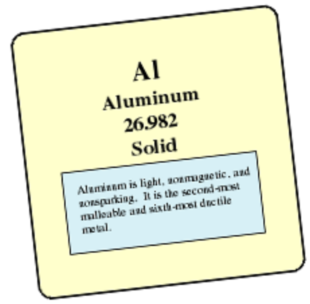
Cosmic Chemistry: An Elemental Question

Exploration of a Problem: Making Sense of the Elements

TEACHER GUIDE

Background Information
This activity uses the questioning and problem solving skills for use with data sets which are missing information as first developed in "The Search for Critical Questions." Students simulate Mendeleev's initial experiences in organizing the elements based on physical and chemical properties.

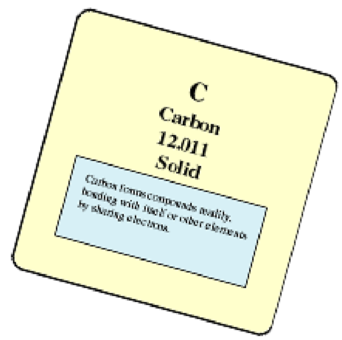


Standard Addressed (Grades 9-12)

Science as Inquiry
- IDENTIFY QUESTIONS AND CONCEPTS THAT GUIDE SCIENTIFIC INVESTIGATIONS
- USE TECHNOLOGY AND MATHEMETICS TO IMPROVE INVESTIGATIONS AND COMMUNICATIONS
- UNDERSTANDING ABOUT SCIENTIFIC INQUIRY

Physical Science
- STRUCTURE AND PROPERTIES OF MATTER

History and Nature of Science
- NATURE OF SCIENTIFIC KNOWLEDGE
- HISTORICAL PERSPECTIVE



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 (See Teaching Tools)
- Copy of Mendeleev's periodic table (See Teaching Tools)
- Student notes of questions and strategies they used in solving the jigsaw puzzle in "The Search for Critical Questions"
- Student Activity, "Exploration of a Problem: Making Sense of the Elements"
- Student Text, "A Historic Overview: Mendeleev and the Periodic Table"
- Student Text, "The Modern Periodic Table"
- (Optional) Copy of "Successful Problem-Solving Process Log" (See Teaching Tools)

Procedure
1. Remind the class of the process they undertook in solving the picture puzzle. Tell them that they may use their notes in the process of solving another more complex problem that faced early scientists.

2. *Set this scenario:*

What if you went into a discount store looking for a recently released CD by your favorite artist? You went to the electronics department and found that all of the CDs had just been put on the shelves in no particular order. "Your CD is here," the sales associate told you, "but I don't know where it is located." How do you find your CD? Do you have other options? (You could go to a store where they are organized by type of music, artist, or producer, etc.)

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 were accepted by all scientists in their work.

Today you will assume that your lab group is a team of scientists in 1860. You know that many of your colleagues are working on a good way of organizing the elements to make sense of their properties. You also know that if you find the best organization scheme, you will go down in history!

Alternate Strategies Tip

If you wish to incorporate more content background on terms students may introduce during this activity, you may use the Student Text, "Atoms, Elements, and Isotopes."

However, as it is important that term-specific content not be introduced out of context, it would be important to give only major highlights of this information this early in the learning cycle.

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.

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.

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.

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

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 they would or should do if not all of the pieces of data fit the model their group is using. Stress to students that their group will be responsible for using a record-keeping mechanism similar to this throughout the *Cosmic Chemistry: An Elemental Question* module, but they may modify the tool to fit their methods of processing information as a group.

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

   Ask them:

   Why did you try certain ideas earlier, yet eliminate them later? (Responses will 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:*

   Sometimes scientists are looking very hard for a particular kind of solution to a problem, but come up with an entirely different way to do it out of the blue. Perhaps the process they are working on doesn't work for this problem but fits another problem they are working on. Scientists and science students need to be open to these kinds of discoveries while solving problems.

9. *Ask students:*

   Did any group have 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.

   Hand out the second group of 3 Element Exploration Modeling Cards.

   Explain to students:

   Mendeleev's earlier periodic table did not include the elements in this new set of cards: 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

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

   Give students time to discuss the addition and placement of these extra cards.

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.

    Examine the modern table's designation of chemical families. What characteristics do students already know belong to certain groups of elements? Which elements are anomalous in their families (e.g., liquid bromine and mercury; solid iodine)?

    If they are available (see Teacher Resources), 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 the atomic weights.

However, since atomic weights also depend on the number of neutrons and protons and the relative abundance of the elements' isotopes, a few pairs of elements are in a reversed order when arranged by atomic weight compared to an arrangement by atomic number.

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. Ask students to read the Student Text, "A Historic Overview: Mendeleev and the Periodic Table." Discuss the reading with them afterward. Highlight the use of the skill of *interpolation* in Mendeleev's work, and discuss the value of interpolation in determining information of which we are indirectly aware from knowledge of nearby data points. Relate this to the jigsaw problem they solved in the previous Student Activity, "The Search for Critical Questions." Assign and discuss responses to the third question on Student Activity, "Exploration of a Problem: Making Sense of the Elements."

12. Ask students to read the Student Text, "The Modern Periodic Table." Compare the descriptions of chemical family characteristics with the students' prior knowledge. Point out well-known and interesting examples of elements. Assign and discuss responses to Question 4 on the Student Activity, "Exploration of a Problem: Making Sense of the Elements."

13. Close the class discussion by asking students to devise a general process for solving a problem. Allow students to return to their groups. Ask them to think about the most successful way they can approach a problem and solve it. Encourage them to record the steps and write appropriate questions for each step. Ask each group to turn one copy in to you. Each student should keep a copy for herself or himself to be used in the following activity in this module.

Alternative Strategies Tip

You may ask each group to vote on the one method presented that they think is the most usable by scientists. Ask them to justify that vote. The members of this lab group will be Famous Scientists for the rest of this module!

If you regroup the students in the next module, groups will have three or four *successful* ways to solve problems and the questions that go with them. They can refine this process as they solve the next problem and come up with a more polished process. You may even choose to continue adding Famous Scientists to the original group.

Teacher Resources

Periodic Table of the Elements

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

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

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

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