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Chemistry for Crime Detection

Introduction

"He is the criminal."

Until investigators can claim the above, they must follow well-defined steps and processes. Crime scene investigations require careful, detailed, and tedious processes to ensure who did what, where, when, and how, based on testimony of reliable witnesses, or preferably, physical evidence obtained from the scene. Crime scene investigators collect evidence to solve the crime. In this collection process, three major chemical techniques of forensic science applied; they are luminol to detect traces of blood, development of fingerprints, and DNA profiling.

Luminol

In a room where a murder has occurred, the lights are turned off and all windows are closed. With the help of a suitable chemical, blue spots appear here and there; these spots can provide crucial evidence. Although nothing was visible when the lights were on, spraying a particular liquid and blocking sources of light can reveal hidden traces of blood. This search for blood is frequently shown on TV whenever the police and FBI solve a crime. Blood traces are often very important in a crime investigation process.

But from where is the blue light coming?

It comes from a chemical called luminol, that exhibits chemiluminescence when it is mixed with an oxidizing agent.[9] Investigators mix luminol powder with a liquid containing

hydrogen peroxide and a hydroxyl group and spray it where blood particles may exist. Blood pools can be cleaned up by criminals after the crime, but without heavy-duty cleaning chemicals, blood particles remain for years, although they may not be visible to the naked eye.[6] Luminol and hydrogen peroxide are the two major fluids that give blue light. As the reactants of the oxidation reaction of luminol have more energy than the products, energy is released in the form of visible light photons. However, the reaction requires a catalyst. Iron found in hemoglobin of human blood acts as the catalyst. Luminol can detect very small amounts of blood that may be very old. [6]

Figure 1 shows the reaction.

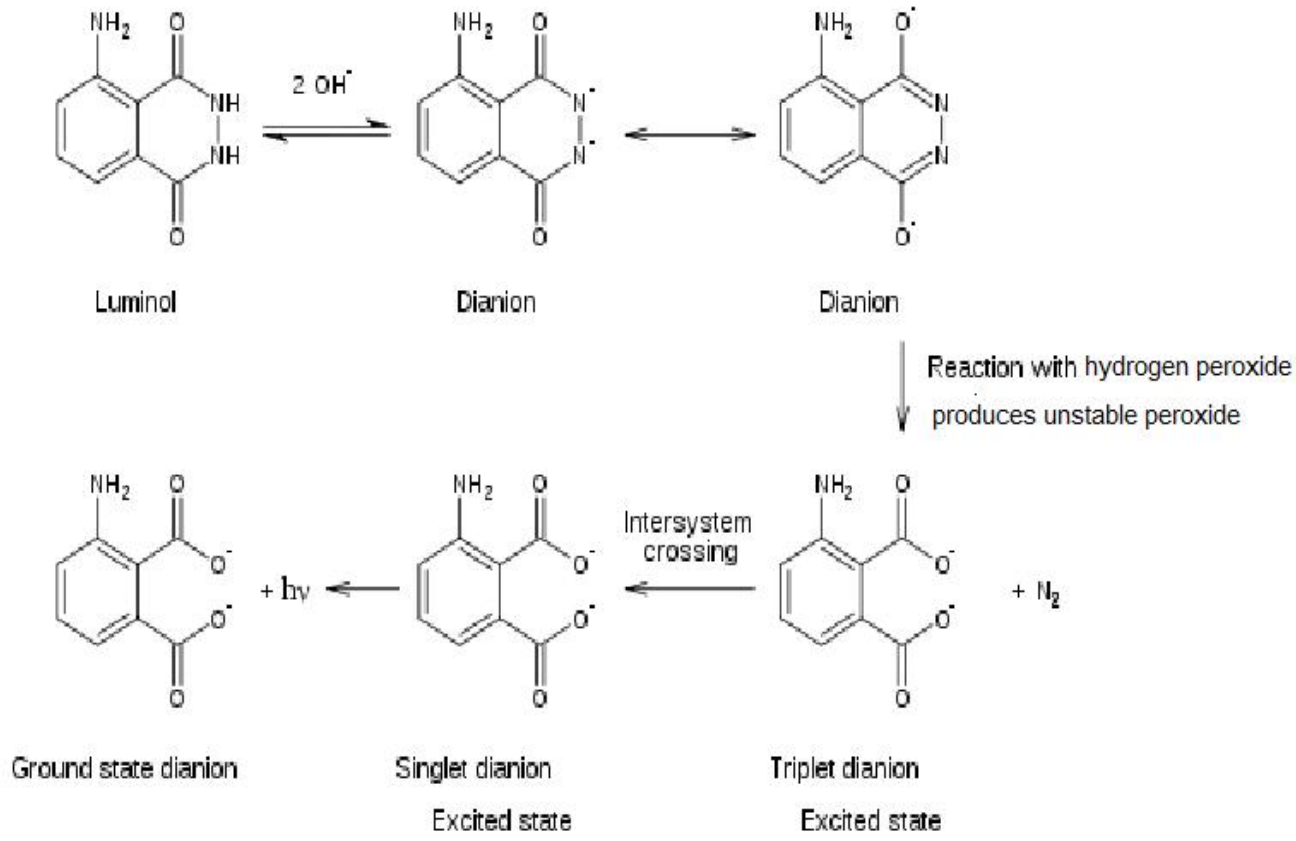

Figure 1. Reaction Process of Luminol and an Oxydizing Agent in the Presence of Iron (from Hemoglobin in Blood) (from Wikipedia [9])

However, luminol has several drawbacks. Luminol chemiluminescence can also be catalyzed by copper containing materials, some types of bleaches, fecal matter, and animal blood. Also, luminol may hinder other tests for evidence. However, DNA samples may be successfully collected from the scene even in the presence of luminol.[9]

Luminol alone usually cannot solve a crime, unlike the other two methods of forensic science explained later. Yet, luminol may give critical clues to solving some mysteries. Hidden blood splatter patterns may indicate how the crime occurred. For example, blood patterns give hints as to what weapon was used in what way and in which direction. Bloody shoe prints reveal what the criminal did right after an attack. Moreover, luminol can lead to more physical evidence. Where blue light appears, traces of blood may be hidden under the surface, for example, on the floorboards under the carpet.[6] This blood sample can be analyzed for DNA profiling, as explained later.

Fingerprinting

It is common knowledge that even two identical twins have different fingerprints. The individual uniqueness and permanence of fingerprints can provide crucial evidence for who was at the scene under investigation. But how are fingerprints collected and visualized?

Sometimes fingerprints are visible with the naked eye, for example, when a material such as paint, dirt, or blood is transferred from the fingers to a surface. In this case, since the prints are visible, they are photographed without extraction or lifting. These visible fingerprints are called patent prints.

However, there are many cases where the fingerprints are not visible to the eye. But, because sweat on the fingertips is deposited wherever the fingers touch a surface, it is possible to capture the fingerprint patterns using chemical reactions. These fingerprints are called latent.

Powder Dusting

The simplest and most common method of fingerprint collection is to use powder that consists of a colorant and a resinous polymer or an inorganic salt. The moisture or oil from sweat adsorbs on the polymer or salt and the polymer or salt adsorbs the colorant.[13] To preserve the fingerprints, the polymers or salts should not chemically react with the surface nor be strongly attracted to it.[14] Some commonly used polymers include silica gel and starch; salts include zinc carbonate, barium carbonate, and magnesium carbonate; some common colorants are charcoal, manganese dioxide, ferric oxide, and aluminum oxide.[13] A grey powder, usually containing aluminum, is used on black or dark surfaces, whereas a black charcoal dust is used on white or colored surfaces.[14] A shortcoming of the powder dusting method is that the moisture or oil in sweat tends to dry up within two or three days.[15] Thus, for older prints, other methods are used.

Silver Nitrate

Silver nitrate is one of the oldest reagents used to develop latent fingerprints. Silver nitrate reacts with the chloride component of sweat to form silver chloride, which is light sensitive. When exposed to light, the silver chloride decomposes into black silver, making the fingerprint patterns visible. However, because chloride diffuses on the surface, distorting the pattern, silver nitrate also cannot be used for prints that are older than about one week.[8]

Ninhydrin

Ninhydrin (2,2-dihydroxyindane-1,3-dione) is a reagent able to detect prints as old as thirty years. Ninhydrin reacts with the amino acid in sweat to give a dark purple color.[13] Ninhydrin is effective when the fingerprints are on paper. They can be enhanced to give a better contrast with the surface by reacting the paper with zinc or cadmium salts to change the color of the prints to orange or red, respectively.[15]

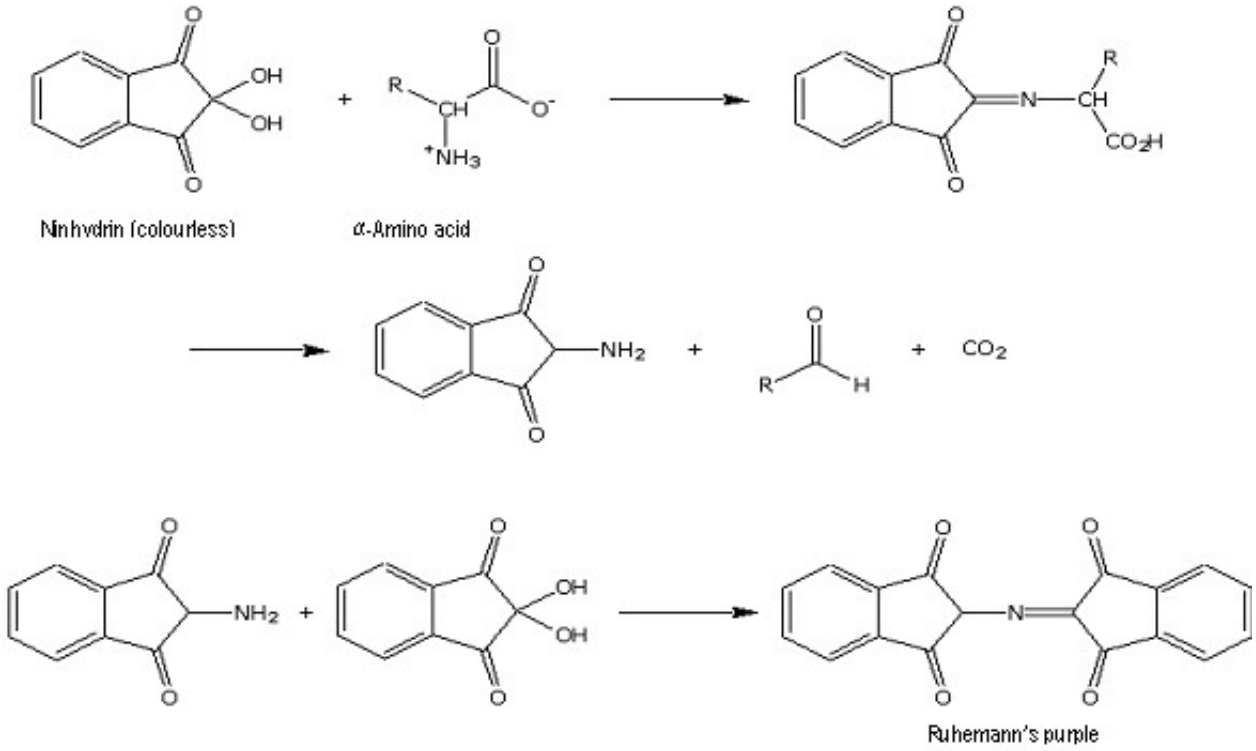

Figure 2. Reaction of Ninhydrin with an amino acid

(from McGrory et. al[10])

History and Development of Fingerprinting Techniques

Although fingerprints were used as substitutes for signatures many centuries ago, fingerprinting was first used in forensics in the 19th century.[15] In 1892, Sir Francis Galton, a British anthropologist and a cousin of Charles Darwin, published the book "Finger Prints,"

that introduced the first system for classifying fingerprints. A criminal was identified using fingerprints in the same year by Juan Vucetich, an Argentine police officer who had studied Galton's works. Vucetich successfully identified a woman guilty of murdering her two sons by looking at bloody fingerprints at the scene. In 1906, fingerprint identification of criminals was first introduced in the U.S.[5] Nowadays, with the development of the Integrated Automated Fingerprint Identification Systems (IAFIS), digital fingerprints collected using sensors are used not only for criminal checks, but also for employment, licenses, and social service programs. In less than thirty minutes, IAFIS allows police, and others, to search and retrieve fingerprints collected anywhere in the country. IAFIS has access to a massive database, containing one in every six people's fingerprints.[5]

DNA Profiling

In December 2005, Evan Simmons was proven innocent of the 1981 attack on a woman that earlier had led to his conviction and twenty four years in prison. In 2002, Douglas Echols was freed from all charges after serving over five years in prison followed by parole for ten years for a 1986 rape case he did not commit.[3] These cases of exoneration made by DNA evidence are representative of over 200, in the U.S. alone.[11] As with fingerprinting, the same basic principles of individuality and permanence apply to the use of DNA profiling. Although humans share 99.9% of their genes, each person has a different DNA sequence. Upon analysis using chemical technology, DNA patterns allow forensic scientists to identify to whom the DNA sample belongs. How is DNA profiled?

DNA profiling is the process of collecting, processing, and analyzing VNTRs (variable number tandem repeats), which are unique sequences on a part of a chromosome. The methods differ according to cost, time analysis, and to quality and quantity of available sample.[4]

RFLP

In a method called RFLP (restriction fragment length polymorphism), first, the double-stranded DNA is extracted from the sample. The DNA is then cut into small pieces with restriction enzymes that cut the DNA where a specific sequence occurs. The fragments are separated by a process called electrophoresis, wherein the fragments are aligned in agarose gel; voltage is applied, stimulating the fragments to move from one end of the gel to the other. The smaller a fragment, the faster it will move.[4]

The fragments are exposed to HCl to cause depurination, that is, hydrolysis of the link between the purine base and the deoxyribose-phosphate backbone; then, they are cleaved by reactions with NaOH or NaCl. This eases the transfer of fragments on to a nitrocellulose or nylon membrane. These stained sheets allow fragments to be visible to the naked eye. The DNA sequences are examined by ^{32}P-radiolabeled single pieces of DNA strands, called probes, that bind on to their complementary fragments. The radiolabelled membrane is exposed to radiation to create dark parallel bands, giving the desired DNA profile.[12] The process is illustrated simply in Figure 3.

RFLP was the first method of profiling DNA. Because it requires a large sample of DNA, for example, as much as 25 hairs and a nickel-sized blood spot, and can take up to a month to complete, another technique, called STRs (short tandem repeats), is commonly used today.[4]

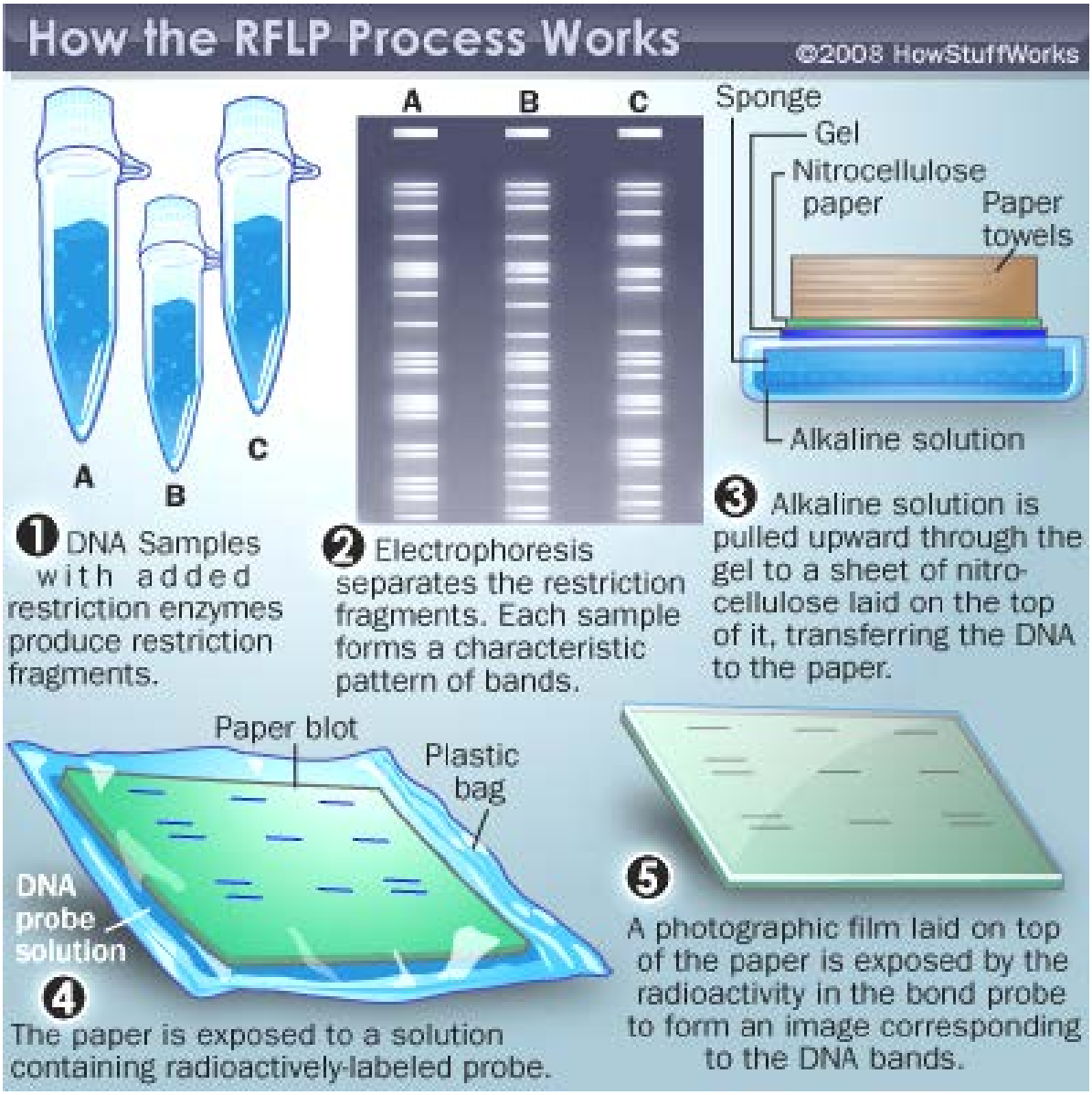

Figure 3. How the RFLP Process Works

(from How Stuff Works[4])

STR

A PCR (polymerase chain reaction) is performed with a small amount of a DNA sample. In a PCR, a heat-stable DNA polymerase is added to make replications of the DNA and then is heated to about 94℃ to separate the strands, then is cooled, and reheated. The

reheating doubles the number of DNA copies, and after the process is repeated about 30 times, the DNA sample is large enough for STR.[12] The amplified DNA is then extracted by capillary electrophoresis, where the fragments are separated based on electric charge and friction forces, proportional to size, in a small capillary filled with an electrolyte.[2] The DNA is visualized by silver staining, done manually, or by a fluorescent dye, done by machines.[12] STR analysis is much more accurate than RFLP analysis because the fragments are smaller, making them easier to separate and tell apart. In the U.S., investigators use the Combined DNA Index System (CODIS), a database with DNA samples of 13 STR analyzed loci, fixed regions of chromosomes. The possibility of two people having an identical record on the CODIS is about one in a billion.[7]

AmpFLP

AmpFLP (amplified fragment length polymorphism) is another method for DNA profiling. It uses a restriction enzyme as in RFLP, then PCR to amplify fragments. The fragments are then separated by gel electrophoresis. The advantage of this technique is that it can be automated and is relatively inexpensive. However, the DNA sample must be of high quality.[3]

History and Development of DNA Profiling

DNA profiling, or DNA fingerprinting as it was called earlier, was first introduced in 1985 by an English geneticist Alec Jeffreys. He discovered that there are regions of DNA that repeat over and over and that the number of repeated regions differs for every individual. These regions of the DNA were called VNTRs (variable number tandem repeats). DNA profiling was first used in crime investigation in 1986, in the UK, to solve a rape and murder

case and at the same time, to exonerate an innocent man who had been wrongfully accused. In the U.S., DNA profiling was first introduced in 1987. Using RFLP analysis, Tommy Lee Andrews was convicted of a series of sexual assaults in Florida.[1]

Today, DNA profiling is not only used to identify or clear potential criminals, but also for paternity testing, identification of bodies and skeletal remains, for studying human evolution and inherited illnesses.[7]

Conclusion

Chemical technology provides effective methods for criminology. Crime scene investigators base their search on the principle that nothing disappears without a trace. Chemical science allows investigators to dig deep, to find hidden traces that are not evident at first sight.

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