Brookwood Invitation Science Olympiad Tournament

Forensics

Reminders:

Proper safety attire must be worn at all times:

- Safety goggles
- Closed toed shoes
- Long sleeves
- Long pants
- Lab coat / apron

Clean up your lab station before leaving.

Write all answers legibly.

You will have 50 minutes to complete this exam.

Failure to follow these instructions or the official ruleset will result in a penalty or disqualification.

Leave some time near the end of the event to write your conclusion – it is worth 116 points

"Justification" means to provide 1-2 short details that uniquely identify your choice (of powder, hair, etc)

Score /365

Team Name

Student Name 1

Student Name 2

Do not open until instructed
### Qualitative Analysis (60 pts)

Identify and justify (1 pt each) the powder samples. Provide both the chemical name (1 pt each) and formula (2 pts each). Give an example of common use of the substance (1 pt each).

<table>
<thead>
<tr>
<th>Sample</th>
<th>Name</th>
<th>Formula</th>
<th>Justification</th>
<th>Common Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Sodium Bicarbonate</td>
<td>NaHCO₃</td>
<td>Burns bright yellow, reacts to HCl, weak base of ~8pH</td>
<td>Baking soda, cooking agent</td>
</tr>
<tr>
<td>B</td>
<td>Calcium Nitrate</td>
<td>Ca(NO₃)₂</td>
<td>Melts while burning, orange-red flame</td>
<td>Preservative, fertilizer, desiccant</td>
</tr>
<tr>
<td>C</td>
<td>Sodium Carbonate</td>
<td>Na₂CO₃</td>
<td>Burns yellow, reacts to HCl, strong base of 10 pH</td>
<td>Fertilizer, water softener, aluminum flux</td>
</tr>
<tr>
<td>D</td>
<td>Sodium Acetate</td>
<td>NaC₂H₃O₂</td>
<td>Burns weak yellow, melts, does not react to HCl, neutral pH</td>
<td>Heat packs, soap, concrete sealant</td>
</tr>
<tr>
<td>E</td>
<td>Lithium Chloride</td>
<td>LiCl</td>
<td>Burns red</td>
<td>Bipolar medication, lithium metals, brazing flux</td>
</tr>
<tr>
<td>F</td>
<td>Sucrose</td>
<td>C₁₂H₂₂O₁₁</td>
<td>Burns black, smells sweet, does not react to Benedict</td>
<td>Table sugar</td>
</tr>
<tr>
<td>G</td>
<td>Cornstarch</td>
<td>C₂₇H₄₈O₂₀</td>
<td>Reacts with Iodine</td>
<td>Cooking, thickener, flour</td>
</tr>
<tr>
<td>H</td>
<td>Calcium Carbonate</td>
<td>CaCO₃</td>
<td>No flame reaction, insoluble, reacts with HCl</td>
<td>Concrete, adhesives, chalk</td>
</tr>
<tr>
<td>I</td>
<td>Calcium Carbonate</td>
<td>CaCO₃</td>
<td>No flame reaction, insoluble, reacts with HCl</td>
<td>Concrete, adhesives, chalk</td>
</tr>
<tr>
<td>J</td>
<td>Sucrose</td>
<td>C₁₂H₂₂O₁₁</td>
<td>Burns black, smells sweet, does not react to Benedict</td>
<td>Table sugar</td>
</tr>
</tbody>
</table>
Qualitative Analysis (continued)

Identify and justify the powder samples. Provide both the chemical name and formula. Give an example of common use of the substance.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Name: Sodium Bicarbonate</th>
<th>Formula: NaHCO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Justification:</td>
<td>Burns bright yellow, reacts to HCl, weak base of ~8pH</td>
<td></td>
</tr>
<tr>
<td>Common Use:</td>
<td>Baking soda, cooking agent</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample</th>
<th>Name: Lithium Chloride</th>
<th>Formula: LiCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Justification:</td>
<td>Burns red</td>
<td></td>
</tr>
<tr>
<td>Common Use:</td>
<td>Bipolar medication, lithium metals, brazing flux</td>
<td></td>
</tr>
</tbody>
</table>

Hair Identification (27 pts)

Determine the identity of the given hair samples (2pts each). Provide a short justification of your choice (2pt each).

<table>
<thead>
<tr>
<th>Hair 1</th>
<th>Species: Human</th>
</tr>
</thead>
<tbody>
<tr>
<td>Justification:</td>
<td>Thin interrupted/not-present medulla, overall smooth cuticle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hair 2</th>
<th>Species: Human</th>
</tr>
</thead>
<tbody>
<tr>
<td>Justification:</td>
<td>Thin interrupted/not-present medulla, overall smooth cuticle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hair 3</th>
<th>Species: Human</th>
</tr>
</thead>
<tbody>
<tr>
<td>Justification:</td>
<td>Thin interrupted/not-present medulla, overall smooth cuticle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hair 4</th>
<th>Species: Bat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Justification:</td>
<td>Extremely spiny cuticle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hair 5</th>
<th>Species: Human</th>
</tr>
</thead>
<tbody>
<tr>
<td>Justification:</td>
<td>Thin interrupted/not-present medulla, overall smooth cuticle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hair 6</th>
<th>Species: Horse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Justification:</td>
<td>Very thick hair with thick continuous medulla</td>
</tr>
</tbody>
</table>

Label the Cuticle, Medulla, and Cortex (1 pt each)

- Cuticle
- Medulla
- Cortex
## Fiber Identification (18 pts)

Determine the identity of the given fiber samples (2pts each). Circle whether the fiber is natural or synthetic (1pt each).

<table>
<thead>
<tr>
<th>Fiber 1</th>
<th>Name: Linen</th>
<th>Natural / Synthetic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber 2</td>
<td>Name: Polyester</td>
<td>Natural / Synthetic</td>
</tr>
<tr>
<td>Fiber 3</td>
<td>Name: Polyester</td>
<td>Natural / Synthetic</td>
</tr>
<tr>
<td>Fiber 4</td>
<td>Name: Wool</td>
<td>Natural / Synthetic</td>
</tr>
<tr>
<td>Fiber 5</td>
<td>Name: Cotton</td>
<td>Natural / Synthetic</td>
</tr>
<tr>
<td>Fiber 6</td>
<td>Name: Polyester</td>
<td>Natural / Synthetic</td>
</tr>
</tbody>
</table>

## Polymers (22 pts)

Identify the following plastic samples (2pts each). Name the polymerization type (1 pt). Burn tests are not permitted.

<table>
<thead>
<tr>
<th>Plastic 1</th>
<th>Name: PETE</th>
<th>Poly. Type: Condensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic 2</td>
<td>Name: LDPE</td>
<td>Poly. Type: Addition</td>
</tr>
<tr>
<td>Plastic 3</td>
<td>Name: PMMA</td>
<td>Poly. Type: Addition</td>
</tr>
<tr>
<td>Plastic 4</td>
<td>Name: LDPE</td>
<td>Poly. Type: Addition</td>
</tr>
<tr>
<td>Plastic 5</td>
<td>Name: LDPE</td>
<td>Poly. Type: Addition</td>
</tr>
<tr>
<td>Plastic 6</td>
<td>Name: HDPE</td>
<td>Poly. Type: Addition</td>
</tr>
</tbody>
</table>

Answer the following questions

What is the most commonly recycled type of plastic? (1 pt)

**PETE**

Draw the chemical structure of a PVC monomer (2 pts)

![PVC monomer structure](image)

What is the main difference in the structure of HDPE and LDPE? (1 pt)

**HDPE has a more linear structure while LDPE has more branching chains.**
Chromatography (29 pts)

Perform the chromatography analysis on all four pens. Attach the chromatographs in the empty space below. Clearly mark which ink is being tested on each chromatograph.

Chromatographies can be conducted on individual strips OR on one sheet.

Calculate the $R_f$ value for the most soluble ink component in each pen. Clearly indicate which pen it corresponds to.

Which suspect’s ink sample matched with the crime scene? (3 pts)

Wayne Roberts

What does the term “mobile phase” refer to in Thin-Layer Chromatography? (1 pt)

The liquid solvent

What does the term “carrier gas” refer to in Gas Chromatography? (1 pt)

The gas solvent

Attach your chromatographs below (4 pts each). Remember to write the $R_f$ value (2 pts each).
Mass Spectrometry (17 pts)

Identify the substance in each mass spectrum (4 pts each)

Identity: **Ethanol**

NIST Chemistry WebBook (http://webbook.nist.gov/chemistry)

Identity: **Caffeine**

NIST Chemistry WebBook (http://webbook.nist.gov/chemistry)
Mass Spectrometry (continued).

Answer the following questions.

What does m/z stand for? (1 pts)
Mass-charge ratio

What is the M+1 peak caused by? (1 pts)
C-13 isotope

List the 3 basic parts of a mass spectrometer. (3 pts)
Ion source, Mass analyzer, Detector

Briefly describe the basic process of mass spectrometry. (4 pts)

A substance is ionized and split into fragments. They are accelerated through a bend containing an electric field which diverts the paths of fragments with different m/z ratios. These fragments collect on the detector which produces the mass spec.

Entomology (5 pts).

Answer the following questions.

After 30 days, what stage of decay would a dead body be in? (1 pts)
Post Decay / Butyric Fermentation

Name 2 examples of insects that could be found on the body in this decay stage. (2 pts)
Beetles, Mites, Brachycera flies

What is the name of the process in which blood settles in a dead body? (1 pt)
Livor mortis

What is the name of the process in which the body temperature changes until it reaches the ambient temperature? (1 pt)
Algor mortis
### Fingerprints (37 pts)

Provide the NCIC classification of each fingerprint (1 pt each) and which suspect it, if any matches (1 pt each). If the fingerprint does not match any suspect, write "none".

<table>
<thead>
<tr>
<th></th>
<th>Type:</th>
<th>Match:</th>
<th></th>
<th>Type:</th>
<th>Match:</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Radial Loop</td>
<td>None</td>
<td>G</td>
<td>Ulnar Loop</td>
<td>Chris</td>
</tr>
<tr>
<td>B</td>
<td>Plain Whorl</td>
<td>Wayne</td>
<td>H</td>
<td>Plain Whorl</td>
<td>Adam</td>
</tr>
<tr>
<td>C</td>
<td>Plain Whorl</td>
<td>David</td>
<td>I</td>
<td>Ulnar Loop</td>
<td>None</td>
</tr>
<tr>
<td>D</td>
<td>Plain Whorl</td>
<td>None</td>
<td>J</td>
<td>Radial Loop</td>
<td>Chris</td>
</tr>
<tr>
<td>E</td>
<td>Radial Loop</td>
<td>Chris</td>
<td>K</td>
<td>Plain Whorl</td>
<td>David</td>
</tr>
<tr>
<td>F</td>
<td>Radial Loop</td>
<td>Adam</td>
<td>L</td>
<td>Tented Arch</td>
<td>Matthew</td>
</tr>
</tbody>
</table>
Answer the following questions.

Identify the following ridge characteristics (1 pt each)

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
</tr>
</tbody>
</table>

Name: Bifurcation  Name: Dot  Name: Spur/Hook  Name: Double Bifurcation  Name: Bridge

How many identifiers need to be correlated to determine a match? (1 pt)

10-16

What kind of surface is Cyanoacrylate Fuming effective on? (1 pt)

Smooth non-porous

What are the two reactive chemicals when developing fingerprints with Silver Nitrate? (1 pt)

Silver Nitrate, NaCl

What should the fingerprint area be sprayed with in order to stabilize iodine fuming? (1 pt)

Starch solution

List the 3 layers of skin from top to bottom. (3 pts)

Epidermis  Dermis  Subcutaneous

Damage to which of these layers will permanently damage a fingerprint? (1 pt)

Dermis
DNA (10 pts)

Answer the following questions

What are the 4 bases in DNA? You do not have to give the full names (2 pts)

A, T, G, C

In RNA, which of these bases is missing and what is it replaced with? (1 pt)

T is replaced with U

What is PCR (1 pt)? What is it used for (1 pt)? What are the 3 major steps of PCR (3 pts)?

Polymerase Chain Reaction

It is used to replicate a piece of DNA many times

Denaturing, Annealing, Primer Extension

Briefly describe the basic process of Gel Electrophoresis (2 pts)

Using an electric field, DNA or RNA fragments are pulled through a thick medium such as agarose. The weight of the fragment determines how far it travels, and this is then captured.

Blood Spatters (8 pts)

Answer the following questions

Determine the angle of impact of Spatter 1 located at the front of the room (2 pts)

30

What kind of impact was Spatter 1? (2 pts)

HVIS (High Velocity) OR Gunshot

Determine the angle of impact of Spatter 2 located at the front of the room (2 pts)

90

What kind of impact was Spatter 2? (2 pts)

HVIS (High Velocity) OR Gunshot
Blood Typing (12 pts)

Identify the ABO blood types of each suspect and spatter (1 pt each).

**Blood Typing guidelines**: Split the blood sample into two groups. In one group, add a drop of antigen A and stir briefly. Add and stir antigen B into the other group. After a short amount of time, observe the groups. If the A group clots, then the blood is type A. If the B group clots, the blood is type B. If both groups clot, then the blood is AB, and if no groups clot, then the blood is type O.

<table>
<thead>
<tr>
<th>Spatter 1</th>
<th>Type: B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatter 2</td>
<td>Type: B</td>
</tr>
<tr>
<td>David Lowsky</td>
<td>Type: A</td>
</tr>
<tr>
<td>Adam Yeng</td>
<td>Type: O</td>
</tr>
<tr>
<td>Wayne Roberts</td>
<td>Type: B</td>
</tr>
<tr>
<td>Matthew Lyons</td>
<td>Type: B</td>
</tr>
</tbody>
</table>

Answer the following questions.

Name the two most important blood grouping systems (2 pts)

**ABO, Rh**

What blood type is the universal donor? (1 pt)

**O-**

What blood type cannot accept any other types? (1 pt)

**O-**

Briefly explain why the blood type AB+ can accept all blood types (2 pts)

AB+ blood cells have all 3 antigens present on the cell surface: A, B, and D. Thus, their blood does not produce A, B, or D antibodies and will not react against foreign blood containing A, B, or D antigens.
Conclusion (120 pts)

Using the evidence, determine which suspect is implicated (10 pts). Explain the significance of each piece of evidence in implicating or not implicating the suspects (110 pts).

(10 points) Suspect implicated: Wayne Roberts

2 pts are awarded for each item included in the bulleted list

Wayne Roberts (supports):

- Powder E matched with Powder L from the crime scene
- Powder F matched with Powder J from the crime scene
- LiCl is used in brazing flux, Wayne’s job
- Fiber 3 matches with Fiber 6
- Fiber 3 found on head, perpetrator wore a ski mask
- Print B at the scene is Wayne’s
- Hair matches hair color and type
- Blood type B
- Ink C matches that found at the crime scene

Wayne Roberts (does not support)

- Sucrose could have been from many sources such as the candy Wayne buys
- Plastic 3 does not match
- Only has 1 print while other suspects have more
- Front door handle is a reasonable place for a fingerprint
- Many different customers, human hair must be common

David Lowsky (supports):

- Hair found with the same color and type
- Fingerprint K found at scene
- Perpetrator wore gloves, would not leave many prints

David Lowsky (does not support):

- No powders matched crime scene
- Plastic does not match crime scene
- Fiber 1 does not match crime scene
- No dog hairs found at the scene
- Only 1 fingerprint found at the front door window, reasonable place for a hand to be
- Blood type A
- Ink does not match

Adam Yeng (supports):

- Powder A matches Powder K
- Plastic 2 matches Plastic 5
- Fiber 2 matches Fiber 6
- Fingerprint F found at scene
- Fingerprint H found at scene
- Hair color found with same color/type

Adam Yeng (does not support):
- Sodium Bicarbonate common ingredient in foods
- No match for Powder C
- Front counter is a reasonable place for a fingerprint
- Shelf is a reasonable place for a fingerprint
- Blood type does not match
- Ink does not match

Matthew Lyons (supports)
- Powder H matches Powder I
- Plastic 4 matches Plastic 5
- Blood type matches spatter 2
- Horse hair found (family farm)
- Bat hair found (family farm)
- Print L matched

Matthew Lyons (does not support)
- No match for powder G
- Fiber 4 does not match
- Injury location does not match spatter 2 characteristics
- Hair can be dropped at any time
- Perpetrator was wearing all black, making it unlikely he visited a farm in those clothes
- Print L on front door window, reasonable place
- Ink does not match

General conclusions:
- Perpetrator was wearing gloves, so few fingerprints should be from the actual crime
- Human hair is not extremely significant; many hairs found with the same color
- Perpetrator was wearing a mask, hair may not be from actual crime

Extra details
- Chris was shot once, but there are 2 gunshot spatters with blood type B. The burglar’s blood type must be B.
- Ink was found on Wayne’s shoe and on the shelf. The perpetrator kicked the shelf.
- A shoulder injury matches with spatter 2’s height with a 90 degree impact angle (implicates Wayne)

NOTE: Students will always be awarded points for including any of the details listed above. However, due to the nature of an open ended analysis, students may also be awarded points for logical thinking in elements not included above.