Case File 11

Ashes to Ashes: Using evaporation rate to identify an unknown liquid

Measure and compare the cooling rates of unknown liquids, and identify the probable arsonist.

PROBABLE ARSON

Investigator: James

Date: 10/05/05

- call in at 3:04 a.m.
- large fire on the East Side; historic log cabin of town founder, James McDonald
- first responders too late to save cabin
- traces of an unidentified chemical residue discovered in cabin remains
- drops of unidentified chemical found between cabin remains and main road

  (??accelerant used to spread the fire??)

  ARSON strongly suspected
- chemical evidence sent to lab for testing

McDonald Cabin Arson
Suspect List

The following four people were found within three blocks of the blaze in the early morning and were brought in for questioning. Each has access to flame accelerants for one reason or another. Chemicals collected from each of the suspects have been sent to the lab for identification and comparison with those collected at the scene.

Suspect 1: Barney Weber: member of school custodial staff
Weber was found cleaning out the back of his truck several blocks from the crime scene.

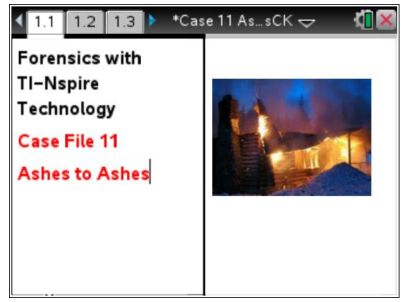
Suspect 2: Anna Appleby: local painter and muralist
Police found Appleby finishing a mural on a warehouse wall across the street from the fire.

Suspect 3: Virginia Lawson Smith: mechanic
Lawson Smith called the fire department. Police questioning her found chemicals on her work clothes.

Suspect 4: Dr. Martin Brown: university chemist
Brown was transporting a cart of chemicals to his college laboratory when police picked him up.

About the Lesson

- This lab introduces the concept of evaporation rate and teaches students how to plot more than one curve on a graph.
- Teaching time: one to two 45 minute class periods



Science Objectives

- Identify the likely accelerant in an arson investigation
- Identify a solution based on evaporation rate
- Understand that evaporation rate is a characteristic property of a liquid

Activity Materials

- TI-Nspire™ technology
- *Case 11 Ashes to Ashes.tns* file
- *Case_11_Ashes_to_Ashes_Student.doc* student activity sheet
- Vernier EasyTemp®
- accelerant samples from 4 suspects
- accelerant samples from crime scene
- 5 small test tubes
- test tube rack
- 6 pieces of filter paper cut into 2 × 2 cm squares
- 6 small rubber bands
- lint-free tissues or paper towels
- masking tape

TI-Nspire™ Navigator™

- Send out *Case 11 Ashes to Ashes.tns* file.
- Monitor student progress using Class Capture.
- Use Live Presenter to spotlight student answers.

Background

In this lab, students use the evaporation rate as a characteristic property with which to distinguish different liquids from one another. The evaporation rate of a liquid depends primarily upon the volatility of the liquid, the temperature of the surrounding air, and the air pressure. Temperature change is a good proxy for evaporation rate because the evaporation of each liquid causes a decrease in its temperature; the faster the liquid evaporates, the faster the temperature drops.

In real arson investigations, gas chromatography, rather than tests of evaporation rates, is usually used to identify accelerants. This is necessary for several reasons: 1) many accelerants are nonvolatile or solid substances; 2) it is rare to find unadulterated accelerant samples near the site of an arson; and 3) trace impurities are often present in different accelerants. Identifying and matching these impurities to other samples can help investigators tie a suspect or a particular batch of accelerant to a particular fire. Many of these impurities do not significantly change evaporation rate, so they could not be detected by the method used in this lab.

Differences in evaporation rate can be difficult to measure and are not as accurate in establishing the identity of an accelerant as is gas chromatography. However, many of the factors that affect evaporation rate also produce distinctive patterns in gas chromatograms. Gas chromatography, like other forms of chromatography, separates the components of a mixture according to their affinities for a particular substrate. These affinities are often related to the same molecular characteristics that cause a substance to be highly volatile or relatively stable. For example, a substance with highly polar bonds will probably have a low evaporation rate; the polar bonds will probably also affect its relationship to the gas chromatography substrate. Therefore, even though the students are not necessarily using the same method to identify accelerants in this lab, the method they are using is based upon the same chemical principles.

Teacher Notes and Teaching Tips

- The student activity sheet and .tns file contain the complete instructions for data collection. All assessment questions are also included in both places giving you the flexibility to either collect the .tns files with student data/answers (using TI-Nspire Navigator) or the student activity sheet.
- Have students work in groups. You may want to use a different “crime scene accelerant” for each group.
- Snug-fitting rubber bands can be made by cutting short sections from a small rubber hose. Surgical tubing works well. Orthodontist’s rubber bands are also a good size; ask for student donations. Small hair ties are another possibility.
- Additional Resources- This web site for the International Association of Arson Investigators contains many links and a great deal of interesting information: http://www.firearson.com/
- **HAZARD ALERTS:**
    - Acetone: Flammable; dangerous fire risk; slightly toxic by ingestion and inhalation. Hazard Code: C—Somewhat Hazardous.
    - Methanol: Flammable; dangerous fire risk; toxic by ingestion (ingestion may cause blindness). Hazard Code: B—Hazardous.
    - 1-Propanol: Flammable liquid; dangerous fire risk; harmful to eyes and respiratory tract. Hazard Code: B—Hazardous.
    - 1-Butanol: Moderate fire risk; toxic on prolonged inhalation; eye irritant; absorbed by skin. Hazard Code: B—Hazardous.
    - The hazard information reference is: Flinn Scientific, Inc., *Chemical & Biological Catalog Reference Manual*, 1-800-452-1261, www.flinnsci.com. See *Appendix D* of this book, *Forensics with Vernier*, for more information.

Allow students to read the forensics scenario on the first page of their student activity sheet

Procedure

Part 1 – Collecting Data

Move to pages 1.1-1

Review the following statement of caution with students:

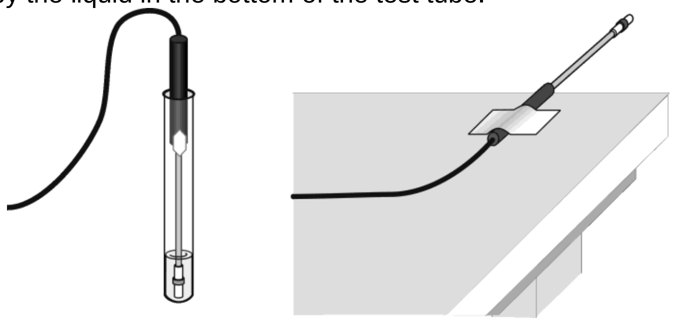
CAUTION: Obtain and wear goggles during this experiment. The compounds used in this experiment are flammable and poisonous. Avoid inhaling their vapors. Avoid touching them with your skin or clothing. Be sure there are no open flames, heat sources, or sparks in the lab during this experiment. Notify your teacher immediately if an accident occurs.

In order to determine whether any of the accelerants found with the suspects matched the accelerant found at the crime scene, students will need to compare the evaporation rate of each suspect's sample with the evaporation rate of the sample from the crime scene. Students will compare the samples by first, graphing the temperature change of each sample as it evaporates and second, comparing the graphs of each sample to look for a match.

Move to pages 2.1-2.5.

1. Using the following procedure, students prepare the samples to be tested:
    a. Obtain five small test tubes and a test tube rack.
    b. Label a separate test tube for each of the four suspects and a fifth test tube for the crime scene.
    c. Pour a small amount of each of the four accelerants into their respective test tubes. Pour a small amount of the accelerant found at the crime scene into the test tube marked "crime scene."
    d. Secure the five test tubes in a test tube rack.
2. Prepare two pieces of masking tape, each about 10 cm long, to be used to tape the probes in position during Step 4.

3. Assist students in wrapping the tip of each of the Temperature Probes with a square of filter paper. Roll the filter paper around the probe tip in the shape of a cylinder. **Hint**: First slip the rubber band up on the probe, wrap the paper around the probe, and then finally slip the rubber band over the wrapped paper. The filter paper should be even with the tip of the probe.
4. Students will then place the temperature sensor into the test tube for Suspect 1. The filter paper should be covered by the liquid in the bottom of the test tube.



5. Students collect temperature data.
6. When data collection has finished, direct students to roll the rubber band on each probe up the probe and dispose of the filter paper.
7. Students determine the maximum and minimum temperatures for each of the data sets.
8. To store the data they collected during this run, they should select the ✔ icon
9. Students repeat Steps 5–8 with the accelerants from Suspects 2-5,
10. Then have students repeat steps 5-7 with the accelerant from the crime scene. Remind students NOT to store the last run of data.
11. Students select **All Runs** to view a graph that displays all of the data

Part 2 – Analyzing the Data

Move to page 3.1.

12. Students should then compare the plots on the graph to determine which of the suspects had an accelerant that is likely to be the same as the accelerant used at the crime scene. If one of the suspects' accelerants produces a plot that matches the shape of the plot from the crime scene accelerant, it could be the accelerant that was used.

Evidence Record

SAMPLE DATA

Substance	T_{max} (°C)	T_{min} (°C)	$T_{max} - T_{min}$ (°C)	Cooling-Rate Graph Match?
Suspect 1 (Methanol)	25.4	8.1	17.3	No
Suspect 2 (Acetone)	22.6	6.3	16.3	Yes
Suspect 3 (Isopropanol)	23.8	16.8	7.0	No
Suspect 4 (t-Butyl Alcohol)	24.6	19.9	4.7	No
Crime Scene (Acetone)	23.7	9.6	14.1	NA

Case Analysis

Have students answer the following questions in the .tns file, on their activity sheet, or both.

Q1. Which of the suspects' accelerants best matches the accelerant from the crime scene?

Answer: Answers will vary.

Q2. Did any of the suspects' accelerants appear to be the same liquid? If so, which ones?

Answer: Answers will vary.

Q3. Why may the graphs of the crime scene accelerant and primary suspect's accelerant not match exactly?

Answer: There may be differences in the amount of liquid on the probe, impurities in one or both of the samples, variations in ambient temperature or humidity, or differences in the starting temperature of the samples.

Q4. In what other ways can you examine the accelerants to determine which one was used in the crime?

Answer: Answers may vary. (Boiling point is probably the most useful.)