1. Counting by Weighing

Objective

Chemists determine how many individual atoms or molecules are in a sample of matter from the *mass* of the sample. This activity will give you some insight into how this can be done.

Introduction

The concept of "counting by weighing" introduced in your textbook may be something new to you. Such an approach is a standard business practice, however, particularly when a business needs to take an inventory of small materials on hand. For example, if a company that makes carpentry nails had to count each individual item in their inventory the situation would be untenable. Rather than having to count each individual nail separately, the mass of a single nail is determined, and then the number of nails present in a bulk sample can be calculated easily. Similarly, in a high-volume "super" drugstore, a prescription for a large number of tablets or capsules of medication may be dispensed by this method.

In this experiment, you will demonstrate the process of "counting by weighing" for yourself using pennies as the item to be counted. This should give you some insight into why we can use average atomic masses in chemical reaction calculations. You will also investigate the effect that the presence of several isotopes has on the average atomic mass of an element.

SAFETY PRECAUTIONS

- **Wear safety glasses at all times while in the laboratory.**

Apparatus/Reagents Required

25 pennies, balance, felt-tip pen

Procedure

A. Counting by Weighing

Obtain 25 pennies. In 1982, the composition of the United States penny coin was changed from one of nearly pure copper to a mostly zinc "sandwich" (the center of the coin is zinc, but the surfaces are layered in copper). Separate the pennies into two piles: those that have dates through 1981, and those that have dates 1983 and following. Since pennies minted in 1982 may be of either type, set aside any such pennies and do not use them in the rest of the experiment.

With a felt-tip pen, number each of the remaining pennies so that you can identify them.

1. Pre-1982 Pennies

Weigh each of the pre-1982 pennies (to the nearest 0.01 g) and record the masses on the data page.

Calculate the average mass of your pre-1982 pennies.

To get a truly representative sample, it would be useful if all the students in the laboratory combined their data on the average mass of the pre-1982 pennies. On the chalkboard of the laboratory, write your name, the average mass you determined for the pre-1982 pennies, and the number of pre-1982 pennies you used.

When all the students in the class have recorded their average masses on the chalkboard, your instructor will demonstrate how to calculate the average mass of the pre-1982 penny using everyone's data. Record this average mass on the data page.

Based on the average mass of the pre-1982 penny as determined from all the students' data, what would be the mass of 55 pennies? How many pre-1982 pennies are contained in a pile of pennies that has a total mass of 310. g?

2. Post-1982 Pennies

You separated the pennies into two groups above, based on their date of minting, and then determined the average mass of the pre-1982 pennies only. Although there may have been minor variations in the masses of the pre-1982 pennies due to different degrees of wear and tear, you should have found that most of the pennies had virtually the same mass. Post-1982 pennies, however, have masses that are considerably less.

Weigh each of your post-1982 pennies and record the masses on the data page.

Calculate the average mass of your post-1982 pennies.

On the chalkboard, write your name, the average mass of your post-1982 pennies, and the number of post-1982 pennies you used. After all the students in the lab have contributed their data on the post-1982 pennies, calculate the overall average mass of a post-1982 penny using all students' data.

Based on the average mass of the post-1982 penny, what would be the mass of 75 such pennies? How many such pennies would be contained in a pile of post-1982 pennies having a total mass of 250. g?

B. Effect of Isotopes on Average Atomic Masses

You have learned that most elements have several isotopic forms. The various isotopes of an element all have the same number of protons and electrons (so they are chemically the same), but differ in the number of neutrons present in the nucleus (which may result in slightly different physical properties).

You have also discussed how the average atomic mass listed for a particular element on the periodic table represents a weighted average of the masses of all the isotopes of the element. By "weighted average", we mean that the relative abundance of the different isotopes of the element is reflected in the average atomic mass.

You can see what we mean by "weighted average" using the data you have collected for the pennies in Parts A.1. and A.2. above.

Using the individual masses of all the pennies (both pre- and post-1982), calculate the average mass of a penny (without regard to its minting date). Record.

You can arrive at the same average mass by another method of calculation, using the average mass you calculated for each type of penny, rather than the individual masses of all the pennies. Consider the following example:

A student has 5 pennies of average mass 3.11 g and 19 pennies of average mass 2.49 g. The weighted average mass of these 24 pennies is given by

$$[5(3.11\ \text{g}) + 19(2.49\ \text{g})]/24 = [15.55\ \text{g} + 47.31\ \text{g}]/24 = 2.62\ \text{g}$$

The weighted average mass (2.62 g) is closer to 2.49 g than it is to 3.11 g because there were more pennies of the lower mass present in the sample: the weighted average has included the relative abundance of the two types of pennies.

Using the method outlined in the example above, calculate the weighted average mass of a penny. Record this average mass both on the data page and on the chalkboard.

How do the average masses reported by the students in your class compare? Are there significant differences in the average masses reported, or are they all comparable?

Counting by Weighing

Date: ..... Student name: .....

Course: ..... Team members: .....

Section: .....

Instructor: .....

Prelaboratory Questions

1. The concept of "counting by weighing" as described in your textbook is often a difficult one for students to appreciate. Describe in your own terms what is meant by this idea.

2. Give a mathematical example of how "counting by weighing" might be used in everyday life.

3. Give an example of how "counting by weighing" is used by chemists in studying chemical reactions.

Counting by Weighing

Date: ..... Student name: .....

Course: ..... Team members: .....

Section: .....

Instructor: .....

Results/Observations

A. Counting by Weighing

1. Pre-1982 Pennies

Number	*Mass*	*Number*	*Mass*	*Number*	*Mass*

Average mass of your pre-1982 pennies .....

Class average mass of pre-1982 pennies .....

Mass of 55 pre-1982 pennies .....

Number of pre-1982 pennies present in total mass of 310. g .....

2. Post-1982 pennies

Number	*Mass*	*Number*	*Mass*	*Number*	*Mass*

Average mass of your post-1982 pennies .....

Class average mass of post-1982 pennies .....

Mass of 75 post-1982 pennies .....

Number of post-1982 pennies present in total mass of 250. g .....

B. Effect of Isotopes on Average Atomic Masses

Average mass of a penny based on average of individual masses .....

Average mass of a penny based on "weighted average" method .....

Questions

1. How do the average masses of a penny reported by your classmates compare to your own average mass? Are there significant differences in the average masses reported, or are they all comparable? What factor(s) might account for *differences* in the average masses reported by your classmates?

2. The element boron consists primarily of two isotopes. Use a handbook to look up the exact masses and relative abundances of these two isotopes, and show how the average atomic mass of boron would be calculated from this data.