LESSON STOPPED DEAD IN ITS TRACKS

About this Activity

Chemical traces of an organism often can be detected long after it dies. In this activity, students will attempt to identify carbon as a possible biomarker. Students must have prior knowledge of simple chemistry concepts, including the difference between physical and chemical changes. Key information about biomarkers is contained in the Classroom Procedure discussion.

Objectives

Students will:

- Observe characteristics of two substances
- Conduct a chemical change experiment
- Discuss how carbon is an example of a biomarker

Background

Picture this – an eager young detective arrives upon the scene of a murder. After a cursory scan of the area, the detective is elated to discover a weapon. Without thinking, the officer picks up the weapon, and then cries out in disappointment, realizing that, in the excitement, the fingerprints of the culprit were likely destroyed.

Astobiologists are looking for clues too – they are looking in ancient Earth rocks and meteorites from Mars for clues to life beyond Earth. They are searching for biomarkers that are like fingerprints of life – telltale evidence left behind by a living organism. Examples of familiar biomarkers are when a deer leaves tracks and or droppings that are found by a hiker. Another type of biomarker might involve an actual part of an organism – hair, saliva, cells, DNA, etc. But, scientists in their quest for the origins of life in the solar system analyze trace chemicals and minerals – these are microscopic biomarkers.

Astrobiologists and detectives share many similar goals. They all must collect and protect evidence with out contaminating it. The evidence must be examined and then plausible conclusions drawn based upon that evidence. Conclusions based upon flawed evidence carry no weight in a courtroom. Conclusions based upon contaminated materials lack credibility within the scientific community.

Great care must be taken in the way a sample is handled. When a substance is discovered in a sample, the scientist must ascertain not only its origin, but also that the specimen in which it was found has not been contaminated (nor will be). Should that substance be a biomarker, astrobiologists must take particular care in protecting its integrity.

One biomarker we might find is the element carbon or complex compounds containing carbon. All living things and decaying matter contain carbon. However, most fossilized organisms, though they retain the shape of an organism, no longer contain any carbon. In addition, a substance containing carbon may not always be the result of **biogenic** activity – diamonds are carbon but they were not alive. Biological material is detected in many ways in the laboratory. In this activity, students found that one way to start the process of identifying carbon is to burn a substance and realize that living things can burn and leave a residue that contains carbon.

Vocabulary List

Element, compound, biogenic, biomarker, chemical symbol, chemical formula(e), astrobiologist

Materials

- Balance or digital scale
- Granulated sugar – 1 gram per group or demonstration
- Table salt – 1 gram per group or demonstration
- Scoops or spoons, 2
- Petri dishes or similar containers, 2 per group
- Marked labels for Petri dishes (A and B, one each per group)
- Hand lenses, 1 per student
- Tongs or pot holders, 1 per group or demonstration
- Disposable aluminum pie pans, 1 per group or demonstration
- Heat source - electric hot plate or Bunsen burner
- Venting hood or arrange to do demonstration in an outside area
- Goggles or appropriate eye protection
- Writing materials, as needed per student
- Display chart of the Periodic Table of the Elements
- Research materials

Procedure

Advanced Preparation

1. Read background information.
2. Consider all safety protection needed to conduct this experiment.
3. Place 1 gram of salt in each Petri dish labeled A and 1 gram of sugar in each Petri dish labeled B. These will be the unknown materials so keep packages hidden from students.
4. Place 1 gram of salt and 1 gram of sugar in the same pie pan. Be sure not to mix the materials and keep them at least 3 cm apart and equidistant from center of pan.
5. Place pan and heat source in demonstration area with proper ventilation (near electric outlet if needed).

Classroom Procedure

1. Group students (3 to 4 per group)
2. Distribute unknown materials A and B in individual dishes, one of each type per group.
3. Caution groups to examine material visually **without** tasting or touching. The materials are unknown, toxicity is unknown, and contamination is not wanted. Look for visible indicators of the origins of the substances.
4. Using a hand lens to observe the granules, have individuals sketch granules of each substance, taking care not to confuse nor mix the samples.
5. Students should predict which, if either, of these substances appear to be biogenically derived. Ask if there are any visual clues as to the identity of the substances or where

they came from. Brainstorm ways, as scientists, they could try to identify the substances or their origins.

6. Focus groups on demonstration. Place pan with samples (see advanced prep) onto hot plate and set plate to high. Make sure each sample gets equal heat.

***CAUTION: Sugar may ignite, but due to the small amount used, it will likely produce only a minimal flame. Be sure to consider all safety precautions before attempting this experiment. Though not likely to harm anyone, the sugar is sticky and could burn. The flame and smoke could set off smoke alarms and or fire suppression devices.**

7. Within about 30 seconds, sugar should begin to smoke. Within about 1 minute, sugar should liquefy, come to a boil, and form a blackened, flattened mass. (Salt will remain unchanged.)
8. With tongs or hot pad, remove pan from heat source.
9. Allow students to visually examine as pan cools, indicating substances A or B.
10. Have students make comparisons of original to heated substances.
11. Lead students to recognize the presence of carbon in sugar ($C_{12}H_{22}O_{11}$) and its possibility as a biomarker via questions such as:
    a. Compare the initial and final substances. What changes have been witnessed? (solid white crystals, liquefaction, solidification, blackening)
    b. What properties in substance A do we see now that we didn't see before we applied heat? (smooth surface, different color)
    c. Is this change a physical or chemical change? Justify your answer. (chemical; new properties)
    d. What similar experiences do students have with things turning black when they burn? (burned food, burned wood)
    e. Give students the chemical formula for each sample and discuss the elements and their occurrences. ($C_{12}H_{22}O_{11}$ and NaCl). Focus on carbon.
    (Be sure to point out to younger students that all chemical symbols have only ONE capital letter; therefore, the "C" in NaCl is the "partner" to the lowercase "l", and represents the element "chlorine", now "chloride".)
    f. Show students the sugar and salt containers.
    g. Why didn't the salt burn? (It is not a combustible substance; it has no carbon; etc.)

h. Where do we get sugar? (It is plant derived, i.e. biogenic.)

i. *** Lead class to recognize that there will always be carbon or complex carbon compounds as a product of life processes – CO_2, etc. -- so these chemical tracers can be a excellent biomarkers**.** The condition of the starting material may be changed chemically but it can be traced back to give a hint of the original material. Be sure students know that the presence of carbon is NOT proof that the material in which it was found was once alive, only that all things that are/were alive have/had carbon within them at some time.

12. Have students add selected information to lab drawings, such as the names and chemical formulae of substances, etc.

Extension

1. Encourage students to suggest appropriate refinements to demo, including other materials that might be used in a demonstration or traditional lab. Repeat experiment using other substances, such as honey, corn starch, or flour, which are produced by living organisms, and see if the results are similar. Honey blackens quickly, after active bubbling and smoking; flour takes a few minutes and smokes a lot; cornstarch takes several minutes to blacken, with less smoking. Later have students brainstorm properties of these substances that may contribute to the time it takes for them to blacken and the amount of smoke produced.
2. Assign elements from the Periodic Table of the Elements to be researched, focusing on whether or not they are a part of a life process. Be sure to include Al, Ca, Fe, H, K, Hg, Na, O, Si and Ti.
3. How could the elements listed in #2 be used as a biomarker?
4. What are some of the carbon residue materials that scientists are finding in ancient samples?
5. Design an activity for other students where they investigate a sample of mixed materials to see if there are any biomarkers present.