



*Exploring the World of Science*

University of Michigan Science Olympiad  
2021 Invitational Tournament

# Forensics C

**Test length:** 50 Minutes

**Team name:** **KEY**

**Student names:** **KEY**

### A. Qualitative Analysis (99 possible points)

The crew-members were able to recover 9 powders found at the left side of the ship, the area where the body was located. As such, you are required to find the identity of these powders and state if they implicate any suspects.

1. Identify the powders [5 pt each]. Provide the full name of the compound (no chemical formula!):
  - a. Powder A: **Sucrose; C<sub>12</sub>H<sub>22</sub>O<sub>11</sub>**
  - b. Powder B: **Sodium Chloride; NaCl**
  - c. Powder C: **Magnesium Sulfate; MgSO<sub>4</sub>**
  - d. Powder D: **Boric Acid; H<sub>3</sub>BO<sub>3</sub>**
  - e. Powder E: **Glucose; C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>**
  - f. Powder F: **Lithium Chloride; LiCl**
  - g. Powder G: **Calcium Carbonate; CaCO<sub>3</sub>**
  - h. Powder H: **Potassium Chloride; KCl**
2. Relate each of the powders to their suspect(s), if there are any. [5 pt each]:
  - a. Powder A: **White; In her slice of cake**
  - b. Powder B: **White; In her salty trail mix**
  - c. Powder C: **Orange; Migraine medication**
  - d. Powder D: **Red; Slowing down nuclear fission reactions in Reactor**
  - e. Powder E: **White; Glucose pills (diabetes medication)**
  - f. Powder F: **Cyan; Bipolar disorder medication**
  - g. Powder G: **Black; In refurbishing the ship using paint and adhesives**
  - h. Powder H: **Cyan; Potassium Chloride samples in Med. lab**

Supplemental Questions:

1. What element has a tendency to contaminate flame tests? [4 pt]
  - a. **Sodium**
  - b. Potassium
  - c. Carbon
  - d. Lithium
2. Write the balanced chemical equation for the reaction between sodium bicarbonate and hydrochloric acid. [6 pt; 3 pt for correct atoms and 3 pt if balanced]



3. Describe the relationship between electrical conductivity and pH. [4 pt]

As ions carry positive or negative charges, electrical conductivity will occur [1 pt]. The more acidic or basic a substance is, the higher the electrical conductivity [2 pt]. On the other hand, the lower the concentration of ions in a solution or soil, the lower the electrical conductivity (EC). Essentially, both strongly acidic and strongly basic substances are both better at conducting electricity [1 pt]. Material closer to pH neutral may be less conductive.

4. Of the powders that were identified at the crime scene, which is the most acidic? [5 pt]  
Boric Acid

## **B. Polymers: Fibers, Plastics, and Hairs** (106 possible points)

The crew-members found a variety of polymers scattered near the security area of the ship, ranging from fibers to plastics to hair. Some plastics, fibers, and hairs may incriminate no one—in that case, write no one in the blank; conversely, they may also implicate multiple crewmembers.

### **Plastics** (30 possible points)

The plastics found around the body were most likely used in the various tasks crew-members had to complete. But, as small pieces, it's difficult to determine the identity by mere inspection. So, you decide to run water displacement and flame tests what type of plastic each might be.

1. Identify the 5 plastics (give abbreviation ONLY) [2 pt each]:
  - a. Plastic A: HDPE
  - b. Plastic B: LDPE
  - c. Plastic C: PETE
  - d. Plastic D: PC
  - e. Plastic E: PVC
2. For each of the following plastics, fill in the blanks [2 pt each (only for first blank)]:
  - a. Plastic A likely implicates Black because he used motor oil bottles.
  - b. Plastic B likely implicates White because she used sandwich bags.
  - c. Plastic C likely implicates No One because N/A.
  - d. Plastic D likely implicates Orange because he was using CD discs.

- e. Plastic E likely implicates **Red** because **he was fixing electrical wires.**

Supplemental Questions:

1. What is the difference between LDPE and HDPE and what are some of the uses for each of these two plastics? [2 pt]  
**LDPE has more strands of polymer while HDPE's strands are more condensed; Answers may vary for uses (possible LDPE: squeeze bottles, grocery bags, thin packaging; possible HDPE: detergent bottles, toys, trash bins)**
2. Of the plastics identified at the crime scene, which ones can char? [2 pt]  
**PVC**
3. Of the plastics identified at the crime scene, are any of them considered condensation plastics? If so, which one(s)? [2 pt]  
**Yes, PETE**
4. Which of the plastics identified above are polar molecules? [2 pt]  
**PC and PVC**
5. **True** or False: **All** of the Forensics plastics are thermoplastics [2 pt]

Fibers (38 possible points)

In addition to the plastics, traces of random fibers were found by the crew-members scattered around the hallway outside of Security. Using the table, identify each fiber presented and who/how it implicates.

1. Identify the fiber presented in [3 pt each]
  - a. Image A: **Linen**
  - b. Image B: **Nylon**
  - c. Image C: **Cotton**
  - d. Image D: **Polyester**
  - e. Image E: **Wool**
2. Based on the above information, which fibers appear to be incriminating, and who does each one implicate? [3 pt each]
  - a. Fiber A appears to implicate **White.**
  - b. Fiber B appears to implicate **no one.**
  - c. Fiber C appears to implicate **Black.**

- d. Fiber D appears to implicate **Red and Orange**.
- e. Fiber E appears to implicate **no one**.

Supplemental Questions:

1. Of the fibers identified, which of them are synthetic fibers? [2 pt; -1 pt per wrong answer] \*Note: You cannot get below zero points on this question

- A. Polyester**
- B. Linen
- C. Cotton
- D. Nylon**
- E. Spandex
- F. Wool

2. How do synthetic and animal fibers react to heat? [2 pt]

**Synthetic fibers melt and animal fibers shrivel**

3. Why do animal fibers react strongly to bases in contrast to synthetic or plant fibers? [4 pt] \*Include a description of the molecular composition of each of these fibers and an example of a base that could react with animal fibers

**The strong bases will denature the peptide bonds of animal fibers (1 pt), causing them to break down. In contrast, glycosidic linkages in plant fibers (1 pt) and carbon-carbon linkages in synthetic fibers (1 pt) are not susceptible to attack by bases. Give any example of a strong base (1 pt).**

**Hair** (38 possible points)

Lastly, crew-members took images under a microscope of the five pieces of types of hair found in the hallway. They seem to be of various types of animals, but they need you to match each accordingly and find if they implicate a suspect.

1. Identify the hair presented in...[2 pt each]
  - a. Image A: **Bat**
  - b. Image B: **Human**
  - c. Image C: **Horse**
  - d. Image D: **Squirrel**
  - e. Image E: **Cow**

2. Based on the above information, which fibers appear to be incriminating, and who does each one implicate? [2 pt each]
  - a. Hair A appears to implicate **Black**
  - b. Hair B appears to implicate **Orange**
  - c. Hair C appears to implicate **Red**
  - d. Hair D appears to implicate **White**
  - e. Hair E appears to implicate **No one**

### Supplemental Questions

1. How were you able to distinguish between the hair cross sections in Image C and Image E? [3 pt]

**Cow hair typically has more cortical fusi and ovoid bodies than horse hair under a microscope. Also the dark part in the middle of the hair (either the medulla or cortex depending on the image), is normally wider in horse hair.**
2. In most parts of the hair, what type of DNA is most easily extracted? [2 pt]

**Mitochondrial DNA (mtDNA)**
3. What macromolecular feature contributes to the wide variety of hair shapes? [2 pt]

**Disulfide Bonds**

## **C. Chromatography and Mass Spectroscopy (75 possible points)**

Chromatography: (45 possible points; 1 bonus point available)

When Cyan found Yellow's body, she also noticed that there was a note left on top of her forehead with the following scrambled sentence:

*yidrm d nryt I efbaee*

From inspection of the note, the crew-members found that there were two different types of ink/pens used. But, they realized they could trace the note back to the impostor by running a chromatography of the ink used. Answer the questions about the chromatograms below, using the rulers provided for you:

1. To two decimal places, calculate the  $R_f$  of all spots on both chromatograms. (need to give  $\pm 0.05$ ) [5 pt per entry]

a. A:

- i. Red: 0.42
- ii. Blue: 0.67
- iii. Orange: 0.23

b. B:

- i. Light Green: 0.18
- ii. Violet: 0.78
- iii. Pink: 0.94

2. Three suspects, Red, Cyan, and White, all had pens collected from them. Red's pen had an  $R_f$  of 0.63, Cyan's pen had an  $R_f$  of 0.87, and White's pen had an  $R_f$  of 0.56. Whose pen matches up most closely to the spots on either the A or B chromatograms? [5 pt] \*Note: there may be more than one person

Red

3. [BONUS] What does the secret message say? [1 pt]

I betrayed my friend...

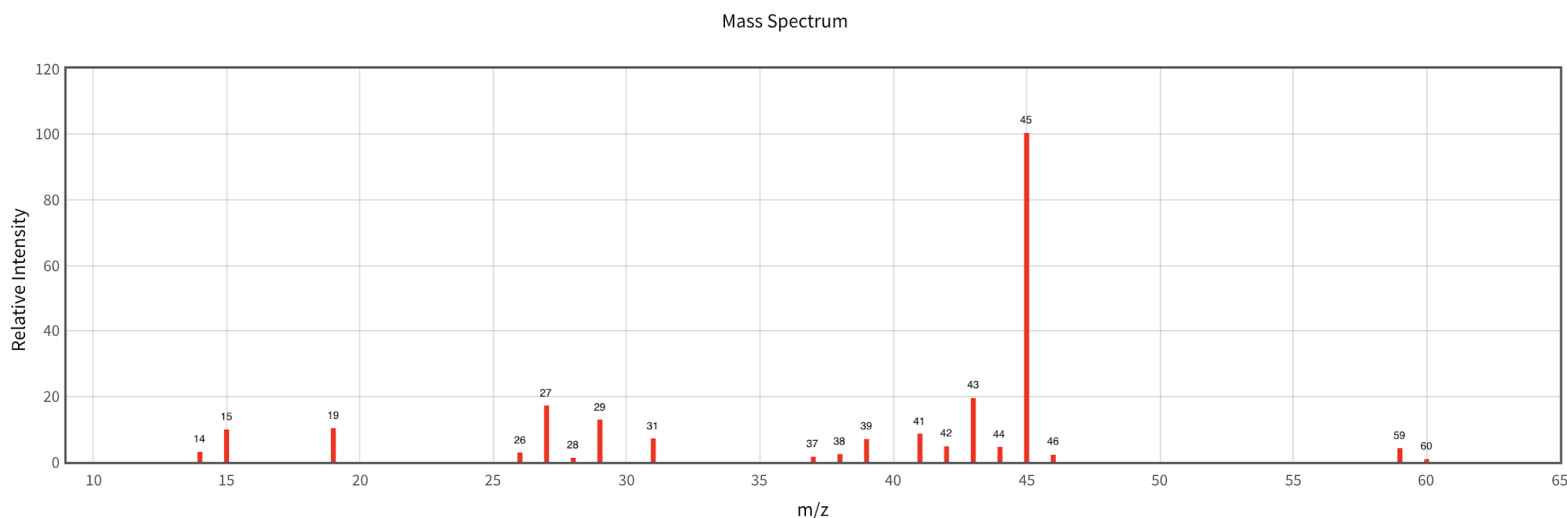
Supplemental Questions:

1. To undergo thin-layer chromatography, an important preliminary step is to set developing solvent conditions. [4 pt]
2. As a follow-up to the previous question, what are the two most common compounds used in these conditions and why? [4 pt]  
Hexane and Ethyl Acetate; Both are used due to their differences in polarity—while hexane is nonpolar, ethyl acetate is polar.
3. True or False. The visualization method used in TLC impacts the  $R_f$  of a compound. [2 pt]

Mass Spectroscopy: (30 possible points)

In addition to the other pieces of evidence, the crew-mates notice a pungent smell coming from a colorless liquid found on the ground. Just to be safe, they decide to run a sample in the

mass spectrometer in the medical laboratory. Answer the following questions below about the mass spec:



1. What is the molecular weight of the compound? [5 pt] **60 g/mol**
2. The intermittent fragmentation shown in the mass spec suggests what atom is getting added to form the larger product? [5 pt] **Carbon**
3. Identify the base peak in this mass spec. [4 pt] **45 m/z**
4. What additional atom is added to this molecule to give the complete structure? [5 pt]  
**Oxygen**
5. What is the name and chemical formula of this compound ? [5 pt]  
**Isopropyl Alcohol; C<sub>3</sub>H<sub>8</sub>O**
6. Using the information above, is this compound likely to implicate one of the suspects? Why or why not? [6 pt]  
**No (3 pt); Isopropyl alcohol is common chemical used in disinfectants, and in such a large ship, disinfectants are most likely used throughout (3 pt)**



## **D. Physical Evidence** (73 possible points)

### **Fingerprinting** (44 possible points)

As any good detective would do, the crew-mates decide to scan the security area for fingerprints, picking them up on the television screens, keyboards, and floor of the security room.

- a) The television screens are made of glass.
- b) The keyboards seemed a bit dirty and greasy, most likely due to a crew-member eating in the room.
- c) The floor of the security room was covered with multiple liquids, particularly the one identified in the mass spectroscopy section.

1. What type of fingerprinting technique should be used to take fingerprints at each of these locations? [9 pt; 3 pt each]

Television Screens: Cyanoacrylate

Keyboards: Iodine Fuming

Floors: Small Particle Reagent

2. After finding prints at the three areas, it is determined they are all from the right hand of the impostor. With this, prints from the right hand of all the crew-members are taken as well. Identify each type of fingerprint and be as specific as possible. [4 pt per fingerprint]

- a. Print A: Ulnar Loop
- b. Print B: Accidental Whorl
- c. Print C: Tented Arch
- d. Print D: Plain Arch
- e. Print E: Ulnar Loop
- f. Print F: Radial Loop
- g. Print G: Tented Arch
- h. Print H: Ulnar Loop

3. Who do Fingerprints A, B, and C implicate? Note: It is possible a fingerprint does not implicate anyone. [3 pts. total; 1 pt per correct answer]

- a. Print A: Red
- b. Print B: No one

- c. Print C: **Cyan**

Glass (21 possible points)

Around Yellow's body, the crew-members also found glass shards everywhere (possibly due to bullets ricocheting and hitting something). However, what they found weird was that the glass shards were not consistent, meaning they all came from a different location.

1. Calculate the index of refraction of glass shards A, B, and C. [3 pt each]
  - a. Glass A: **1.50**
  - b. Glass B: **1.47**
  - c. Glass C: **1.51-1.52**
2. Identify each type of glass. [3 pt each]
  - a. Glass A: **Television Glass**
  - b. Glass B: **Pyrex Glass**
  - c. Glass C: **Crown Glass**
3. Based on where the body was found (security room), which of the three types of glass makes most sense to come from that room? [3 pt]
  - a. **A**
  - b. B
  - c. C

Blood: (8 possible points)

Blood typing of the sample was done and you find the following results shown below (spotty blood represents agglutination)

1. What is the blood type of the sample? [3 pt] **A+**
2. Who does the sample incriminate, if anyone? [3 pt] **No One**
  - a. If the sample does not implicate anyone, where did the blood most likely come from? [2 pt] \*Note: Answer N/A if the blood sample implicates someone.  
**This blood could be from Yellow's body**

## **E. Analysis** (153 possible points; 1 bonus point is available)

Circle the suspect(s) you believe you should hold for questioning and explain who you believe the prime suspect is [10 pt: 5 pt are given per correct person held for questioning; -2pt off total analysis score per additional/wrong crewmember chosen] :

Black

Red

White

Cyan

Orange

In your analysis, justify the name(s) you did circle and refute the name(s) you did not circle. If you circled multiple names, make sure to mention who you believe is the prime suspect.

- 4 pts per piece of evidence mentioned [23 pieces of evidence x 4 pts per piece = max possible total of 92 pts]
- 1 additional pt per connection/disconnection to the crime scene per piece of evidence mentioned [max possible total of 23 pts]
- 3 pts per piece of evidence mentioned that refutes the crewmembers not suspected [8 pieces of evidence x 3 pts per piece of evidence= max possible of 24 pts]
- 4 points given mentioning how mass spec and blood sample does not implicate anyone [only has to be mentioned once; four points are split evenly between the two]
- 1 bonus point for the mention of the ink message and how it relates to Red
- Additional points can be given by the ES depending on the use of motives or the story elements

### **Black**

- Powders: Calcium Carbonate (G) (Specifies no implication as found in Storage)
- Polymers:
  - Plastics: HDPE (A)
  - Fibers: Cotton (C)
  - Hairs: Bat (A) (Specifies no implication as found by gasoline station in Upper Engine)
- Chromatography: None
- Mass Spectroscopy: None
- Fingerprints: None
- Blood Typing: No Blood Found

### Red

- Mentioned that he is the prime suspect and explained due to wider variety and more implications
- Powders: Boric Acid (D)
- Polymers:
  - Plastics: PVC (E) (Specifies no implication as found by wiring in Electrical)
  - Fibers: Polyester (D)
  - Hairs: Horse (C)
- Chromatography: Pen A matches with chromatography
  - Bonus Point: Red wrote the note based on the case notes given
- Mass Spectroscopy: None
- Fingerprints: Fingerprint A was found
- Blood Typing: No Blood Found

### White

- Powders: Sucrose (A) (Specifies no implication as found in Cafeteria); Sodium Chloride (B); Glucose (E)
- Polymers:
  - Plastics: LDPE (B)
  - Fibers: Linen (A)
  - Hairs: Squirrel (D) (Specifies no implication as found in Cafeteria)
- Chromatography: None
- Mass Spectroscopy: None
- Fingerprints: None
- Blood Typing: No Blood Found

### Cyan

- Powders: Lithium Chloride (F); Potassium Chloride (H) (Specifies no implication as found in MedBay)
- Polymers:
  - Plastics: None
  - Fibers: None
  - Hairs: None
- Chromatography: None
- Mass Spectroscopy: None
- Fingerprints: Fingerprint C found
- Blood Typing: No Blood Found

## Orange

- Powders: Magnesium Sulfate (C)
- Polymers:
  - Plastics: PC (D)
  - Fibers: Polyester (D)
  - Hairs: Human (B) (Specifies no implication as found in Storage)
- Chromatography: None
- Mass Spectroscopy: None
- Fingerprints: None
- Blood Typing: No Blood Found