NATIONAL CENTER FOR CASE STUDY TEACHING IN SCIENCE

Is It a Meteorite?

Applying Problem-Solving Strategy to Mass Spectra and Atomic Mass

by
Maryuri Roca
Chemistry Department
Skidmore College, Saratoga Springs, NY

Part I – Introduction

Some years ago, a Missouri farmer found a rare meteorite. The news media went crazy announcing the discovery when the meteorite was appraised for more than three million dollars. Since then, Dan was obsessed with finding a rock from space to change his life.

"I'll help you with that once I get rich," was Dan's declaration to anyone in need, no matter if they were friend or strange to him. Dan was a selfless old man who had encountered many adversities during his life; he had gone down many times, but he had never lost his faith. Yes, Dan was a dreamer, but somehow he was certain that a shooting star was going to change his luck.

Tracy, who had known Dan for many years, was keenly aware of his friend's naïveté, and it was Tracy's quantitative and inquisitive nature that protected Dan from heartless scammers. Tracy was an amateur meteorite collector; intrigued by their rarity, he looked at meteorites for their historical and scientific value. Regardless of the reason, both friends wanted to find a meteor; and together they bought an old farm only because it had once been hit by a meteor shower.

But when they arrived at the farm, they thought the meteorites fell days and not decades ago. Holes had been dug all around the land, and heaps of soil were too many to count. Tracy was not encouraged by what he saw; if there was ever a meteorite here, the person who made all those holes would have found it. On the contrary, Dan was happy because half the work was already done.

Although Dan was eager to get into the dirt, Tracy forced him to get in the rundown farmhouse in order to make a plan. Tracy's intention was to make a map of the area, but while looking for a piece of paper to draw the map, Dan found many disintegrating pieces of paper that looked like invoices. One handwritten fragment caught Tracy's interest. It described the chemical treatment of a green rock.

> 1.000 g of green rock boiled with acid then decanted → black sediment + green liquid
>
> Black sediment dried and weighed → 0.832 g
>
> Green liquid separated (chromatography) → two liquid fractions
>
> Fractions reduced (heated H_2) → solids formed → Solid #1 = 0.144 g + Solid #2 = 0.015 g
>
> Solids analyzed (Mass Spectrometry) → MS spectrum #1 + MS spectrum #2

It appeared that a long time ago someone found a green rock and tried to analyze it. At the end, two elements were isolated and analyzed via mass spectrometry. Tracy had in his hands the mass spectra of the elements from the green rock. Was the rock a meteorite? Could there be more in the yard? Where they going to be rich? ... only if Tracy knew how to read the mass spectra.

Task

Before next class watch the following brief video that explains how a mass spectrometer works and then answer the questions below.

Video

- *The Mass Spectrometer*, 2:43 min, uploaded 2012 by Evagating, at: <https://youtu.be/EzvQzImBuq8>

Questions

1. In a mass spectrum, where all particles have the same charge, the X axis indicates
   a. Mass of the particles
   b. Abundance of the particles
   c. Geometry of the particles
   d. Geological source of the particles

2. In a mass spectrum, where all particles have the same charge, the Y axis indicates
   a. Mass of the particles
   b. Abundance of the particles
   c. Geometry of the particles
   d. Geological source of the particles

3. All atoms of an element have the same number of protons but can have different masses; why?

Part II – Problem-Solving

Each solid formed in the chemical treatment of the green rock is a pure element. The following (Figure 1) is a clean reproduction of the mass spectra found by Tracy.

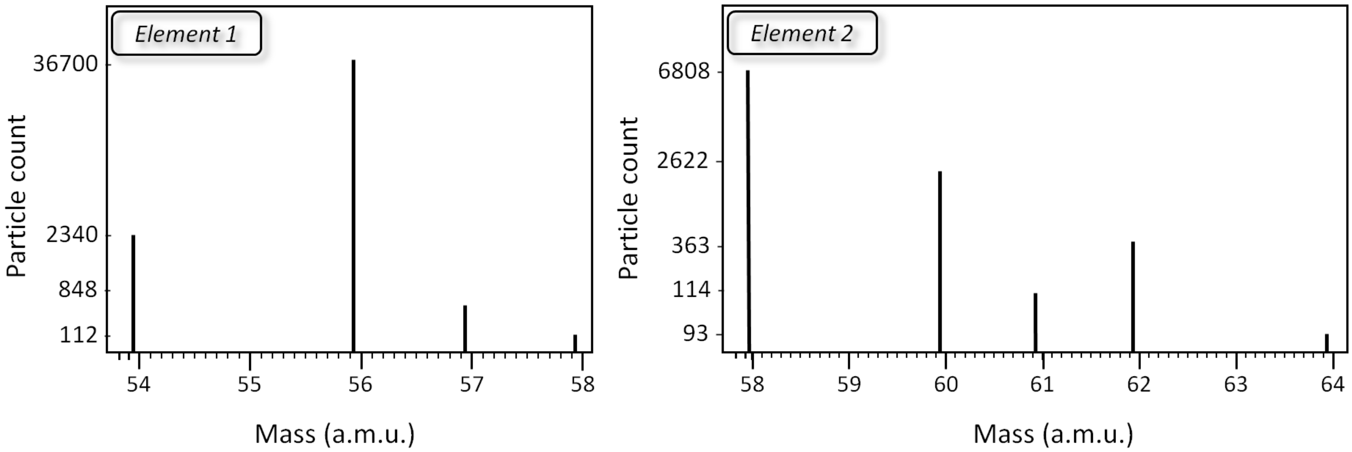


Figure 1. Mass spectra for solid #1 (Element 1) and solid #2 (Element 2).

Use the problem-solving approach described below. Each of the five stages will require you to write something down. At the end of the process, you will identify the elements from their mass spectra in Figure 1.

Stage I: Think About the Answer
Think about what your answer should look like, then think about a strategy to obtain it. Describe your strategy.

Stage II: Examine the Data
Examine the data provided and think about the relations that may be needed to apply your strategy. *Hint:* Summarize the information from the graphs into tables.

Element 1

Element 2

Stage III: Make a Detailed Plan

Write detailed steps (Step 1, Step 2, etc.) to take in order to solve the problem. If necessary, gather information that is needed but not provided in the problem (e.g., conversion factors, equations, periodic table).

Step 1:

Stage IV: Crunch the Numbers

Solve the problem following your steps. Keep record of significant figures and units.

Step 1:

Stage V: Check the Answer

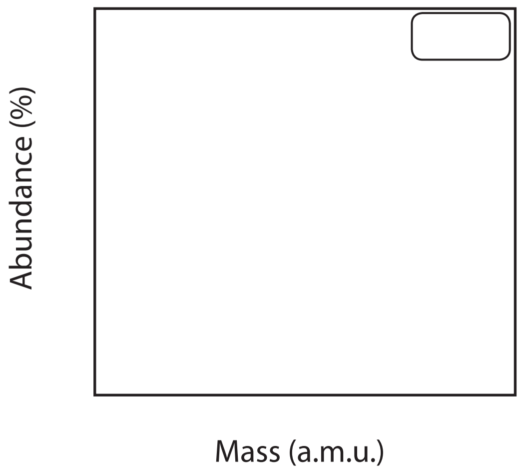
Explain why your answer makes sense:

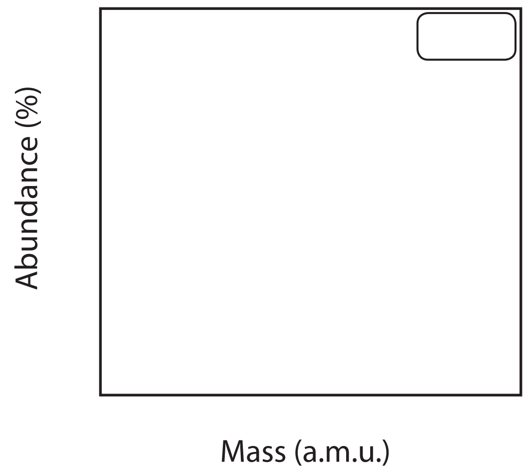
Part III – Assessment

Questions

1. What is the identity of Elements 1 and 2 in the green rock? ______________________________

2. In the graphs below, sketch the mass spectrum for each element; write the symbol of the isotope above each spectral line.





3. Although nickel has a higher atomic number than cobalt, nickel's atomic mass is less than that of cobalt. Why?

4. *(Optional)* Is this rock a meteorite or a meteorwrong? (*Hint:* look at the metal composition of FeNi meteorites; http://meteorites.wustl.edu/id/metal.htm.)