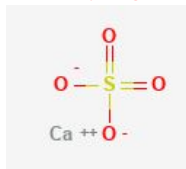


## Section A: Qualitative Analysis (Tiebreaker #1) [192.5 pts]

## Powders: (69/69)

	Identification [3 pts each]	Implication(s) [1 pt each]
S-1	Gypsum (Calcium Sulfate)	Vannesa
S-2	Vitamin C (Ascorbic Acid)	Nobody
S-3	Salt (Sodium Chloride)	Robert, Mike, Gabriel
S-4	Sugar	Vanessa, Robert
S-5	Calcium Carbonate	Vannesa, Gabriel
S-6	Cornstarch	Robert
S-7	Baking Soda (Sodium Bicarbonate)	Vanessa
S-8	Gelatin	Vanessa
S-9	Sodium Acetate	Mike

1. Sodium hydrogen carbonate

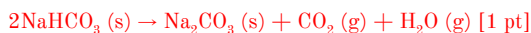


- 2.
3. 456.29 g/mol
4.  $\text{NaHCO}_3 (\text{aq}) + \text{HCl} (\text{aq}) \rightarrow \text{NaCl} (\text{aq}) + \text{H}_2\text{O} (\text{l}) + \text{CO}_2 (\text{g})$  [1 pt]

This chemical reaction is endothermic because the chemical reaction between sodium bicarbonate and hydrochloric acid absorbs heat, [1 pt]

5. *Saccharomyces cerevisiae* [0.5 pts for *saccharomyces*]
6.  $\text{CaCO}_3 (\text{s}) \rightarrow \text{CaO} (\text{s}) + \text{CO}_2 (\text{g})$  [1 pt]

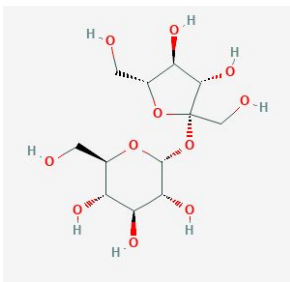
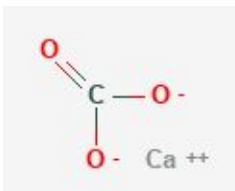
Shown in this chemical reaction is calcium carbonate being decomposed down into calcium oxide and carbon dioxide. This reaction is endothermic. [1 pt]



Shown in this chemical reaction is sodium bicarbonate being decomposed down into sodium carbonate, water, and carbon dioxide. This reaction is endothermic. [1 pt]

7. The hydrogen ion concentration of acids are low, while the hydrogen ion concentration of bases are high.
8. The two monosaccharides that make up the sugar sucrose are fructose and glucose. [1 pt] Sucrose is a non-reducing sugar. Therefore, sucrose would not react to Benedict's solution and Benedict's solution would remain the same blue color. [1 pt]
9. Sodium bicarbonate, sodium acetate, sodium chloride, and alka-seltzer.
10. Examples of conductive powders include sodium acetate, sodium chloride, etc. An example of an NaOH-reactive powder is baking soda.
11. See below for answers.

	Density	Melting Point	Chemical Structure	Molecular Weight
S-3	2.16 g/cm <sup>3</sup>	1,474 °F (801 °C)		58.44 g/mol

S-4	1.59 g/cm <sup>3</sup>	366.8°F (186°C)		342.3 g/mol
S-5	2.71 g/cm <sup>3</sup>	1,517°F (825°C)		100.0869 g/mol

\*Note that these all the numerical answers are approximate answers, and any answers reasonably close enough to these answers will be marked as correct.

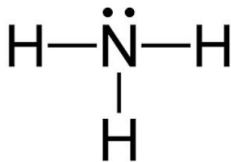
12. The pOH of ascorbic acid is 12, [1 pt] which is equivalent to a hydroxide ion concentration of  $10^{-12}$  mol/L, which is equivalent to a hydronium ion concentration of 0.01 mol/L. [1 pt]
13. Calcium chloride, carbon dioxide and water.
14. 2.15 grams
15.  $C_{16}H_{17}NaO_{14}$

#### Mixtures: (52/52)

	Identification [3 pts each]	Implication(s) [1 pt each]
S-10	Baking Soda + Flour	Vanessa
S-11	Flour + Salt + Sugar	Robert
S-12	Cornstarch + Alka-Seltzer + Calcium Carbonate + Salt	Nobody
S-13	Gelatin + Sugar + Alka-Seltzer	Vanessa

#### Liquids: (34/34)

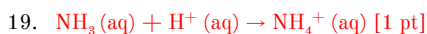
	Identification [3 pts each]	Implication(s) [1 pt each]
S-14	Lemon Juice	Vanessa, Gabriel
S-15	Ammonia	Mike
S-16	Hydrogen Peroxide	Vanessa
S-17	Water	Robert



- 16.
17. There are 8 valence electrons in one water molecule.
18. See answers below.

	Density	Boiling Point	IUPAC ID	Molecular Weight
S-15	0.682 g/cm <sup>3</sup>	-28.01 °F (-33.34 °C)	Azane	17.031 g/mol
S-16	1.45 g/cm <sup>3</sup>	302.4 °F (150.2 °C)	Hydrogen Peroxide	34.0147 g/mol
S-17	1.00 g/cm <sup>3</sup>	212 °F (100 °C)	Water/Oxidane	18.01528 g/mol

\*Note that these all the numerical answers are approximate answers, and any answers reasonably close enough to these answers will be marked as correct.



$\text{NH}_3$  is ammonia,  $\text{H}^+$  is a hydrogen ion, and  $\text{NH}_4^+$  is an ammonium ion. [1 pt]

20. Hydrogen peroxide over time slowly decomposes into oxygen and water. [1 pt] Two substances included in this event that catalyze the decomposition reaction are yeast and iodine. [1 pt]
21.  $10^8$ - $10^9$  times more acidic
22. Examples of possible symptoms include: dizziness, low blood pressure, stomach pain, low body temperature, slurred speech, feeling drunk, slow breathing, nausea, vomiting, throat pain or burning, unresponsive reflexes, coma, etc.
23. Vinegar
24. Acetic acid typically makes up 5–8% percent of the volume in vinegar. [0.5 pts] Citric acid typically makes up 3-4% percent of the volume in lemon juice. [0.5 pts]
25. The process of the mass production of ammonia is produced through a gas phase reaction between nitrogen and hydrogen gas at a moderate temperature and high pressure, which is known as the Haber-Bosch process.
26.  $2\text{NH}_3(\text{l}) + 3\text{I}_2(\text{l}) \rightarrow 2\text{NI}_3(\text{g}) + 3\text{H}_2(\text{g})$  [1 pt]

A large quantity of nitrogen triiodide gas can be hazardous due to the fact that it is an explosive and is very contact sensitive, meaning that if the slightest thing, such as a feather touches it, it will explode, which can cause damage if there are large amounts of it. [1 pt]

**Metals: (37.5/37.5)**

	Identification [3 pts each]	Implication(s) [1 pt each]
S-18	Zinc	Vanessa
S-19	Magnesium	Nobody
S-20	Copper	Mike, Gabriel
S-21	Aluminum	Vannesa

27. The atomic number of copper is 29, the atomic number of aluminum is 13, and the atomic number of zinc is 30.
28. Magnesium and aluminum
29. Magnesium was discovered in 1755 by Joseph Black.
30. Aluminum- paramagnetic [1 pt]  
Copper- diamagnetic [1 pt]  
Iron- ferromagnetic [1 pt]  
Magnesium- paramagnetic [1 pt]  
Tin- diamagnetic (gray) [1 pt]  
Zinc- diamagnetic [1 pt]
31. 3.15 ppm
32. Magnesium
33. 1,400-2,100  $\mu\text{g}$
34. 0.0075%
35. 4478 °F
36. 118.71 g/mol
37.  $\text{Mg}(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{H}_2(\text{g}) + \text{Mg}^{2+}(\text{aq})$  [1 pt]

Mg is magnesium,  $2\text{H}^+$  is 2 hydrogen ions,  $\text{H}_2$  is hydrogen gas and  $\text{Mg}^{2+}$  is a magnesium ion. [1 pt] This reaction is exothermic. [0.5 pts]

38. Copper-  $\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$  [1 pt]  
Tin-  $\text{Sn} \rightarrow \text{Sn}^{2+} + 2\text{e}^-$  [1 pt]  
Zinc-  $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$  [1 pt]

## Section B: Polymer Testing/Natural and Man-made Substances

## Hairs: (20.5/20.5)

	Identification [2 pts each]	Implication(s) [1 pt each]	Medulla Pattern [1 pt each]
S-A	Human	Vannesa, Mike	Fragmental
S-B	Dog	Robert, Mike	Continuous
S-C	Cat	Vannesa	Discon

39. **In Order:** Anagen Phase, Catagen Phase, Telogen Phase [1 pt]

The Anagen Phase has the most hair growth in the hair growth cycle. [0.5 pts]

40. Anagen- years

Catagen- weeks

Telogen- months

[all or nothing]

41. Hair S-A → Imbricate [1 pt]

Hair S-B → Imbricate [1 pt]

Hair S-C → Spinous [1 pt]

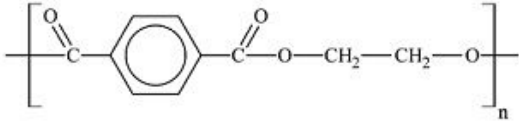
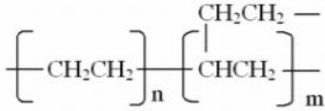
42. The layers of the hair shaft from outermost to innermost layer are cuticle, cortex, medulla. [0.5 pts] The layer of skin the hair shaft is located in is the epidermis, and the layer of skin the hair follicle is located in is the dermis. [0.5 pts, both or nothing]

## Fibers: (13/13)

	Identification [2 pts each]	Implication(s) [1 pt each]	Burn Test Scent [1 pt each]
S-D	Acetate (Synthetic)	Nobody	Melts and drips in flame, pungent smell afterwards, leaves behind black melted beads of ash
S-E	Cotton (Vegetable)	Vannesa	Burns quickly, burns even when away from flame, smells like burning paper, leaves behind skeletal ash
S-F	Nylon (Synthetic)	Vannesa	Burns slowly and melts in flame, smells like celery, leaves behind light colored beads of ash

43. S-F (Nylon)

## Plastics: (11/11)

	Identification [2 pts each]	Implication(s) [1 pt each]	Monomer Structure [1.5 pts each]	Burn Test [1 pt each]
S-G	PETE	Robert		Has bubbles, burns slowly, pungent smell, leaves soot
S-H	LDPE	Vannesa		Fast, clean burn, has white smoke, drips flames

44. Plastic S-G → (C<sub>10</sub>H<sub>8</sub>O<sub>4</sub>)<sub>n</sub>

### Section C: Chromatography

45. Vanessa
46. The purpose of chromatography is to separate a mixture into several compounds or pigments. This can be used to identify organic or inorganic substances, to help identify the culprit of a crime scene, DNA and RNA sequencing, etc. [0.5 pts]  
Chromatography was first used in the early 18th century. [0.5 pts]
47.  $R_f$  stands for retention factor in paper chromatography. [0.5 pts] Its formula is:
- $$R_f = \frac{\text{distance travelled by solute}}{\text{distance travelled by solvent}}$$
- [0.5 pts]
- When the value  $R_f$  is equivalent to 0, this indicates that the solute has not moved. When it is equivalent to 1, this indicates that the solute is moving with the solvent, at the same rate. [0.5 pts]
48. Juice
49. The mobile and stationary phase in paper chromatography are the solvent and the paper used, respectively, [1 pt] and in thin-layer chromatography the mobile and stationary phase are the solvent (or mixture of solvents) and a thin-layer of absorbent, such as a gel. [1 pt]

### Section D: Crime Scene Physical Evidence [41.5 pts]

#### Fingerprints: (18.5/18.5)

	Fingerprint Type [1 pt each]	Matches with Fingerprint #1 [1 pt each]	Matches with Fingerprint #2 [1 pt each]
Vanessa	Plain Whorl	Yes / No (Circle One)	Yes / No (Circle One)
Robert	Plain Whorl	Yes / No (Circle One)	Yes / No (Circle One)
Mike	Plain Whorl	Yes / No (Circle One)	Yes / No (Circle One)
Gabriel	Radial Loop (Right Thumb)	Yes / No (Circle One)	Yes / No (Circle One)

50. >2
51. IAFIS was first operated by the FBI on July 28, 1999. [1 pt] IAFIS stands for Integrated Automated Fingerprint Identification System. [0.5 pts] The operation of IAFIS was significant because before it was used, fingerprints were recorded with paper and ink. With the technology used by IAFIS, fingerprints could be processed and identified much faster than ever before. [1 pt] It was developed due to a high demand for fingerprint identification. [0.5 pts]
52. Answers may vary. [0.5 pts for each correct answer]

Answers may include Ninhydrin, Cyanoacrylate Fuming, Small Particle Reagent, Iodine Fuming, Dusting, Silver Nitrate, Laser Illumination, etc.

#### DNA: (6/6)

	Matches with DNA found at Crime Scene [1 pt each]
Vanessa	Yes / No (Circle One)
Robert	Yes / No (Circle One)
Mike	Yes / No (Circle One)
Gabriel	Yes / No (Circle One)

53. The four nucleobases are adenine, thymine, cytosine, and guanine. [0.5 pts] Adenine pairs with thymine and cytosine pairs with guanine. [0.5 pts] The purines are adenine and guanine and the pyrimidines are thymine and cytosine. [1 pt]

**Shoe Prints: (5/5)**

	Matches with Shoe Print found at Crime Scene [1 pt each]
Vanessa	Yes / No (Circle One)
Robert	Yes / No (Circle One)
Mike	Yes / No (Circle One)
Gabriel	Yes / No (Circle One)

## 54. Plastic print

**Blood Types and Spatters: (12/12)**

	Blood Type [1 pt each]	Matches with Blood Type found at Crime Scene [1 pt each]
Vanessa	O-	Yes / No (Circle One)
Robert	A+	Yes / No (Circle One)
Mike	B+	Yes / No (Circle One)
Gabriel	AB-	Yes / No (Circle One)

## 55. Low-Velocity

## 56. High-Velocity

57. Its angle is  $30^\circ$ , [1 pt] its direction of travel is left, [0.5 pts] part A is the tail, and part B is the parent drop. [1 pt] The velocity of the drop is medium-velocity. [0.5 pts]

**Section E: Analysis (Tiebreaker #2) [98 pts]**Vanessa

**Strong Motive:** Holds a grudge on Dave after breaking up with him.

*Potential Evidence:*

- S-1 Gypsum was found on Vanessa, also found at the crime scene.
- S-4 Sugar was found on Vanessa, also found at the crime scene. However, this piece of evidence could possibly be from Robert.
- S-5 Calcium Carbonate was found on Vanessa, also found at the crime scene. However, this piece of evidence could possibly be from Gabriel.
- S-7 Baking Soda (Sodium Bicarbonate) was found on Vanessa, also found at the crime scene.
- S-8 Gelatin was found on Vanessa, also found at the crime scene.
- S-10 Baking Soda + Flour was found on Vanessa, also found at the crime scene.
- S-13 Gelatin + Sugar + Alka-Seltzer was found on Vanessa, also found at the crime scene.
- S-14 Lemon Juice was found on Vanessa, also found at the crime scene. However, this piece of evidence could possibly be from Gabriel.
- S-16 Hydrogen Peroxide was found on Vanessa, also found at the crime scene.
- S-18 Zinc was found on Vanessa, also found at the crime scene.
- S-21 Aluminum was found on Vanessa, also found at the crime scene.
- S-A Human hair was found on Vanessa, also found at the crime scene. However, this piece of evidence could possibly be from Mike.
- S-C Cat hair was found on Vanessa, however this was not found at the crime scene.
- S-E Cotton was found on Vanessa, also found at the crime scene.
- S-F Nylon was found on Vanessa, also found at the crime scene.
- S-H LDPE was found on Vanessa, also found at the crime scene.
- Fingerprint matches with Fingerprint #2, which was found at the crime scene.
- DNA matches with the DNA sample that was found at the crime scene.
- Shoe print matches with the shoe print found at the crime scene.
- Blood type matches with the blood type of the blood drops (window) found at the crime scene.

**Conclusion:** Using the large amounts of evidence from the crime scene pointing towards Vanessa above along with Vanessa's strong motive, we can conclude that she is the/a perpetrator of the crime.

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Robert

**Strong Motive:** Irritated with Dave for low pay despite everyone being hardworking. He was also scolded a lot by Dave for making mistakes on the soups.

*Potential Evidence:*

- S-3 Salt was found on Robert, however this was not found at the crime scene.
- S-4 Sugar was found on Robert, also found at the crime scene. However, this piece of evidence could possibly be from Vanessa.
- S-6 Cornstarch was found on Robert, however this was not found at the crime scene.
- S-11 Flour + Salt + Sugar was found on Robert, however this was not found at the crime scene.
- S-17 Water was found on Robert, however this was not found at the crime scene.
- S-B Dog hair was found on Robert, however this was not found at the crime scene.
- S-G PETE was found on Robert, however this was not found at the crime scene.

**Conclusion:** Although Robert has a strong motive, the amount of evidence from the crime scene found on him is not enough to prove that he is guilty. Therefore, he is not the/a perpetrator of the crime.

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Mike

**Weak Motive:** Feels concerned about Dave, as his friend's wealth and success has had quite an impact on his personality

*Potential Evidence:*

- S-3 Salt was found on Mike, however this was not found at the crime scene.
- S-9 Sodium Acetate was found on Mike, however this was not found at the crime scene.

- S-15 Ammonia was found on Mike, however this was not found at the crime scene.
- S-20 Copper was found on Mike, however this was not found at the crime scene.
- S-A Human hair was found on Mike, also found at the crime scene. However, this piece of evidence could possibly be from Vanessa.
- S-B Dog hair was found on Mike, however this was not found at the crime scene.
- Fingerprint matches with Fingerprint #1, which was found at the crime scene.

**Conclusion:** Since Mike has a weak motive, and not much evidence was pointed towards him, we can't say that he is guilty. Therefore, Mike is not the/a perpetrator of the crime.

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### Gabriel

**Strong Motive:** Jealous of Dave's success and wants to overtake his restaurant in sales.

*Potential Evidence:*

- S-5 Calcium Carbonate was found on Gabriel, also found at the crime scene. However, this piece of evidence could possibly be from Gabriel.
- S-14 Lemon Juice was found on Gabriel, also found at the crime scene. However, this piece of evidence could possibly be from Vanessa.
- S-20 Copper was found on Gabriel, however this was not found at the crime scene.

**Conclusion:** Although Gabriel has a strong motive, the amount of evidence from the crime scene found on him is not enough to prove that he is guilty. Therefore, he is not the/a perpetrator of the crime.

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+2 points for each correct piece of evidence

+3 points for each correct motive

+3 points for each correct conclusion