Conceptual Chemistry

Laser Hair Analysis as a Forensic Investigation Tool

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Conceptual Chemistry

Conceptual Chemistry is a graduate course designed for grade school and middle school teachers to assist in their understanding of chemistry and to provide concrete ideas that they can take back to their classrooms to teach their students.

Conceptual Chemistry

Participants in this course receive:

- Free tuition and five graduate credit hours from the College of Education of Kent State University. ($2,425 value)
- Over $850 worth of materials and supplies to take back to the classroom.

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Conceptual Chemistry

Spectroscopy

Spectroscopy

The investigation into the nature of matter using electromagnetic radiation.

Most Common Types

Infrared, ultraviolet, visible, NMR, X-ray and microwave.

Activity Objectives

Key Concepts

- Molecular Spectroscopy
- Electromagnetic Radiation
- Quantitative Analyses
- Forensic Science
- Having fun with science!
**Safety**

- Never look directly into a laser beam.
- Never direct laser beams at others.
- Never reflect laser beams off mirrors or other reflective materials.

**Laser Hair Analysis**

1. Make a hair sample holder using the notecard and single-hole punch.

2. Tape the hair sample vertically in the holder.

3. Tape 3 sheets of 8½” x 11” printer paper together and tape them on a whiteboard.

4. Place the whiteboard ~4 m (400 cm) away from the hair sample. Record this distance, $l$.

$\theta \approx 4 \text{ m} = \approx 400 \text{ cm}$

5. Shine a red laser pointer light onto the hair sample and view the image on the paper:

6. Use a pen to place a small line in the middle of the center spot and each node to the left and right of the center spot.

7. Use a meter stick or ruler to measure the distance from the center spot to the nodes in centimeters, ± 0.01 cm.
**Laser Hair Analysis**

8. Repeat the process using a green laser pointer.

![Diagram of laser hair analysis](image1.png)

**Calculations**

9. Calculate the hair width as follows:

![Diagram of laser hair analysis](image2.png)

\[ w_{\text{hair}} = \frac{n\lambda\ell}{d} \]

where:
- \( n \) = node number
- \( \lambda \) = laser wavelength
  - red = 650 nm
  - green = 532 nm

**Small Angle Approximation**

For angles less than 20°:

\[ \sin \theta = \frac{d}{h} = \tan \theta = \frac{d}{\ell} \approx \theta \]

![Diagram of small angle approximation](image3.png)

**Laser Hair Analysis**

\[ w_{\text{hair}} = \frac{n\lambda\ell}{d} \]

- \( n = 3, d = 15.00 \text{ cm} \)
- \( \lambda = 650 \text{ nm (red laser)} \)

- \( \ell = 435.30 \text{ cm} \)
Laser Hair Analysis

For High School or College

**Excel Calculations**

<table>
<thead>
<tr>
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<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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<td>B</td>
<td>C</td>
<td>D</td>
<td>F</td>
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<td>Red</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3</td>
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<td>λ</td>
<td>t</td>
<td>d, cm</td>
<td>hair width, nm</td>
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<td>650</td>
<td>435.3</td>
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Hair width, nm: =A4*B4*C4/D4
Hair width, μm: =E4*1000

**Results**

Heather

Red

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<tr>
<th>Node</th>
<th>λ</th>
<th>t</th>
<th>d, cm</th>
<th>hair width, nm</th>
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Green

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Laser variance ± 10 nm

1.54% (red)
1.88% (green)

1.54% difference!
Results

Suspect Hair Widths

Graph Results

Don

Graph results

Data Average

Overall Method Comparison 0.582%

Why This Works

• Light behaves as waves.
• When an obstacle is encountered the beam splits.
• The waves scatter and interference patterns result.

Diffraction Pattern

\[ w_{\text{slit}} = \frac{n\lambda}{\sin \theta} \]

Where:
- \( n \) = node number
- \( \lambda \) = wavelength of light
- \( \theta \) = angle of diffraction
Conclusions
✧ Both red and green lasers gave excellent results. ± 0.13% - 2.78%, σ < 1.00 µm
✧ Graphing vs. averages, <1% difference
✧ Differences were within the laser variance!
✧ Suspects were easily identified!
✧ Numerous teaching topic can be covered with one activity: measurement, error analysis, trigonometry, quantum theory, wave theory, etc.

References