**Forensics** is a [Division C](https://scioly.org/wiki/index.php/Division_C) chemistry event that involves identification of powders, polymers, fibers, and hair samples, blood serum and fingerprint analysis, and interpretation of chromatography. 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.

The competition will involve using pre-brought materials to analyze data. The participants may also bring five pages (both sides) containing information in any form from any source (sheet protectors are permitted). Note: in the past, only one or two note sheets were allowed.

This event is closely associated with the [Division B](https://scioly.org/wiki/index.php/Division_B) event, [Crime Busters](https://scioly.org/wiki/index.php/Crime_Busters), both of which have been in rotation continuously for many years.

**Resources and Requirements**

Forensics requires each competitor to bring safety equipment - specifically, [Category C goggles](https://scioly.org/wiki/index.php/Safety_Glasses#Category_C) and either a lab coat or an apron - in addition to complying with various safety requirements listed in the rules. Teams are typically not allowed to compete without satisfying these conditions.

Forensics allows each team to bring in five [note sheets](https://scioly.org/wiki/index.php/Note_Sheet). In addition, the rules include a list of labware that teams may bring to the competition (it is allowable to compete without these, but this is very disadvantageous).

**Topics Covered**

* Qualitative Analysis (powders)
* Polymers
* Chromatography/Spectroscopy
* Fingerprint Analysis
* DNA
* Glass Analysis
* Entomology
* Spatters
* Seeds and Pollen
* Tracks and Soil
* Blood
* Bullet Striations
* Balancing Chemical Reactions/Chemistry

**Qualitative Analysis**

Qualitative Analysis is the section of the test that involves the identification of unknown powders. The number of powders given can be within the given ranges based upon the level of competition. 3-8 powders will be given at the regional level, 6-10 samples will be given at the state level, and 10-14 powders will be given at the national level competition.

It is helpful to include a flowchart to aid with powders identification on your note sheet.

There are fifteen different substances that may be given in a test. These are sodium acetate, sodium chloride, sodium hydrogen carbonate (sodium bicarbonate), sodium carbonate, lithium chloride, potassium chloride, calcium nitrate, calcium sulfate, calcium carbonate, cornstarch, glucose, sucrose, magnesium sulfate, boric acid, and ammonium chloride. Utilizing all availible means of identification will give the best results and help draw a more accurate conclusion.

**Methods of Identification**

**Flame test**: The flame test uses a Bunsen burner and a nichrome wire. If nichrome wire is not available, wooden splints (such as coffee stirrers) soaked in water work well too. To perform this test, dip a clean nichrome wire in distilled water, and then dip the loop of the wire into a small sample of the dry chemical. Hold the loop of the wire in the cone of the flame, and observe the color of the burning chemical. If desired, a piece of cobalt blue glass may be used for viewing. Chemical cations determine the color of the flame, and their characteristics may indicate the chemical identity.

* **Sodium**: yellow flame, very distinct. Even a small amount of sodium will contaminate other compounds.
* **Lithium**: carmine or red flame
* **Calcium**: yellow-red flame
* **Boric Acid**: bright green flame, very visible
* **Ammonium Chloride**: faint green flame
* **Potassium**: light purple, lavender flame

Note that sodium can easily contaminate some substances, and its presence can mask the other cation colors, giving off a yellow flame. The purpose of the cobalt blue glass is to block of the yellow color given off by sodium in case the sample may have been contaminated. In some cases, this yellow color can appear a little orangish.

**Tests with liquids**: Liquids used for identification are iodine, sodium hydroxide, hydrochloric acid, Benedict's solution, and water. Not all liquids are applicable to all samples.

* **Iodine**: When iodine is added to cornstarch, the sample will turn black. If cornstarch is not present, the iodine will remain brown.
* **Sodium Hydroxide**: Sodium hydroxide is used simply to categorize your samples into two fields: NaOH reactive- and non-reactive. For this reason, it is extremely useful when using a flowchart. To perform this test, a few drops of NaOH is added to a small sample of chemical dissolved in water. If a milky-white precipitate forms, the sample is NaOH reactive. If a precipitate does not form, the sample is NaOH non-reactive.
* **Hydrochloric Acid**: Hydrochloric acid will react when added to samples contaning carbonates--therefore, it is useful in identifying calcium carbonate, sodium carbonate, and sodium hydrogen carbonate.
* **Benedict's solution**: Benedict's solution is used to detect glucose. To perform this test, dissolve a small sample of chemical in water in a test tube. Add two to three drops of Benedict's solution, then place the test tube in a hot water bath. If the glucose is present, the sample will react and form an orange precipitate. This test may take a few minutes; be patient. An important fact to note is that sucrose will **not** react with Benedict's solution but glucose will. Benedict's solution can also be used to test for ammonium chloride. Adding a couple drops will turn the sample a dark blue.
* **Water**: Water is used for determining the solubility of chemical samples, and is used for making solutions.

**pH**: The pH data for chemicals can be useful, especially for determining between two similar chemicals. Most samples have a pH of between 5 and 7, but there are several chemicals that have distinct pH's.

**Conductivity**: Certain chemical samples will dissociate and become conductive when dissolved in water. To perform this test, dissolve a small sample of dry chemical in water. Using a 9-volt conductivity tester will determine whether a sample is conductive or semi-conductive. This data is especially helpful when following a flowchart.

**Solubility**: All samples can be divided into two fields--soluble and non-soluble. Water is used to perform this test.

* **Soluble Samples**: sodium acetate, sodium chloride, sodium hydrogen carbonate, sodium carbonate, lithium chloride, potassium chloride, calcium nitrate, glucose, sucrose, magnesium sulfate, boric acid, ammonium chloride
* **Non-soluble Samples**: calcium sulfate, calcium carbonate, cornstarch

**Polymers**

Methods of Identification

* Burn test--fibers and hair only
* Density in liquids--oil, water, alcohol, etc.--plastics
* Microscope--useful for distinguishing different hairs and fibers

**Hints** Burn tests for fibers, when permitted, will usually be done with a small candle (Bunsen burners are too hot). Burn tests on plastics will not be permitted at the event, but burn test results may be provided. If not, it is important to know densities and other identifying properties. Common liquids used to test plastic densities include water, vegetable oil, isopropyl alcohol, and NaCl solution (10%, 25%, and saturated).

**Plastics**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Plastic**  | **Abbreviation**  | **Density**  | **Monomer Unit Structure**  | **Other Key Features**  | **Commonly Used to Make**  |
| **Polystyrene**  | PS  | ~1.05 g/cm^3  | Sty01.gif | Polymerizes by addition, reacts with acetone  | styrofoam, tableware, coffee cups, toys, lighting, signs, insulation  |
| **Polypropylene**  | PP  | ~0.90 g/cm^3  | Prop01.gif | Polymerizes by addition  | food containers, medicine containers, automobile batteries, carpet, rope, plastic wrap, lab equipment  |
| **Polyvinyl Chloride**  | PVC  | ~1.38 g/cm^3  | Pvc01.gif | Burns green, polymerizes by addition  | food packaging, shampoo containers, construction (ahem PVC pipes ... you see them often), tiles, credit cards  |
| **Low Density Polyethylene**  | LDPE  | ~0.92 g/cm^3  | Pe.jpg | Polymerizes by addition, ethylene monomer units branch out more than HDPE  | food containers (specifically bags), grocery bags, plastic wrap, etc.  |
| **High Density Polyethylene**  | HDPE  | ~0.95 g/cm^3  | Pe.jpg | Polymerizes by addition, monomer units more linear  | food containers, bags, lumber, furniture, flower pots, signs, trash cans, toys  |
| **Polycarbonate**  | PC  | ~1.20 g/cm^3  | Pc.jpg | Polymerizes by condensation, clear  | shatterproof glass, eyeglass lenses  |
| **Polyethylene Terephthalate**  | PETE  | ~1.37 g/cm^3  | Polyethylene terephthalate svg.jpg | Polymerizes by condensation, shrivels with heat  | soft drink bottles, carpet, fiberfill, rope, scouring pads, fabric, Mylar  |
| **Polymethyl Methacrylate**  | PMMA  | ~1.16 g/cm^3  | Pmma.gif | Polymerizes by addition, reacts with acetone  | Plexiglas, glass substitute  |

Just to clarify how LDPE differs from HDPE ...



(Lines represent the connected ethylene monomer units)

**Fibers**

There are three types of fibers: animal, vegetable, and synthetic/man-made. Each of these types of fibers behave differently in different tests, but generally fibers of the same type will react in a similar way.

**Burn Test**

* Animal fibers shrivel, but don't melt
* Synthetic fibers melt and shrivel, and loose ends fuse together
* Vegetable fibers do not melt or shrivel, but they ignite easily and usually appear charred after being burned.

**Other Useful Facts**

* Animal fibers dissolve in bleach, but the other types will not react at all (nice to know although the bleach test isn't available during competition)
* Smoother fibers are more likely to be synthetic
* Synthetic fibers are generally uniform in thickness whereas natural fibers vary.

**Individual Fiber Information**

|  |
| --- |
| **Fiber Information**  |
| **Name of Fiber**  | **Type of Fiber**  | **Fact About Fiber Type**  | **Burn Test Results**  | **Microscopic View**  |
| Wool  | Animal  | Most commonly used animal fiber  | shrivels, leaves brown-black residue, smells like burning hair  | cylinder with scales  |
| Silk  | Animal  | Smoother than wool  | shrivels, leaves black residue, smells like burning hair  | thin, long and smooth cylinder  |
| Cotton  | Vegetable  | Most widely used plant fiber, fairly short fibers  | burns with a steady flame, smells like burning paper, able to blow flame from thread like a match, leaves a charred whitish ash  | irregular twisted ribbon  |
| Linen  | Vegetable  | fibers generally longer and smoother than cotton  | burns at a constant rate, does not produce smoke, smells like burning grass, produces sparks  | smooth, bamboo like structure  |
| Polyester  | Synthetic  | fibers can be any length  | melts, only ignites when in the flame, drips when it burns and bonds quickly to any surface it drips on, produces sweet odor and hard, colored (same as fiber) ash  | completely smooth cylinder  |
| Nylon  | Synthetic  | long fibers  | curls, melts, produces black residue, smells like burning plastic (some sources say it smells like celery?), ignites only when brought into flame  | fine, round, smooth, translucent  |
| Spandex  | Synthetic  | can stretch to eight times its original length  | melts quickly  | Flattened, ridged fibers, clustered  |

**Hair**

There are five types of hair to know for competition: human, squirrel, cow, horse and bat hair. While you can perform burn tests, they aren't as effective differentiators as they are for fibers, so microscope is the primary way to identify hair.

**Hair parts**

Also see the Anatomy Wiki's Integumentary System section for more info, but the ones to know for Forensics are the cuticle, cortex, medulla, and root. The cuticle, cortex, and medulla are layers of the shaft from the outermost to the innermost. Most hairs in Forensics are characterized and distinct by their medulla and cuticle.



**Human**

Characteristics:

* scaly cuticle (called imbricate)
* amorphous medulla, very thin if visible at all



**Squirrel**



**Cow**



**Horse**

Characteristics:

* very coarse, thick
* medulla is absent to unbroken; cellular or amorphous (mosaic pattern)
* imbricate scales on cuticle



**Bat**

Characteristics:

* very fine
* distinguishable by coronal scales on cuticle - looks like a stack of paper cups, or as the Woz says, "strawberries on a stick"



**Chromatography**

There are several types of chromatography, but only two will likely be covered in competition: paper chromatography and TLC (thin layer chromatography). Paper chromatography is just paper, and TLC is a glass slide with a thin silicone layer, but they both do the same thing, and you can set both up using the same process. There are plenty of youtube videos out there that can show how to set it up. Basically, chromatography is used to separate the chemicals within a substance, allowing identification between seemingly similar substances.

There is also ink chromatography and juice chromatography. Likewise, both are set up the same way, but with juice chromatograms, the sample must be applied to the paper or TLC slide by another instrument.

Most competitions ask for Rf calculations. Rf is retention factor or rate of flow.

Formula: Rf=p/s where the variable "p" is the distance the pigment (the ink or juice) travels and the variable "s" is the distance the solvent (usually water or acetone) travels.

**Mass Spectrometry**

Mass spectrometry is an analytical method used to determine the mass to charge ratio of charged particles.

The mass spectrogram of dodecane is shown below:



A few things to note about the mass spectrogram of dodecane:

* The y-axis is a measure of the percent abundance
* The x-axis is the m/z ratio (molar mass)
* The lines are known as peaks

**Reading Mass Spectrograms**

1) Search for a molecular ion peak first. It may not always be present, but it is the peak with the highest m/z ratio. The Nominal Molecular Weight (MW) is a rounded value assigned to the molecule representing the closest whole number to the molecular weight. This value is even if the compound being analyzed contains simply Carbon, Hydrogen, Oxygen, Sulfer, or Silicon. The value will be odd if any of these elements are combined with an odd number of Nitrogen.

2) Attempt to calculate the chemical formula, using isotopic peaks and using this order: Look for A+2 elements: O, Si, S, Cl, Br; Look for A+1 elements: C, N; And then: "A" elements: H, F, P, I. From looking at the isotopic peaks, it is possible to determine relative abundance of specific elements.

3) Calculate the total number of rings plus double bonds: For the molecular formula: CxHyNzOn rings + double bonds = x - (1/2)y + (1/2)z + 1

4) Try to determine the molecular structure based upon abundance or isotopes and m/z of fragments.

**Fingerprints**

Fingerprints are formed by the arrangement of volmer (or volmar) pads. They are made mostly of sweat and water but can also contain various organic and nonorganic compounds.

**Patterns**

There are eight fingerprint patterns to know. They are:

* Plain Whorl
* Ulnar Loop
* Radial Loop
* Plain Arch
* Tented Arch
* Central Pocket Loop
* Double Loop
* Accidental Whorl



Whorls have two or more deltas. The presence of more than two deltas indicates an accidental whorl.

Loops have only one delta. The difference between an ulnar loop and a radial loop is that ulnar loops "enter and exit" on the side facing the pinky (the side of the wrist containing the ulna) while radial loops do so on the side facing the thumb (the side of the wrist containing the radius).

Arches have no deltas. Tented arches are easily distinguishable by the triangular core.

**Types of Prints**

Fingerprints can be in different forms when found.

* **Visible**: As the name suggests, these ones can easily be seen because they were made with a substance like ink or blood. They can also easily be photographed without development.
* **Impression**: Made in soft material such as clay. Less easy to detect than visible fingerprints, but can still be photographed without development.
* **Latent**: Invisible fingerprints. These must be developed before photographed.

**Methods of Development**

Latent prints must be developed in order to be seen. There are four common methods and one less common method:

* **Dusting**: Powder applied to prints sticks to fatty acids and lipids.
* **Iodine Fuming**: Self-explanatory by its name. It was one of the earliest methods of fingerprint development. The iodine reacts with body fats and oils in prints.
* **Ninhydrin**: a chemical method useful for lifting latent prints on paper. It reacts with amino acids in prints.
* **Cyanoacrylate (Superglue) Fuming**: Also self-explanatory by its name. It also reacts with moisture in the air as well as reacting with substances in the prints, forming sticky white material along ridges. Good for nonporous surfaces.
* **Small Particle Reagent (SPR)**: Not as common as the other methods used, but still important. SPR is used for wet surfaces and reacts with the lipids present in fingerprints.

**Features**



**DNA**

Although many competitions that have include DNA as evidence require matching of DNA fingerprints, questions about basic DNA physiology and principles come up along with them. PCR (Polymerase Chain Reaction), a method of synthetic DNA replication, also comes up sometimes.

**Ground Facts You Should Know**

* DNA stands for deoxyribonucleic acid (yes, sometimes they ask this)
* The four nucleotides that compose DNA are adenine, cytosine, thymine, and guanine.
* With a DNA fingerprint, larger fragments of DNA are located on the right side while smaller ones are located on the left.
	+ This is because of gel electrophoresis, which make the fingerprints. When the current runs through the gel during this process, because DNA is negatively charged, it will move towards the positive end of the box. Smaller fragments of DNA will obviously move farther through the gel filter than larger ones.



**PCR**

PCR, as already stated, stands for **P**olymerase **C**hain **R**eaction; it is a method of synthetic DNA replication developed in the late 20th century. PCR has been very crucial to molecular biology and forensics, then and now, so its development earned a Nobel Prize.



**Glass**

**The Rule to Remember!**

If the glass's refractive index is the same or close to that of a liquid, then the piece of glass will not be visible in that liquid (use exact same liquids that are used for plastics)

**Fractures**

* Cracks end at existing cracks
* A small force forms circular cracks
* Radial cracks and chonchoidal cracks make right angles, but face different ways. When dealing with fractures, remember the 3Rs of glass fracture: **R**adial cracks at **R**ight angles on the **R**everse side of impact.
* A force very close to the glass before impact, such as a gunshot or a rock, will completely shatter the glass

**Entomology**

Stages of insects found on a dead body can tell how long the victim has been dead. The most common are the blowfly and the beetle. Blowflies appear first, within minutes or hours of the death. Flesh flies can arrive at the same time as blow flies, but generally arrive slightly later. Certain amounts of time lapse between each life stage, which can tell this time. For example, if only maggots were found on the dead body, that means the victim probably died less than twenty-four hours ago. Beetles usually arrive well after the blow and flesh flies, and are generally the last insect left on the body after months of decomposition. Mites are also generally present with these beetles initially because they help suppress maggots, and as such allow certain types of beetles.



Life Cycle of Blowflies



Fly Life cycle



Insects Involved in Forensic Entomology

**Blood Spatters**

Blood Spatters are generally classified by velocity at which they form.

|  |
| --- |
| Blood Spatters  |
| Blood spatter low.gif | Low Velocity Formation.  | Appears to be droplike and forms at speeds less then 5f/s  |
| Blood spatter med.gif | Medium Velocity Formation | Appears in a linear type of drop pattern 5-25 f/s  |
| Blood spatter high.gif | High Velocity Formation | Appears in essentially a random pattern around 100 f/s  |

**Angle of Impact:** The angle at which a spatter hits a surface. The formula for it is:

θ=arcsin(W/L)

Where theta (θ) is the angle, W is the width of the spatter, and L is the length.

Note that arcsin is also known as inverse sine.

**Seeds and Pollen**

In this section of the competition, almost no practice is needed. The participants must be able to compare the evidence from the crime scene to that which is found on the suspects. They may also be required to match certain types of seeds or pollens to a region of the nation or world, which is generally common sense. It is, however, helpful to have a general knowledge about various kinds of pollen and common regionally identifiable plants. This may include plants such as cotton or rice, which can only gro in specific climates.

**Tracks and Soil**

**Tracks**

In this section, most observations will be qualitative. Often, the only necessary action is to compare the given photographa to the track provided at the "scene." These tracks can be footprints or tire tracks, both of which can be identified by the tread that is left on the ground. Checking the pattern, shape, and size of each distinct part of the sole on a shoe is generally necessary to make a 100% accurate match.

**Soil**

Soil can be used as a way to possibly connect a suspect to the general area of the crime. For example, if the crime was committed at the beach (however unlikely it is), and one suspect had sand on him, then you could possibly infer that the suspect was near the scene of the crime.

**Blood Typing**

It is important to remember the ABO blood typing system when identifying a blood sample. There are four blood types in human blood; These include A, B, AB, and O. The ABO blood testing method is used to determine the blood type of any human. Using Antigen A and Antigen B serums, it is possible to find any blood type. If the blood reacts with the A antigen only, then it is type A. If it reacts only with B antigen, it is type. If it reacts with both, then the blood type is AB, and if it reacts with none of the testing liquids, then it is O.

**Bullet Striations**

Bullet striations are pretty much just like tracks. Pretty much the only thing you have to do is try to match the one of the suspects' bullet striation to that of the one found at the scene.

**Competition Strategies**

* Although the lab and written portions of Forensics are weighted almost at an even 50-50, make it a priority to include lab practice with the substances themselves as part of competition preparation. Many experienced competitors cannot stress this enough as a key factor to success because even with the amount of points you can earn from the Crime Scene Physical Evidence questions or even the Crime Scene Analysis essay, which are written, you'll still need to do well on the lab portion to score even higher. Plus, even the Crime Scene Analysis essay is usually dependent on the lab portion since you'd have to identify which powders were at the scene in order to get a better idea of who the suspect is.
* Make flowcharts (or develop a mental routine if that suits you better) while you observe the lab tests, especially for powders and plastics.
* Forensics is a very partner-dependent event. Most exams are so long that it is nearly impossible to finish without two people.
	+ Once you find out who your partner is, split the different skill areas with him or her however you wish and learn each of the areas you have so you can split the test accordingly when you go into the competition so you'll be able to get to most of the test. (Pro-tip: national medalist pikachu4919's favorite strategy is a powder/polymer split)

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