The Sun and Solar Wind: A Search for the Beginning

MASS, MASS – Who has the MASS? Analyzing Tiny Samples

TEACHER GUIDE

BACKGROUND INFORMATION

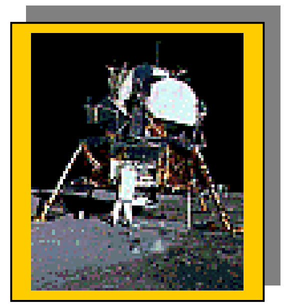

Photo courtesy of NASA

In these activities students ultimately will learn about the analysis technique called mass spectrometry. They will use their knowledge to determine the isotopic composition of solar wind material that was collected on the moon during the Apollo missions. On the way to developing an understanding of mass spectrometry, it is necessary to develop a clear picture of isotopic masses in the minds of the students.

In the first activity of "Mass, Mass-Who has the Mass?" the students pursue an experimental activity that models isotopic masses and some of the subtle points surrounding them. The students are challenged to think carefully about the basic building blocks of nature as they model them. They will develop a clear understanding of what is meant by "atomic weight" and how averages come into play in determining atomic weights. The mathematical concept of a weighted average is introduced. They will discover why atomic weights of the elements seldom are simple integers. They will also learn how isotopic masses are determined and how these ideas about isotopic mass connect to the real world of identifying unknown elemental substances. This section will set the stage for the next activity in which the students analyze some simple mass spectroscopic data pertaining to isotopes.

In the second activity, the students begin with learning the fundamentals of mass spectrometer operation. They are challenged to analyze the results of a mass spectrometric experiment conducted on actual solar wind material that was collected in space. Initially they are directed to find and interpret isotopic data. Then, based on the data they locate, they are asked to construct a simulated mass spectrum. As part of this exercise they will think about percentages and deal with the concept of relative amounts of matter in a sample. Following this, they will be led into the interpretation of simple isotopic mass spectra and the analysis of a mixture by mass spectroscopic techniques. Finally, they are asked to analyze the mass spectrum of solar wind material. Following the activity, classroom discussion is focused on extending the concept of mass spectrometry.

Appendix B contains useful background material entitled "Mass Spectrometry: A Historic Technique for Analysis of Great Importance to Genesis." The material in this appendix can either be copied for student use or incorporated into the background that you give your students during classroom discussions.

STANDARDS ADDRESSED

Grades 5-8

Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Science and Technology
- Understandings about science and technology

Physical Science
- Structure and changes in properties of matter
- Transfer of energy

History and Nature of Science
- Science as a human endeavor
- Nature of science and scientific knowledge
- History of science and historical perspectives

Grades 9-12

Science as Inquiry

Abilities necessary to do scientific inquiry
Understandings about scientific inquiry

Science and Technology

Understandings about science and technology

Earth and Space Science

The origin and evolution of the Earth system
The origin and evolution of the universe

Physical Science

Structure and changes in properties of matter
Transfer of energy
Structure of atoms

History and Nature of Science

Science as a human endeavor
Nature of science and scientific knowledge
History of science and historical perspectives

MATERIALS

For each student

A calculator
Copy of Student Activity #1 "Analyzing Tiny Samples of Heavy Elements"
Copy of Student Text "Atoms, Elements, and Isotopes," from Cosmic Chemistry: An Elemental Question

For each pair of students

Copy of the Record/Data Sheet
A balance capable of measuring masses to the nearest 0.1 gram.
[*If a better balance than this is used, have the students round their measurements to the nearest 0.1 gram.*]

In addition:

For PART 1: Provide each pair of students with a penny, a nickel, a dime, and a quarter. Each coin should have a sticky label attached to the coin's face that changes its identity to a new, superheavy "element." Label the penny, nickel, dime, and quarter with the symbols: ^{1}Pn, ^{1}Nik, ^{1}Di, and ^{1}Q, respectively. [*HINT: Avoid using worn coins.*]

For PART 2: Provide each pair of students with additional coins that have been glued together to make sets as follows:
Five pennies
Two nickels
Three nickels
Each set should again have a sticky label attached to indicate the identity of the "element" and labeled as follows: ^{5}Pn, ^{2}Nik, and ^{3}Nik.

For PART 3: Provide each pair of students with additional coins that have been glued together to make sets as follows:
Two sets containing two dimes
One set containing four dimes
[*Use Superglue® if you plan to keep the sets for further use; otherwise use a water soluble glue so that the coins can be used as legal tender after the activity.*]

Alternative Teaching Tip

You may use pieces of unbreakable laboratory equipment, such as washers, cork, or rubber stoppers in place of actual coins. Equipment should be checked for equivalent masses and be used in the same multiples as the coins.

PROCEDURE

1. Before class:
   a) make copies of the Student Activity #1 “Analyzing Tiny Samples of Heavy Elements” and the Reporting/Data Sheets #1 and #2; and,
   b) prepare a data table on the board, on newsprint, or on an overhead transparency for teams to report the results of their experimentation.

2. Group the class into pairs and tell them that one member of each pair is a brilliant scientist and the other is a fairly smart robot who works in the scientist’s laboratory. Make it clear that the robot has some ability to think, that it can talk and follow instructions, but that it can only do mechanical things such as grasping objects and moving them from place to place. Have them designate who will be the scientist and who will be the robot at this time.

3. Continue with the scenario. Tell them that the scientist has been temporarily blinded in an unfortunate accident and that his/her hands are bandaged so that the robot must initially do all of the laboratory work.

4. For PART 1, give each pair of students a $.01, $.05, $.10 and $.25 coin. Continue the scenario by telling them that you (or a space alien), have transformed the coins into individual atoms of new superheavy elements having the symbols Pn, Nik, Di, and Q, respectively. Each coin has a sticky label attached that changes its specific identity to ^{1}Pn, ^{1}Nik, ^{1}Di, or ^{1}Q.

5. Hand out a copy of the instructions for Part 1 of the Student Activity and the Reporting/Data Sheet #1 to each pair of students. Tell them to start at the top of the instruction sheet and to work their way step-by-step through Part I. Have them record data on the sheet provided.

Alternative Strategies Tip

To emphasize the point of this activity, blindfold the “scientists” and have them wear gloves or socks on their hands.

6. As the teams complete Part I, hand out copies of the remainder of the instructions and Reporting/Data Sheet #2. Tell them that the scientist has now recovered fully from the accident and has regained his/her sight and sense of touch so that the scientist and the robot can work together on making the remaining measurements. Give each pair of students the packets of pennies and nickels that have been glued together for PART 2. Have them work their way through Part 2, recording their results on Reporting/Data Sheet #2.

7. For PART 3 give the students the remaining sets of dimes that have been glued together. They should complete the rest of the activity. They should report their results on their Reporting/Data Sheets and on the board, newsprint, or overhead on the table that you have prepared.

8. When they have completed the entire assignment, bring them back together for a general class discussion of averages (means) and weighted averages. Ask questions similar to the following to test their understanding of the model. Sample questions are:
   a) What was the significance of the fact that, in Part 1, the scientist could neither touch or see the new superheavy elements?
   b) What methods did you use to complete Part 1 of the activity to overcome the scientists’ lack of ability to touch and see the new superheavy elements? Do you think your method was successful? If not, why?

9. Use questions like the following to introduce them to, or to review the concept of, isotopes:
   a) How do your results compare with those of other groups that are reported on the board, newsprint, or the overhead? How are your findings with the new elements Pn, Nik, Di, and Q relevant to the real elements in the periodic table of the elements?
   b) How do the masses measured for your superheavy elements actually compare to the masses of real atoms?
   c) Why are the atomic masses of some elements, such as fluorine (atomic mass =18.998), very nearly whole numbers, whereas the atomic masses of other elements, such as chlorine (atomic mass = 35.453) are far from being whole numbers?

10. Handout copies of the Student Text, "Atoms, Elements, and Isotopes," from Cosmic Chemistry: An Elemental Question for students to read before the next class. Have students review the material in Appendix B, "Mass Spectrometry."

11. Start the next period's class discussion with questions like the following:

    a) What are atomic weights and how do the measurements you made for the new superheavy elements in this activity resemble real atomic weights?
    b) If the superheavy elements were listed in the periodic table, what atomic weight would appear for each element along with its atomic number?
    c) What are isotopes?
    d) Do all elements have the same number of isotopes?
    e) Do isotopes of a given element behave the same chemically?
    f) What kinds of measurement(s) do we need to make to distinguish one isotope from another?
    g) If a given element has more than one isotope, do these isotopes occur naturally in the same proportion?
    h) Do all isotopes of a given element occur naturally?
    i) Are isotopes radioactive?
    j) What element has isotopes that show the greatest percentage increase in mass in going from one isotope to the next?
    k) What are the most important isotopes found in the sun?
    l) Based only on the information gathered in this activity, which superheavy element—Pn, Nik, Di, or Q—is more like fluorine?
    m) What role did technology play in distinguishing among the new superheavy elements?
    n) What properties other than mass (atomic weight) might conceivably have been used to distinguish among the new superheavy elements?

TEACHER RESOURCES

SOLAR WIND

http://cass.jsc.nasa.gov/expmoon/Apollo11/A11_Experiments_SWC.html
http://cass.jsc.nasa.gov/expmoon/Apollo14/A14_Experiments_SWC.html
http://cass.jsc.nasa.gov/expmoon/Apollo15/A15_Experiments_SWC.html
http://cass.jsc.nasa.gov/expmoon/Apollo16/A16_Experiments_SWC.html
Solar wind composition experiments—Apollo missions

http://ulysses.jpl.nasa.gov
Ulysses satellite mission—solar wind (Includes general written references on the solar wind)

http://umbra.nascom.nasa.gov/spartan/the_solar_wind.html
Spartan satellite mission— solar wind