Lesson Plan: Chemical Analysis of Martian Rocks

FOR THE TEACHER

Summary
In this lesson, students are challenged to analyze the spectral graphs obtained by the Curiosity Mars Rover. Based on their examination students will determine the component elements of each sample, as well as the relative abundance of each element. With this information the student will complete calculations to find the empirical formula and identify the composition of the unknown rock. Finally students will complete research to see if these rocks are actually like those on Earth.

Grade Level
High School

NGSS Alignment
This classroom resource will help prepare your students to meet the performance expectations in the following standards:

- **HS-ESS1-2**: Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.
- **Disciplinary Core Ideas**
  - PS4.B: Electromagnetic Radiation: Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.
- **Cross-cutting Concepts:**
  - Connections of Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems
  - Science assumes the universe is a vast single system in which basic laws are consistent.
  - Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.
- **Science and Engineering Practices**
  - Analyzing and interpreting data
  - Using mathematics and computational thinking
  - Constructing explanations (for science) and designing solutions (for engineering)
  - Engaging in argument from evidence
  - Obtaining, evaluating, and communicating information

Objectives
By the end of this lesson, students should be able to
- Determine an empirical formula from percent composition data of a substance.
- Analyze and interpret a spectral analysis graph.
- Use evidence to draw conclusions.
- Present their reasoning logically using facts and system thinking.

Chemistry Topics
This lesson supports students’ understanding of
- Quantitative Chemistry
- Spectral Analysis
- Percent Composition
- Empirical Formulas
- Significant Digits

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Thanks to:
ACS National Chemistry Week 2018
Time
Teacher Preparation: 15 minutes
Lesson: 40 minutes

Materials
- Teacher PowerPoint Presentation with examples (available for download)
- Student Handout
- Spectral Graphs (available for download)
- Periodic Table
- Calculator
- Device with Internet access for research

Safety
- No specific safety precautions need to be observed for this activity.

Teacher Notes
- The key to this lesson is excitement. Show enthusiasm for the amazement that is the landing of Curiosity on Mars. Be enthralled by the ability to record information from rocks on the Martian surface!
- The lesson should begin with review of key-concepts such as percent composition and empirical formulas (use slides 1-4 from the provided PPT).
- Next use the short video clips to engage and motivate students:
  o 7-minutes of Terror: The Challenges of Getting to Mars (approximately 5 minutes)
  o Curiosity Mars Rover CheMin Data (approximately 2 minutes)
- Following the videos use the teacher led example of how to solve reverse percent composition questions with students (use slides 5-9).
- Depending on the level of your students, additional practice questions may need to be reviewed before giving the students the “rock data” included in the student activity to analyze. However there is a practice question at the start of the student handout to either be worked through individually or collectively that will serve as good preparation.
- I would suggest creating groups of student with similar ability levels. Plan to provide each group with an empirical formula based on difficulty level. A variety of examples are available for use with this activity, progressing in difficulty level by number. For example Asteroid 1 data is the least difficult to analyze, while Asteroid 5 is the most difficult.
- Each group should be given one graph to analyze and will report their findings to the class.
- Although partners could work together to submit a result, I would suggest having groups of 2-3 students and using a whiteboard to organize their thinking and calculations. This will allow for presentations of their results at the conclusion of the period.
- Each presentation should be 1-2 minutes with a brief explanation of any difficulties they had in analysis.
- Note that there is background noise in the graphs. I don’t address this prior to the activity and allow for students to discover it on their own. Some students may try to include the smaller percentages in their calculations, but quickly realize that there are no corresponding elements for these peaks, but also that the total percentage will exceed 100. This often leads to a discussion during the presentations.
- I have attached hypothetical graphs of spectral analysis for Asteroids 1-5, “Martian Rocks”. Based on their analysis, students should determine the following empirical formula for each asteroid. (Note that a complete answer key, showing all calculations is available for download):
  o Asteroid 1: SiO₂
  o Asteroid 2: FeO₂
  o Asteroid 3: CaCO₃
  o Asteroid 4: Mg₂SiO₄
  o Asteroid 5: Fe₂SiO₄
• Provide each group with a different graph and have them work through the reverse percent composition to arrive at the chemical formula. For large classes, groups may analyze identical graphs. For accelerated students, give them multiple graphs to analyze.
• If time allows (or alternatively as a bell-ringer in the following class) have students give presentations of their findings as described in the student lab handout. This should not be graded, but should serve as discussion and review.
• Bonus Extension: students use IUPAC nomenclature to name their rock and research common names to see if they can be found on earth (Resource for list of rocks on Mars)
• Teachers can use this Google Document to easily add their own compounds and create graphs for analysis.

FOR THE STUDENT
Lesson

Chemical Analysis of Martian Rocks

Background
Reverse Percent Composition is a method used in spectral analysis of stars and meteors. This method can also be used to analyze rocks. Using data collected from spectrographs, the percentage of each element present in a sample is determined. By knowing the gram formula mass of each element (from a periodic table), the empirical formula of a specimen may be determined.

Example
A rock sample is determined to contain 58.8% Barium, 13.74% Sulfur, and 27.45% Oxygen by mass. What is the empirical formula of the compound?

Step 1: Assume there is a 100g sample:

Our 100g sample would contain 58.8g of Barium, 13.74g of Sulfur, and 27.45g of Oxygen.

Step 2: Using the gram formula mass of each element, calculate the number of moles of each element in the sample

Barium: 58.8 grams x (1mole/137.3grams) = 0.43 mole Barium
Sulfur: 13.74 grams x (1mole/32.1grams) = 0.43 mole Sulfur
Oxygen: 27.45 grams x (1mole/16.0grams) = 1.72 mole Oxygen

Step 3: Empirical formulas contain whole numbers as subscripts. Find the common denominator between the molar quantities to arrive at subscripts for the empirical formula for the compound.

\[ \text{Empirical Formula} = \text{BaSO}_4 \]
**Practice Question**
A compound has 14.6% Carbon and 85.4% Chlorine by mass. What is the empirical formula for the compound?

**Objective**
Analyze the spectral graph to determine the empirical formula for the Martian Rock (asteroid) discovered by Curiosity Rover. Be prepared to defend your answer to your classmates.

**Procedure**
1. Use the graph provided to determine what elements are in your sample:
   a. Locate the Emission Energies that exhibit peaks.
   b. By comparison to the Chart of Emission Energies, determine the element that most likely caused that peak.
   c. Record the element names in the data table provided.
2. Use the graph provided to determine the percentage of each element that is present in your sample.
   a. Record the Percent Composition for each element that an obvious peaks occur in the data table.
   b. Read the graphs to the nearest TENTHS.
3. Use the percent composition of each element to complete calculations and determine the empirical formula for your sample.
4. Once you have the empirical formula, you can find molecular formulas that naturally exist on earth. Use your research materials (textbook, Google, etc.) to find the name of your compound and locate, if possible, where a similar sample could be found on earth.
5. As a group, prepare a brief presentation of your findings on your whiteboard. Include your estimated percent compositions (from the graph), all calculations, and any difficulties you had arriving at results.

**Data** (you may not need all of the rows)

<table>
<thead>
<tr>
<th>Asteroid #:</th>
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<tr>
<th><strong>Elements Present</strong></th>
<th><strong>Percent Composition</strong></th>
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<tbody>
<tr>
<td>(by comparison to Chart of Emissions)</td>
<td>(determine from graph)</td>
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**Calculations**
Record all necessary calculation used to determine empirical formula below:

**Conclusion**
Is this compound unique to Mars or can it be found on Earth? Explain.