GENESIS SEARCH FOR ORIGINS Education

The Sun and Solar Wind: A Search for the Beginning

Analyzing Tiny Samples Using Mass Spectrometry

TEACHER GUIDE

BACKGROUND INFORMATION

Review Background Information in the Teacher's Guide for "Analyzing Tiny Samples." It is necessary for the students to complete Student Activity #1 before attempting this module

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:

Copy of Instructions for Student Activity "Analyzing Tiny Samples"
Copy of Reporting/Data Sheet for Student Activity "Analyzing Tiny Samples Using Mass Spectrometry"
Copy of Student Text "Solar Wind"
Copy of Appendix B "Mass Spectrometry"

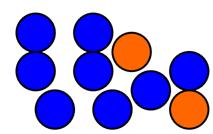
PROCEDURE

1. Before class make copies of the Student Activity Instructions and the Reporting/Data Sheet. Hand out copies of Appendix B for the students' reading assignment (if this was not done previously in the module).

2. Prior to beginning the activity, use questions to:

   Make sure that the students know that a histogram is essentially the same as a bar graph, so that they will not be confused by the wording in the activity, where the term histogram is used exclusively.

   Review the symbolism that is used for isotopes, especially that the left superscript attached to an element's symbol is the isotope's mass number. Make sure they understand that the actual mass of an isotope in amu (or Daltons) is not the same as the mass number, although the two will be numerically close.

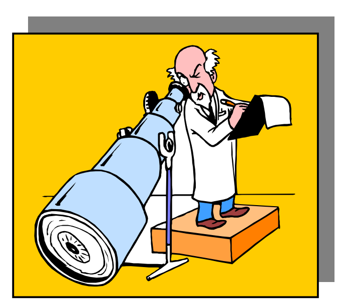
   Review, if necessary, the concept of percent and stress the idea that it is parts per one-hundred. Make sure they understand that if we have 100 marbles, of which twenty are red and eighty are blue, the percentage of red marbles is 20%, *i.e.,* twenty parts per 100. Likewise if we have only forty marbles and eight of them are red, we still have 20% red marbles, because if we scale up to 100 marbles (40 x 2.5), we proportionately have 20 red marbles (8 x 2.5).

3. Use questions to determine whether or not the students have read Appendix B and to discern if they understand the general principles of mass spectrometry. They should understand that mass spectral intensity is a measure of the number of ions of a given type. Also, they should remember that for the elements, percent natural abundance is a measure of the number of atoms of a given isotopic type as the element occurs in nature on Earth.

4. For the class, carefully distinguish the difference between abundance of the elements and relative abundance of the elements. Relative abundance is determined from natural abundance by proportionately scaling each natural abundance to the most abundant natural abundance (usually). For example, if we consider the two major isotopes of neon, neon-20 and neon-22, which have natural abundances of 90.48% and 9.25% respectively, their relative abundances are (90.48/90.48) and (9.25/90.48). Frequently it is convenient to multiply these relative abundances by another arbitrary scaling factor, such as 1000. If we do this here, the result would say that for every 1000 atoms of neon-20, there are 102 atoms of neon-22.

5. Use questions to make sure that the students understand the following relation: relative abundance compares numbers of isotopic atoms of a given mass, and in a mass spectrum relative intensity is a measure of numbers of atoms having a given mass. Therefore, we can use relative abundance as a measure of relative intensity when dealing with the mass spectra of isotopes. The scaling factor in this case usually is 100.

6. Set the scenario by telling the students that:
   a. They have been hired as a technician in a mass spectrometry laboratory and that they are fast learners. As time passes they quickly become more and more experienced in the field of mass spectrometry, as evidenced by their ability to solve increasingly more difficult problems. Ultimately they become the laboratory director and analyze an actual mass spectrum of material collected from the solar wind.
   b. They will have access to reference materials and Internet addresses that are appropriate for this activity. These largely are materials dealing with isotopic composition of the elements.



c. They are to assume that all of the spectra in this activity are to be considered low resolution, *i.e.,* the mass spectrometer can measure masses only to plus or minus 1 amu.

7. After the class has finished the activity, engage them in a discussion that centers on the following:
   a. Would a mass spectrum containing only one line suffice to identify an element with absolute confidence? If so, what would have to be true? This discussion can be carried on to inquire about how many lines the class thinks they would have to observe in a general case in order to identify an element. It would be appropriate to point out that the simulations in this activity are of low resolution spectra. Pursue the question of how the certainty of isotope identification could be improved by using an instrument having a resolution that would, for example, provide masses to two decimal places.
   b. Have the class discuss why they think it will be possible to obtain more accurate data for Genesis samples if the analysis was performed here on Earth, rather than by a mass spectrometer sent into space on the Genesis spacecraft.
   c. Challenge the class to consider whether or not a mass spectrometer can be used for both quantitative and qualitative purposes. In other words, how can a mass spectrum be used to determine HOW MUCH of something is present? You might ask them how many atoms of a sample (theoretically) would be required to conduct a mass spectrometric experiment, with the goal of leading them to the conclusion that a mass spectrometer can theoretically analyze for only a few atoms. You might point out that very few atoms of some of the heavy elements such as platinum are expected in the Genesis sample.

For Further Exploration

With high school students enrolled in chemistry or physics, pursue the role of mass spectrometry, using questions like the following:

a. Everything in this activity has focused on elements. Ask the class whether they think a mass spectrometer could be used to investigate molecules such as propane, an insecticide such as malathion, or a mixture of amino acids? Have them speculate about how they think the mass spectrum might look.

b. Should you wish to pursue this topic with the class, have them work out the molecular weights for a series of positively charged (cationic) hydrocarbons having the general formulas $C_nH_{2n+}{}^{1+}$ and then predict how the mass spectra of the hydrocarbons would differ. You might ask them whether or not mass spectroscopy could be used to distinguish between $C_2H_5{}^+$ and CHO^+.

c. Ask the students whether or not isotopic effects would be seen in the mass spectra of molecules.

d. Engage the students in a discussion of how mass spectroscopy might be used in environmental science.

TEACHER RESOURCES

ELECTROMAGNETIC RADIATION/SPECTROSCOPY:

http://www.scimedia.com/chem-ed/ms/ms-intro.htm
A World Wide Web introduction to mass spectrometry

http://www.sisweb.com/cgi-bin/mass10.pl
A Web site on generating mass spectra.