Crime Busters/Forensics

[Division B/C]

Georgia Tech Event Workshop Series
2024-25

Science Olympiad at Georgia Tech®

01 RULES SHEET

02 DIFFICULT TOPICS

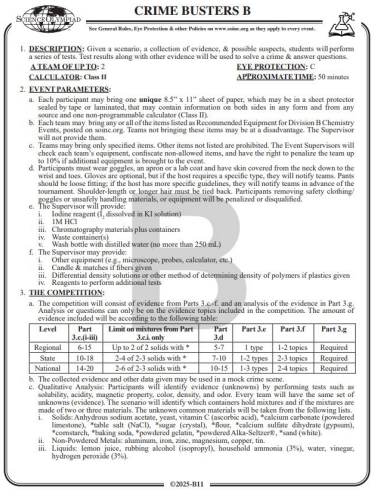
03 COMMON QUESTIONS

04 TIPS FROM A VETERAN

05 OTHER FREE RESOURCES

The Rules Sheet (B)

- **1** 8.5” x 11” sheet of paper **per person**
- **1 non-programmable** calculator (no TI-84)
- Wear proper clothing!
- Guaranteed to be tested on powders, polymers (hair, plastics, fibers), and chromatography
- Check the Chemistry Equipment List!
  - Beakers, test tubes, petri dishes, slides/cover slips, spatulas, stirring rods, ruler, etc.
- Analysis of powders/solids has the most points!! (~50%)



CRIME BUSTERS B

See General Rules, Eye Protection & other Policies on www.soinc.org as they apply to every event.

1. **DESCRIPTION:** Given a scenario, a collection of evidence, & possible suspects, students will perform a series of tests. Test results along with other evidence will be used to solve a crime & answer questions.
   A TEAM OF UP TO: 2 **EYE PROTECTION:** C
   CALCULATOR: Class II **APPROXIMATE TIME:** 50 minutes
2. **EVENT PARAMETERS:**
   a. Each participant may bring one **unique** 8.5” x 11” sheet of paper, which may be in a sheet protector sealed by tape or laminated, that may contain information on both sides in any form and from any source and one non-programmable calculator (Class II).
   b. Each team may bring any or all of the items listed as Recommended Equipment for Division B Chemistry Events, posted on soinc.org. Teams not bringing these items may be at a disadvantage. The Supervisor will not provide them.
   c. Teams may bring only specified items. Other items not listed are prohibited. The Event Supervisors will check each team’s equipment, confiscate non-allowed items, and have the right to penalize the team up to 10% if additional equipment is brought to the event.
   d. Participants must wear goggles, an apron or a lab coat and have skin covered from the neck down to the wrist and toes. Gloves are optional, but if the host requires a specific type, they will notify teams. Pants should be loose fitting; if the host has more specific guidelines, they will notify teams in advance of the tournament. Shoulder-length or longer hair must be tied back. Participants removing safety clothing/goggles or unsafely handling materials, or equipment will be penalized or disqualified.
   e. The Supervisor will provide:
      i. Iodine reagent (I_2 dissolved in KI solution)
      ii. 1M HCl
      iii. Chromatography materials plus containers
      iv. Waste container(s)
      v. Wash bottle with distilled water (no more than 250 mL)
   f. The Supervisor may provide:
      i. Other equipment (e.g., microscope, probes, calculator, etc.)
      ii. Candle & matches if fibers given
      iii. Differential density solutions or other method of determining density of polymers if plastics given
      iv. Reagents to perform additional tests
3. **THE COMPETITION:**
   a. The competition will consist of evidence from Parts 3.c-f. and an analysis of the evidence in Part 3.g. Analysis or questions can only be on the evidence topics included in the competition. The amount of evidence included will be according to the following table:

Level	Part 3.c.(i-iii)	Limit on mixtures from Part 3.c.i. only	Part 3.d	Part 3.e	Part 3.f	Part 3.g
Regional	6-15	Up to 2 of 2 solids with *	5-7	1 type	1-2 topics	Required
State	10-18	2-4 of 2-3 solids with *	7-10	1-2 types	2-3 topics	Required
National	14-20	2-6 of 2-3 solids with *	10-15	1-3 types	2-4 topics	Required

   b. The collected evidence and other data given may be used in a mock crime scene.
   c. Qualitative Analysis: Participants will identify evidence (unknowns) by performing tests such as solubility, acidity, magnetic property, color, density, and odor. Every team will have the same set of unknowns (evidence). The scenario will identify which containers hold mixtures and if the mixtures are made of two or three materials. The unknown common materials will be taken from the following lists.
      i. Solids: Anhydrous sodium acetate, yeast, vitamin C (ascorbic acid), *calcium carbonate (powdered limestone), *table salt (NaCl), *sugar (crystal), *flour, *calcium sulfate dihydrate (gypsum), *cornstarch, *baking soda, *powdered gelatin, *powdered Alka-Seltzer®, *sand (white).
      ii. Non-Powdered Metals: aluminum, iron, zinc, magnesium, copper, tin.
      iii. Liquids: lemon juice, rubbing alcohol (isopropyl), household ammonia (3%), water, vinegar, hydrogen peroxide (3%).

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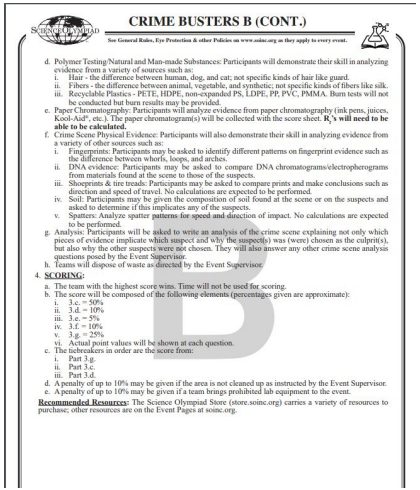


CRIME BUSTERS B (CONT.)

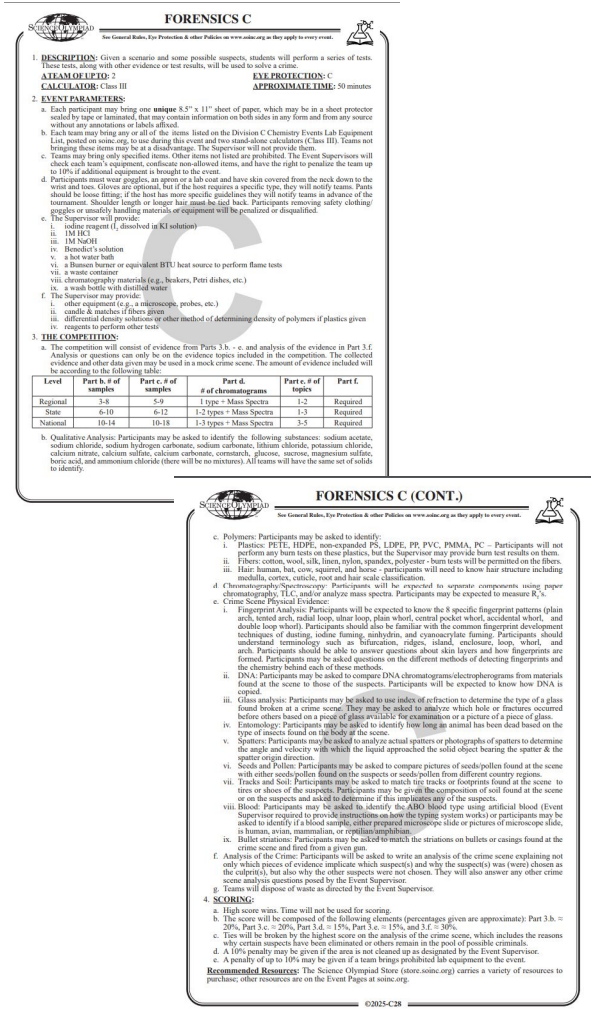
See General Rules, Eye Protection & other Policies on www.soinc.org as they apply to every event.

   d. Polymer Testing/Natural and Man-made Substances: Participants will demonstrate their skill in analyzing evidence from a variety of sources such as:
      i. Hair - the difference between human, dog, and cat; not specific kinds of hair like guard.
      ii. Fibers - the difference between animal, vegetable, and synthetic; not specific kinds of fibers like silk.
      iii. Recyclable Plastics - PETE, HDPE, non-expanded PS, LDPE, PP, PVC, PMMA. Burn tests will not be conducted but burn results may be provided.
   e. Paper Chromatography: Participants will analyze evidence from paper chromatography (ink pens, juices, Kool-Aid®, etc.). The paper chromatogram(s) will be collected with the score sheet. **K’s will need to be able to be calculated.**
   f. Crime Scene Physical Evidence: Participants will also demonstrate their skill in analyzing evidence from a variety of other sources such as:
      i. Fingerprints: Participants may be asked to identify different patterns on fingerprint evidence such as the difference between whorls, loops, and arches.
      ii. DNA evidence: Participants may be asked to compare DNA chromatograms/electropherograms from materials found at the scene to those of the suspects.
      iii. Shoeprints & tire treads: Participants may be asked to compare prints and make conclusions such as direction and speed of travel. No calculations are expected to be performed.
      iv. Soil: Participants may be given the composition of soil found at the scene or on the suspects and asked to determine if this implicates any of the suspects.
      v. Spatters: Analyze spatter patterns for speed and direction of impact. No calculations are expected to be performed.
   g. Analysis: Participants will be asked to write an analysis of the crime scene explaining not only which pieces of evidence implicate which suspect and why the suspect(s) was (were) chosen as the culprit(s), but also why the other suspects were not chosen. They will also answer any other crime scene analysis questions posed by the Event Supervisor.
   h. Teams will dispose of waste as directed by the Event Supervisor.
4. **SCORING:**
   a. The team with the highest score wins. Time will not be used for scoring.
   b. The score will be composed of the following elements (percentages given are approximate):
      i. 3.c. = 50%
      ii. 3.d. = 10%
      iii. 3.e. = 5%
      iv. 3.f. = 10%
      v. 3.g. = 25%
      vi. Actual point values will be shown at each question.
   c. The tiebreakers in order are the score from:
      i. Part 3.g.
      ii. Part 3.c.
      iii. Part 3.d.
   d. A penalty of up to 10% may be given if the area is not cleaned up as instructed by the Event Supervisor.
   e. A penalty of up to 10% may be given if a team brings prohibited lab equipment to the event.

Recommended Resources: The Science Olympiad Store (store.soinc.org) carries a variety of resources to purchase; other resources are on the Event Pages at soinc.org.

The Rules Sheet (C)

- **1** 8.5” x 11” sheet of paper **per person**
- **1 programmable calculator** per person
- Make sure to check the Chemistry Lab Equipment List!
  - Beakers, test tubes, petri dishes, cover slips, flame loop, ruler, calculator, etc.
- Analysis of the crime has the most points - make sure to write something down for this!



FORENSICS C

See General Rules, Eye Protection & other Policies on www.soinc.org as they apply to every event.

1. **DESCRIPTION:** Given a scenario and some possible suspects, students will perform a series of tests. These tests, along with other evidence or test results, will be used to solve a crime.
   A TEAM OF UP TO: 2 **EYE PROTECTION:** C
   CALCULATOR: Class III **APPROXIMATE TIME:** 50 minutes
2. **EVENT PARAMETERS:**
   a. Each participant may bring one **unique** 8.5" x 11" sheet of paper, which may be in a sheet protector sealed by tape or laminated, that may contain information on both sides in any form and from any source without any annotations or labels affixed.
   b. Each team may bring any or all of the items listed on the Division C Chemistry Events Lab Equipment List, posted on soinc.org, to use during this event and two stand-alone calculators (Class III). Teams not bringing these items may be at a disadvantage. The Supervisor will not provide them.
   c. Teams may bring only specified items. Other items not listed are prohibited. The Event Supervisors will check each team's equipment, confiscate non-allowed items, and have the right to penalize the team up to 10% if additional equipment is brought to the event.
   d. Participants must wear goggles, an apron or a lab coat and have skin covered from the neck down to the wrist and toes. Gloves are optional, but if the host requires a specific type, they will notify teams. Pants should be loose fitting; if the host has more specific guidelines they will notify teams in advance of the tournament. Shoulder length or longer hair must be tied back. Participants removing safety clothing/goggles or unsafely handling materials or equipment will be penalized or disqualified.
   e. The Supervisor will provide:
      i. Iodine reagent (I_2 dissolved in KI solution)
      ii. 1M HCl
      iii. 1M NaOH
      iv. Benedict's solution
      v. a hot water bath
      vi. a Bunsen burner or equivalent BTU heat source to perform flame tests
      vii. a waste container
      viii. chromatography materials (e.g., beakers, Petri dishes, etc.)
      ix. a wash bottle with distilled water
   f. The Supervisor may provide:
      i. other equipment (e.g., a microscope, probes, etc.)
      ii. candle & matches if fibers given
      iii. differential density solutions or other method of determining density of polymers if plastics given
      iv. reagents to perform other tests
3. **THE COMPETITION:**
   a. The competition will consist of evidence from Parts 3.b. - e. and analysis of the evidence in Part 3.f. Analysis or questions can only be on the evidence topics included in the competition. The collected evidence and other data given may be used in a mock crime scene. The amount of evidence included will be according to the following table:

Level	Part b. # of samples	Part c. # of samples	Part d. # of chromatograms	Part e. # of topics	Part f.
Regional	3-8	5-9	1 type + Mass Spectra	1-2	Required
State	6-10	6-12	1-2 types + Mass Spectra	1-3	Required
National	10-14	10-18	1-3 types + Mass Spectra	3-5	Required

   b. Qualitative Analysis: Participants may be asked to identify the following substances: sodium acetate, sodium chloride, sodium hydrogen carbonate, sodium carbonate, lithium chloride, potassium chloride, calcium nitrate, calcium sulfate, calcium carbonate, cornstarch, glucose, sucrose, magnesium sulfate, boric acid, and ammonium chloride (there will be no mixtures). All teams will have the same set of solids to identify.

FORENSICS C (CONT.)

See General Rules, Eye Protection & other Policies on www.soinc.org as they apply to every event.

   c. Polymers: Participants may be asked to identify:
      i. Plastics: PETE, HDPE, non-expanded PS, LDPE, PP, PVC, PMMA, PC – Participants will not perform any burn tests on these plastics, but the Supervisor may provide burn test results on them.
      ii. Fibers: cotton, wool, silk, linen, nylon, spandex, polyester - burn tests will be permitted on the fibers.
      iii. Hair: human, bat, cow, squirrel, and horse - participants will need to know hair structure including medulla, cortex, cuticle, root and hair scale classification.
   d. Chromatography/Spectroscopy: Participants will be expected to separate components using paper chromatography, TLC, and/or analyze mass spectra. Participants may be expected to measure R_f's.
   e. Crime Scene Physical Evidence:
      i. Fingerprint Analysis: Participants will be expected to know the 8 specific fingerprint patterns (plain arch, tented arch, radial loop, ulnar loop, plain whorl, central pocket whorl, accidental whorl, and double loop whorl). Participants should also be familiar with the common fingerprint development techniques of dusting, iodine fuming, ninhydrin, and cyanoacrylate fuming. Participants should understand terminology such as bifurcation, ridges, island, enclosure, loop, whorl, and arch. Participants should be able to answer questions about skin layers and how fingerprints are formed. Participants may be asked questions on the different methods of detecting fingerprints and the chemistry behind each of these methods.
      ii. DNA: Participants may be asked to compare DNA chromatograms/electropherograms from materials found at the scene to those of the suspects. Participants will be expected to know how DNA is copied.
      iii. Glass analysis: Participants may be asked to use index of refraction to determine the type of a glass found broken at a crime scene. They may be asked to analyze which hole or fractures occurred before others based on a peice of glass available for examination or a picture of a piece of glass.
      iv. Entomology: Participants may be asked to identify how long an animal has been dead based on the type of insects found on the body at the scene.
      v. Spatters: Participants may be asked to analyze actual spatters or photographs of spatters to determine the angle and velocity with which the liquid approached the solid object bearing the spatter & the spatter origin direction.
      vi. Seeds and Pollen: Participants may be asked to compare pictures of seeds/pollen found at the scene with either seeds/pollen found on the suspects or seeds/pollen from different country regions.
      vii. Tracks and Soil: Participants may be asked to match tire tracks or footprints found at the scene to tires or shoes of the suspects. Participants may be given the composition of soil found at the scene or on the suspects and asked to determine if this implicates any of the suspects.
      viii. Blood: Participants may be asked to identify the ABO blood type using artificial blood (Event Supervisor required to provide instructions on how the typing system works) or participants may be asked to identify if a blood sample, either prepared microscope slide or pictures of microscope slide, is human, avian, mammalian, or reptilian/amphibian.
      ix. Bullet striations: Participants may be asked to match the striations on bullets or casings found at the crime scene and fired from a given gun.
   f. Analysis of the Crime: Participants will be asked to write an analysis of the crime scene explaining not only which pieces of evidence implicate which suspect(s) and why the suspect(s) was (were) chosen as the culprit(s), but also why the other suspects were not chosen. They will also answer any other crime scene analysis questions posed by the Event Supervisor.
   g. Teams will dispose of waste as directed by the Event Supervisor.
4. **SCORING:**
   a. High score wins. Time will not be used for scoring.
   b. The score will be composed of the following elements (percentages given are approximate): Part 3.b. ≈ 20%, Part 3.c. ≈ 20%, Part 3.d. ≈ 15%, Part 3.e. ≈ 15%, and 3.f. ≈ 30%.
   c. Ties will be broken by the highest score on the analysis of the crime scene, which includes the reasons why certain suspects have been eliminated or others remain in the pool of possible criminals.
   d. A 10% penalty may be given if the area is not cleaned up as designated by the Event Supervisor.
   e. A penalty of up to 10% may be given if a team brings prohibited lab equipment to the event.

Recommended Resources: The Science Olympiad Store (store.soinc.org) carries a variety of resources to purchase; other resources are on the Event Pages at soinc.org.

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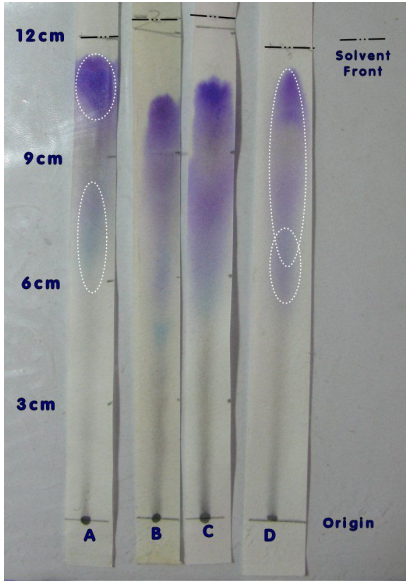
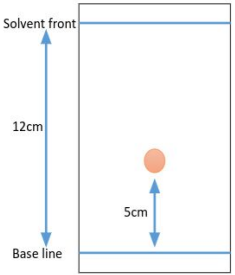
DIFFICULT
TOPICS

Topic 1: Chromatography

- Relies on capillary action and polarity
- Rf - Retention Factor
  1. Measure from the base line to the center of the compound (how far the compound traveled)
  2. Measure from the base line to the solvent front
  3. Find their ratio
- Mobile phase - solvent
- Stationary phase - paper
- Start this at the beginning of the test



How to calculate the R*f* value



$$Rf = \frac{distance\ moved\ by\ substance}{distance\ moved\ by\ solvent}$$

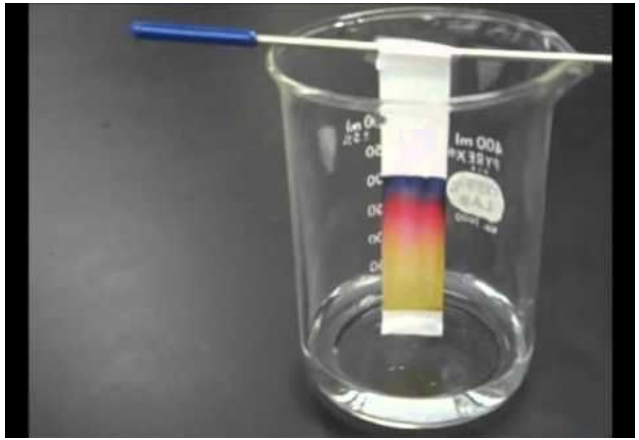
$$Rf = \frac{5cm}{12cm}$$

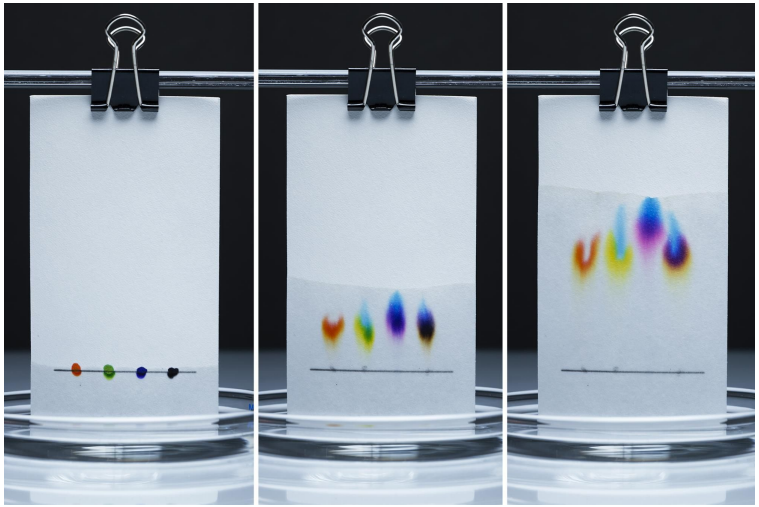
$$Rf = 0.42$$

Key -
Solvent = Water
Substance = Red spot

Topic 1: Chromatography

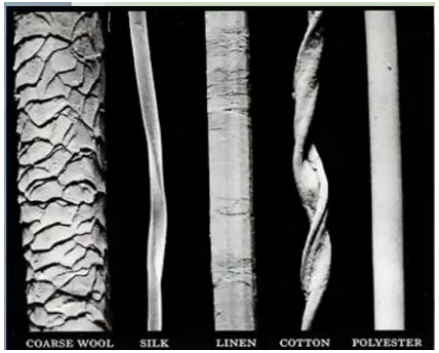
- Practice with this!
- Sometimes it might not work, but that's okay - do what you can





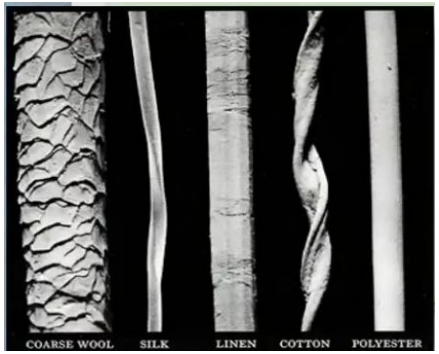
Topic 2: Fibers

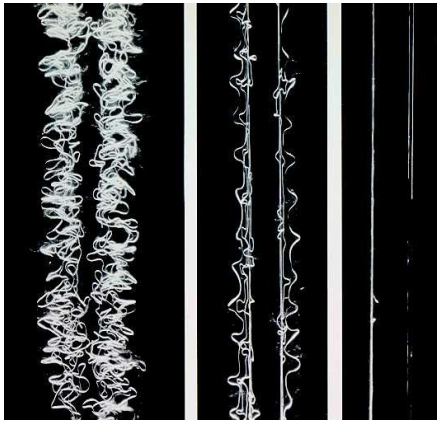
- Animal (wool, silk)
  - Shrivel and form a grainy ash under heat
  - Smell like burning hair
  - Self-extinguish
  - Made of keratin
- Plant (cotton, linen)
  - Smell like burning paper
  - Catch on fire even without touching the flame
- Synthetic (nylon, polyester, spandex)
  - Melt and produce a hard bead of plastic



Topic 2: Fibers

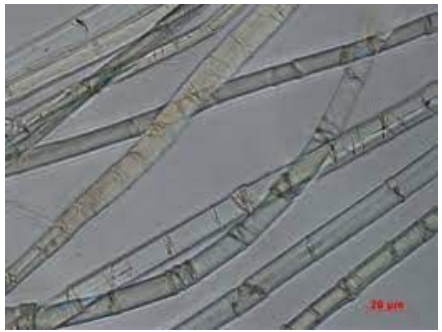
- Be familiar looking at microscope images of fibers!



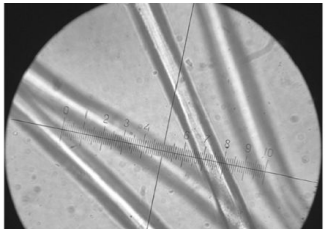


Silk

Cotton



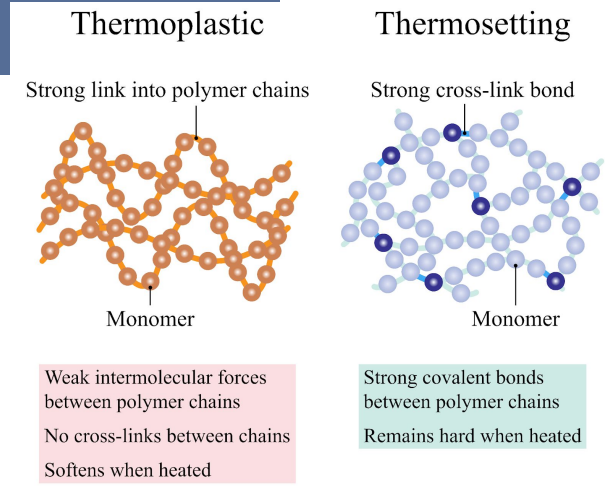
Linen

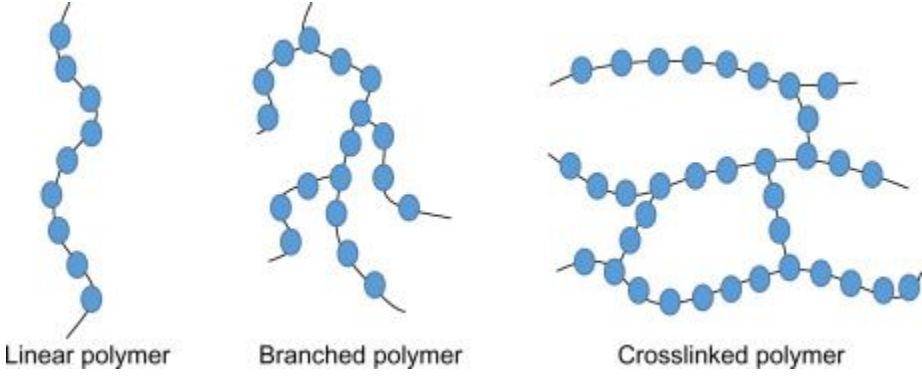


Synthetics

Topic 3: Plastics

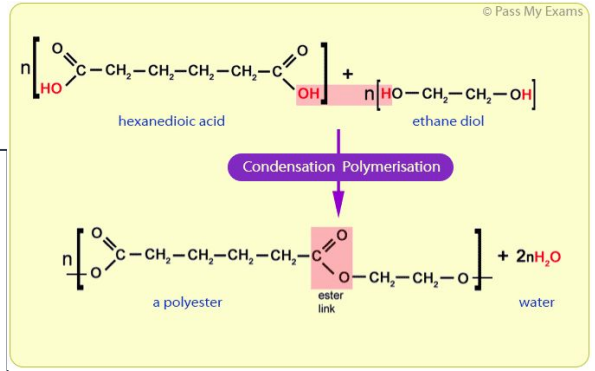
- Be familiar with density tests!
- Thermoplastics - pliable after heating
  - Made of **branched** polymer chains
  - Recyclable
- Thermosets - can't be returned to their original states
  - Made of **cross-linked** polymer chains



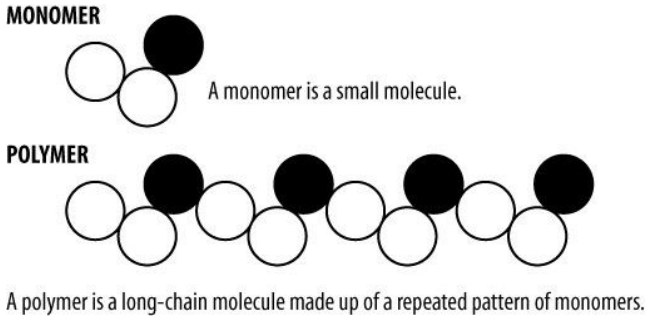


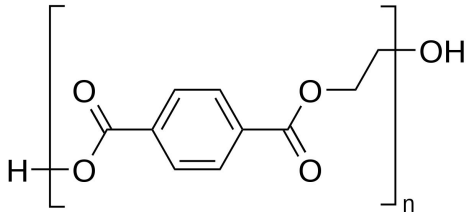
Topic 3: Plastics

- Polymerization - synthesis of polymers
  - Addition/chain growth - polymers added one step at a time
  - Condensation/step growth - chain doubles with each step (exponential growth)

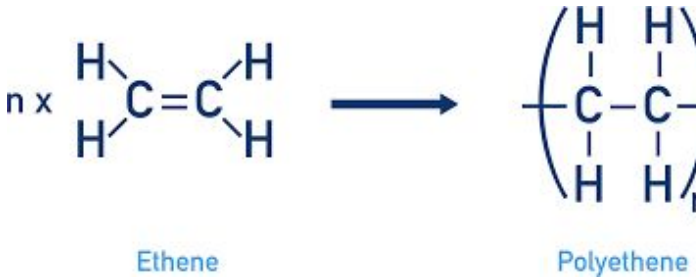


Condensation V.S. Addition





Monomer of PETE (Polyethylene Terephthalate)



COMMON QUESTIONS

All of the following questions have been pulled from past YJI exams (which can be found on our website) or the Text Exchange on SciOly Wiki

Question 1

Plastics:

Plastic A was found at the scene. Float tests were conducted in various liquids. F means float, and S means Sink. ID all plastics (2pts each)

Plastics	A	B	C	D
Vegetable Oil	F	F	S	S
46% isopropyl alcohol	F	F	S	S
Water	F	F	S	S
10% NaCl	F	S	S	S
25% NaCl	F	S	F	S
Saturated NaCl solution	F	S	F	F

A:

B:

C:

D:

Draw the monomer structure of PETE (2pts) :

Solution	Density (g/cm^3 = g/mL)
Water	0.999 (1)
100% Isopropyl Alcohol	0.786
70% IA	0.88
46% IA	0.9011
Vegetable Oil	0.91 - 0.93
Sat. NaCl	1.202
10% NaCl	1.071
Calcium Chloride ($CaCl_2$)	1.4
Corn Oil	0.917 - 0.925

Plastic -- density (g/cm^3)
PETE -- 1.37
HDPE -- 0.95
LDPE -- 0.92
PVC -- 1.38
PP -- 0.9
PS -- 1.05
PMMA -- 1.16
PC -- 1.2

Question 1: ANSWERS

Plastics:
Plastic A was found at the scene. Float tests were conducted in various liquids. F means float, and S means Sink. ID all plastics (2pts each)

Plastics	A	B	C	D
Vegetable Oil	F	S	S	S
46% isopropyl alcohol	F	S	S	S
Water	F	S	S	S
10% NaCl	F	F	S	S
25% NaCl	F	F	F	S
Saturated NaCl solution	F	F	F	F

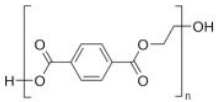
A: **PP** **Lightest density, floats in everything**

B: **PS** **More dense than water, less dense than 10% NaCl**

C: **PMMA** **More dense than 10% NaCl, less dense than saturated NaCl**

D: **PC** **More dense than PMMA**

Draw the monomer structure of PETE (2pts) :



Solution	Density (g/cm^3 = g/mL)
Water	0.999 (1)
100% Isopropyl Alcohol	0.786
70% IA	0.88
46% IA	0.9011
Vegetable Oil	0.91 - 0.93
Sat. NaCl	1.202
10% NaCl	1.071
Calcium Chloride ($CaCl_2$)	1.4
Corn Oil	0.917 - 0.925

Plastic -- density (g/cm^3)
PETE -- 1.37
HDPE -- 0.95
LDPE -- 0.92
PVC -- 1.38
PP -- 0.9
PS -- 1.05
PMMA -- 1.16
PC -- 1.2

Question 2

The blood test at the lab produced the following results:

ANTI - A	ANTI - B	ANTI - D	CONTROL

What is the blood type shown in the lab results?

12. What is hair made of? What pigment gives hair its color?

14. What is the medullary index? How can it be used to identify hairs?

Question 2: ANSWERS

The blood test at the lab produced the following results:

ANTI - A	ANTI - B	ANTI - D	CONTROL

What is the blood type shown in the lab results?

(2 pts for correct letter, 1 pt for correct sign)

O+

12. What is hair made of? What pigment gives hair its color?

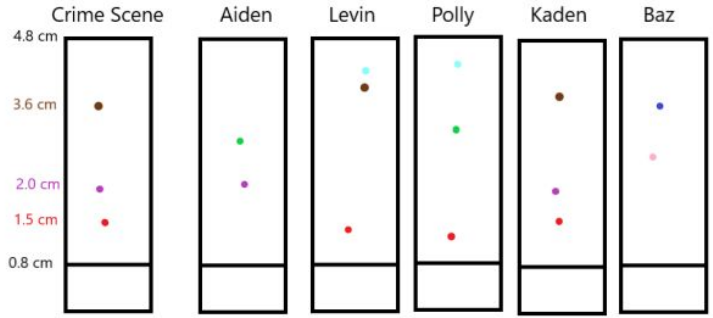
Keratin, melanin

14. What is the medullary index? How can it be used to identify hairs?

Ratio of the medulla width to the cortex width, animals have larger medullary indices than humans

Question 3

A chromatography lab was run on the ink used to write the note at the crime scene. Analyze the results and compare them to the chromatogram of each of the suspect's pens. The distance traveled is labeled for the crime scene only. You do not need to calculate the distance traveled for the suspects.



Calculate the Rf values to two decimal places for the red, purple, and brown dot on the Crime Scene chromatogram. (Assume that the solvent traveled the complete distance of the paper)

Red (3 pts):

Purple (3 pts):

Brown (3 pts):

What does Rf stand for? (2pts)

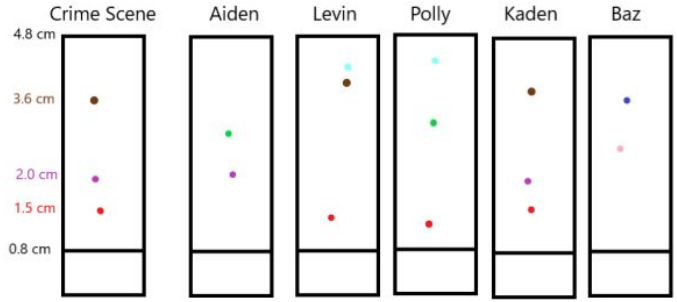
The stationary phase was polar, and the mobile phase was nonpolar. Based off this information, which pigment was the most polar in the Crime Scene chromatogram? The least polar?

Most Polar (3 pts):

Least Polar (3 pts):

Question 3: ANSWERS

A chromatography lab was run on the ink used to write the note at the crime scene. Analyze the results and compare them to the chromatography of each of the suspect's pens. The distance traveled is labeled for the crime scene only. You do not need to calculate the distance traveled for the suspects.



Calculate the Rf values to two decimal places for the red, purple, and brown dot on the Crime Scene chromatogram. (Assume that the solvent traveled the complete distance of the paper)

Red (3 pts): 0.18

Purple (3 pts): 0.30 (accept 0.3)

Brown (3 pts): 0.70 (accept 0.7)

What does Rf stand for? (2 pts) Retention Factor or Retardation Factor

The stationary phase was nonpolar, and the mobile phase was polar. Based off this information, which pigment was the most polar in the Crime Scene chromatogram? The least polar?

Most Polar (3 pts): Brown

Least Polar (3 pts): Red

Tips from a Veteran

- Practice with your cheatsheet
- Split up the workload - I recommend the powder/polymer split for Forensics
- Timing is key - maximize your points no matter what
- Keep organized notes - these are key to understanding some concepts so you don't have to overfill your cheatsheet
- Practice, practice, practice (tests)!!

Additional Resources

NC State SO

Some practice tests + notes

Forensic Science Simplified

Wikipedia (lol)

Resources: Chemicals/Lab Equipment

- Ward's Science Forensics kits
- Ward's Science Crime Buster kit
- Ward's Science Crime Buster Lab Equipment
- Official soinc.org website also links to these kits!

THANKS!