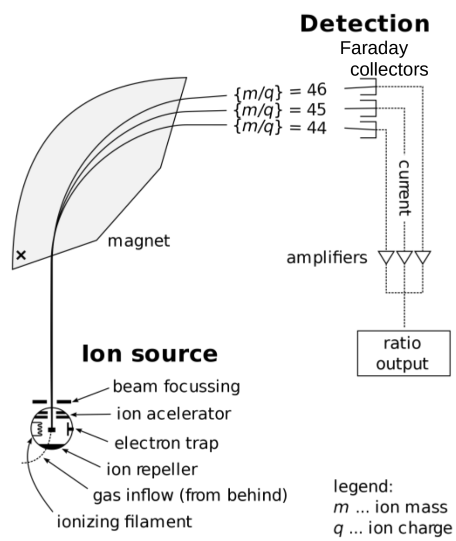
Since a chemical sample of an element consists of billions upon billions of atoms of the element, the sample will contain a mixture of all of these isotopes. The amount of each isotope is its 'fractional abundance' or 'natural abundance'.

The atomic weight (or relative atomic mass) applies to the element in general – accounting for all the isotopes and the relative abundance of each isotope found in nature. Relative atomic mass is based on the mass of carbon-12 (carbon-12 is assigned a mass of exactly 12 atomic mass units (*u*)). This mass, which is the mass represented on the periodic table, may change on occasion as the abundance of elements is more precisely determined.

Mass Spectrometry

Mass spectrometry (MS) is the technique currently used to identify the mass and abundance of different isotopes so that the relative atomic mass may be calculated.

- The sample to be analyzed is ionized by bombarding it with electrons to create a positive ion (negative ion spectrometry is a thing, but not common).
- These charged particles are accelerated so that they have all have the same kinetic energy.
- As they leave the accelerator, the particles enter a curved tube and are separated by applying a magnetic or electrical field. Particles with the same mass-to-charge ratio will experience similar deflection.
- The amount of deflection is measured as the particles strike a detection plate at the end of the tube. (Picture two cars, one large and one small, moving the same speed as they take a corner on a racetrack. The heavier car will swing wider as it tries to navigate the corner, thereby creating separation between the cars.)
- The deflection can be related to a standard, like carbon-12, to determine the mass of the different isotopes. The relative number of particles striking the detection-plate at each point determines the abundance of each isotope.



Calculating Relative Atomic Mass

The calculation of the relative atomic mass is simply a calculation of the weighted average mass of the isotopes based on their fractional abundances. Each isotope (a, b, c in the example below) has a specific mass contribution that may be calculated by multiplying its mass by its fractional abundance:

$$\text{Relative atomic mass} = (\text{mass}_a \bullet \text{abundance}_a) + (\text{mass}_b \bullet \text{abundance}_b) + (\text{mass}_c \bullet \text{abundance}_c) \ldots$$

Safety

- There are no particular safety recommendations for this lab.
- Wash hands with soap and water before leaving the laboratory.

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I. PURPOSE

To replicate the method used to determine atomic mass using a fictional element – ‘pennium’ (Pe).

II. MATERIALS

1. 20 penny sample
2. Electronic balance

III. PROCEDURES

1. Count the pennies to verify that the sample contains twenty (20). Determine and record the combined mass of the twenty pennies.
2. Find the mass of each penny separately and record it in the data table, along with the year the penny was minted. Record masses to the nearest 0.01 g.
3. Return all twenty pennies to their original container and return to instructor.
4. Based on the mass of each penny, assign it to either isotope ‘X’ or ‘Y’. X’s should have similar masses. Y’s should have similar masses. Each penny must be assigned to one group or the other. Note the group in the data table.

IV. PRE-LAB QUESTIONS

1. How are pennies like atoms of an element?
2. What are the independent and dependent variables in the experiment?
3. How are isotopes of a particular element alike? How are they different?
4. How will fractional abundance be calculated given that you are working with 20 pennies in your sample?

V. DATA & CALCULATIONS

A. DATA

Mass of 20 penny sample: __________g

Data Table 1 – Mass of Individual Pennies			
Penny	Year Minted	Mass (g)	Isotope (Y or X)
1			
2			
3			
add rows for 20 samples			

B. CALCULATIONS

1. Calculate the fractional abundance of each isotope.
2. Calculate the average atomic mass of each isotope.
3. Using the fractional abundance and the average atomic mass of each isotope, calculate the atomic mass of the pennium (Pe) sample.
4. Assume the weighted average mass of pennium is 2.61g. What is the fractional abundance of each isotope?

VI. POST-LAB QUESTIONS

1. Why was the collective mass of the twenty pennies not equal to ‘20 x’ the mass of any individual penny?
2. How can you explain the fact that there are two isotopes of ‘pennium’?
3. Why are the atomic masses for most elements not whole numbers?
4. How are the three isotopes of hydrogen (hydrogen-1, hydrogen-2, and hydrogen-3) alike? How are they different?
5. How does the oxidation of pennies (the black copper oxide coating on old pennies) affect the weighted average of the pennies?
6. In 1943, the U.S. printed zinc-coated steel pennies for just one year. The steel penny weighed 2.72 grams. How would the weighted average of the pennies been affected if two pennies of each isotope present in the samples were replaced by steel pennies?

VII. CONCLUSION