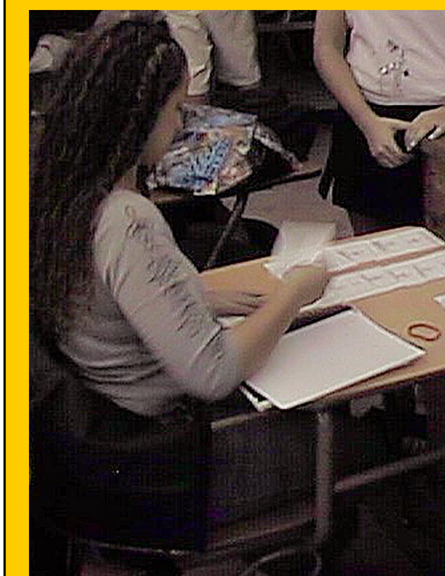
Cosmic Chemistry: Understanding Elements

Making Sense of the Elements

TEACHER GUIDE

BACKGROUND INFORMATION



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The initial concept and development of the periodic table in the 1800s brought us what we know today as the modern periodic table. For decades, the educational approach to student learning of the table has been strict memorization. What if students could learn the periodic table by patterning the same approach that Mendeleev used in the 19th century? This simulation activity is a hands-on approach that is also found in "Exploration of a Problem: Making Sense of the Elements," from the module *Cosmic Chemistry: An Elemental Question.*

"Modeling the Periodic Table" uses a unique questioning and problem-solving approach. Students simulate Mendeleev's initial experiences in organizing the elements based on known physical and chemical properties. Content knowledge and process skills as they relate to the student learning objectives remain fully intact. The focus of the activity is on understanding the element characteristics and families and on how the development of the periodic table exemplifies the use of scientific modeling in our quest for knowledge.

NATIONAL SCIENCE STANDARDS ADDRESSED

Grades 5-8

Science As Inquiry

- Abilities Necessary to do scientific inquiry
- Understandings about scientific inquiry

Physical Science

- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy
- Interactions of matter and energy

Science and Technology

- Understandings about science and technology

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

Physical Science

- Properties and changes of properties in matter

Motions and forces
Transfer of energy
Interactions of matter and energy

Science and Technology

Understandings about science and technology

History and Nature of Science

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

(View a full text of the National Science Education Standards.)

MATERIALS

For each group of three to four students:

- Set of 63 Element Exploration Modeling Cards with information about individual elements that Mendeleev worked with prior to 1870 (See Teaching Tools)
- Set of 3 Element Exploration Modeling Cards with information about elements discovered prior to Mendeleev's 1871 periodic table (See Teaching Tools)
- Overhead of Prediction of Properties of an Unknown Element (See Teaching Tools)
- Copy of the modern periodic table
- Copy of Mendeleev's periodic table
- Student Activity, "Making Sense of the Elements"
- (Optional) "Successful Problem-Solving Process Log"
- (Optional) Album stamps from a music club, or list of albums of various styles

PROCEDURE

1. Remind the class that the approach to solving a problem in science is like solving a jigsaw puzzle. Holes, or missing pieces, can be as informative as known information. Tell them that they may use notes in the process of solving a complex problem that faced early scientists.

2. *Set this scenario:*

> You enter a discount store in search of a CD. It's a new release by your favorite artist. After locating the electronics department, you find that all of the CDs are scattered about on various shelves in no particular order. The clerk tells you, "We have your CD in stock, but I don't know where it is shelved."

How do you find your CD? What are your options?

A similar situation existed among chemists in the mid-nineteenth century. As more and more elements were being discovered, scientists soon found themselves with a lot of data on each individual element, but no real way to make sense of this information. Several scientists came up with different ways to organize the elements, but none of these systems was accepted by all scientists in their work.

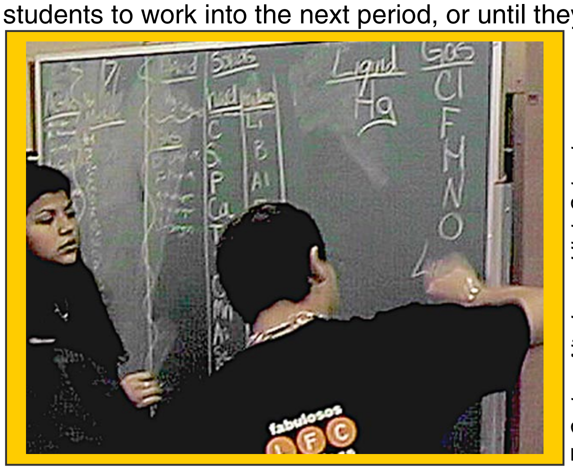
In setting the scenario, students are obviously working on organizing the elements in a different manner, or with different tools than those available to scientists in 1860. Ask them to consider and note some of these differences as they complete the exercise.

3. *Tell students:*

   Your task is to take these cards (*hold up samples of the Element Exploration Modeling Cards)* with information on each element known at that time and try to make some sense out of them. You can sort and organize them any way you wish. Just keep track of what seems to work for you and what doesn't. Write down your ideas for organizing and the results of that organization. During this process, try to think about the logic you are using. If someone says, "Let's try this," ask that person why he/she thinks that it is a good idea. Record the response. There is no right answer here. We are looking for some good thinking in this process of solving a problem. As you complete the activity with your group, make sure you continue to record this type of information as answers to the first question on the Student Activity sheet.

4. Hand out a set of 63 Element Exploration Modeling Cards to each group of students. The ensuing element organization process may take the better part of a period. Be prepared to allow students to work into the next period, or until they are satisfied with their organizational model.

   Ask them to duplicate their organizational system of the elements on a display of their choosing (second question). While creating their display, students should continue recording information relating to their questioning and decision-making on questions one and two.



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5. When all groups are finished, ask them to report to the class. Each group should report how they organized the elements, why they felt this was a successful method, and what problems they still find with the organization. Keep a record on the board or chart paper of the responses, asking students to take notes in their own laboratory notebook. The format could resemble the diagram in Table 1 below, or could be modified to fit your needs and the needs of your students. (See also Teaching Tools, Successful Problem-Solving Process Log*,* for a printable version.)

Alternate Strategy Tip

Tell students:

Working in small groups, write step-by-step instructions to organize the CDs into categories. The directions should be specific so that all the CDs can be classified.

Write definitions and examples for each category of music. Also, your group must decide what to do if some CDs fall into two or more categories.

Using your set of music "stamps," group the stamps under the proper heading with your chosen categories.

Alternate Strategies Tip

You may prefer to supply students with a sheet of posterboard for this activity. Science fair project boards work very nicely. Scissors, laminating supplies (or pre-laminated cards), and glue (or tape, velcro, etc.) to adhere cards to the display will also be helpful. Velcro works well, as it allows students to move and replace elements, altering their design at will.

To emphasize differences between metals and non-metals, start step 4 by handing out only the following cards: Br, I, Li, K. Na, F, Cl, Rb, Cs, As.

After the students have these arranged, discuss metal vs. nonmetal characteristics. Then hand out the remaining 53 cards. Encourage students to see if they fit into the model arrangement they just developed.

Table 1: Successful Problem-Solving Process Log

Student Group	Variable(s) Used	Why Successful	Difficulties
Lab Group One			
Lab Group Two			
Lab Group Three			
Lab Group Four			
Lab Group Five			
Lab Group Six			

6. When all of the groups have finished, ask them to study the information on the posted class log. Examine the list of difficulties and have the students address them as a class. A potential difficulty may be that there are empty spots in the chart. Ask the students what they would predict could go there. Another difficulty may be that not all elements fit this method of organization. Ask students what should be done if some pieces of data do not fit the model that their group is using. Student groups may modify the tool to fit their methods of processing information.

7. Refer students to their notes. Ask them to report on the types of ideas they had for organizing the data early in the process as compared to those approaches that they came up with later in the process.

   Ask them:

   What ideas did you try first? As time went on, did you eliminate some ideas? If so, why? (Responses may center around trying an early idea and eliminating it later because a piece of data didn't fit into the organization. Others may focus on later ideas being refined by what they learned earlier in the process.)

8. *Explain to students:*

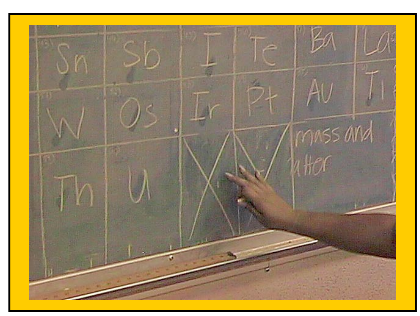
   Scientists often engage in a process of intense study to solve a problem. However, sometimes, the solution comes to them out of the blue. The process may not have worked on this problem, but may fit another problem on which they are working. Scientists and science students need to be open to these kinds of discoveries and applications while solving problems.

9. *Ask students:*

   Did any group have spaces or holes in your element arrangements? (*Give students time to examine their displays and report any holes they left.*)

   Explain to students:

   Mendeleev and other chemists left spaces on their periodic tables because they did not "force" the known elements to fit any preconceived pattern. These holes also allowed them to make predictions of the chemical and physical properties of the undiscovered elements. These predictions guided the search for new elements.



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Address the potential for use of technological and computer programming techniques for assisting with interpolation in other types of data studies. You may allow groups time to process and come up with a few examples per group.

Call students' attention to the element cards that comprise the second group. This group has white text and appears at the end of the tile cards. These elements can be placed on the table where appropriate according to the characteristics of the surrounding elements.

Explain to students:

Mendeleev's earlier periodic table did not include the elements in this new set of tiles: scandium, gallium, and germanium. Mendeleev left holes in his table, indicating the presence of additional elements that had not yet been discovered. He predicted the properties of an element he called ekasilicon, which are close to those of germanium.

Show overhead, Prediction of Properties of an Unknown Element

Alternate Strategy Tip
Examine the modern periodic table's designation of chemical families. (*See teacher background information.*) Students may discuss what known characteristics belong to certain groups of elements. Which elements are anomalous in their families (i.e., liquid bromine and mercury; solid iodine)?

Resource: VideoDiscovery® Chemistry at Work Laserdisc: http://www.videodiscovery.com has a short video clip called "the periodicity of Alkali Metals."

If you were Mendeleev, where would you put these three element tiles (for scandium, gallium, and germanium), in your element display?

Give students time to discuss the addition and placement of these extra cards on their table display.

10. Share copies of the modern periodic table and of Mendeleev's periodic table with students. Compare and contrast both tables with various lab groups' arrangements. Focus on reasons for different interpretations of the same information. Remember, both of these versions of the periodic table are correct. Discuss why one version might be more useful than another.

    If they are available (see Teacher Resources below), show other versions of the periodic table. Discuss why there may be more than one correct way to organize information.

    Explain to students:

    At the time that Mendeleev made his statement of the periodic behavior of the elements, the scientific world did not know about electrons, protons, and neutrons. It wasn't until thirty years after his observations that it became evident that the properties of elements are really related to their atomic number, and that as atomic numbers of elements increase, so do their atomic weights.

    However, since atomic weights also depend on the number of neutrons and protons and the relative abundance of the elements' isotopes, (see teacher background) a few pairs of elements are in a reversed order when arranged by atomic weight compared to an arrangement by atomic number. (For example, Ar atomic number 18 has an atomic mass of 39.948 amu and Potassium atomic number 19 has an atomic mass of 39.0983 amu.)

    Study the copy of today's periodic table and determine which elements would be rearranged if today's table were based on atomic weights rather than atomic numbers. [Possible answers: potassium and argon, tellurium and iodine, thorium and protactinium, uranium and neptunium, plutonium and americium.]

11. Assign and discuss responses to questions 3 and 4 on Student Activity, "Making Sense of the Elements."

12. Ask students to devise a general process for solving a problem. Allow students to return to their groups and think about the most successful way they can approach a problem and solve it. Ask each group to record the steps and write appropriate questions for each step, providing you with a final copy. Each student should keep a copy of the recorded steps and questions to be used in solving other problems.

TEACHER RESOURCES

Periodic Table of Elements

http://c.chem.ualberta.ca/~plambeck/che/p101/p01024.htm
A discussion of the arrangement of the modern periodic table, including a short historical piece on Mendeleev.

http://chemlab.pc.maricopa.edu/periodic/lyrics.html
Lyrics to "The Elements" by Tom Leher.

http://chemlab.pc.maricopa.edu/periodic/spiraltable.html
A periodic table shaped as a spiral.

http://chemlab.pc.maricopa.edu/periodic/stowetable.html
An unusually-shaped periodic table designed for use by physicists.

http://chemlab.pc.maricopa.edu/periodic/triangletable.html
A periodic table shaped as a triangle.

http://hpngp01.kaeri.re.kr/CoN/index.html
Table of the Nuclides from the Korean Atomic Energy Research Institute.

http://wulff.mit.edu/pt/
A series of periodic tables showing, for example, specific heat capacities, densities, thermal conductivity, or electronegativity, in tabular and graphic form.

http://www.chemicalelements.com
An on-line periodic table with links.

http://www.shef.ac.uk/chemistry/web-elements/pdf/periodic-table.html
A modern periodic table that can be printed using Adobe Acrobat Reader.

http://www-tech.mit.edu/chemicool/
An on-line table with background information.

Writings of Mendeleev

http://maple.lemoyne.edu/~guinta/mendel.html
Article by Mendeleev in the Journal of the Chemical Society from 1889 explaining periodicity.

http://maple.lemoyne.edu/~guinta/mendeleev.html
Article (translated from German) by Mendeleev in Zeitschrift fur Chemie from 1869 showing his original table.

Mendeleev

http://nit.spb.su/eng/school/sc470/thinkquest/project2/mend_e.htm
A short biography written in English by Russian schoolchildren provides an interesting perspective.

http://www.chem.ualberta.ca/courses/plambeck/p101.new/p01024.htm
A history of the development of the periodic table, focusing on Mendeleev. Includes description of the modern table.

http://www.cis.lead.org/MUCT/Mendeleyev.html
An interesting short biography.

http://www.woodrow.org/teachers/ci/1992/Mendeleev.html
An extensive biography titled “Ich bin Mendelejeff” and bibliography.

Other

http://www.videodiscovery.com
Video discovery home page, where you can order “Chemistry at Work” laserdisc.