Forensic Aspects of Fire Investigation and Explosives

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Lecture Order Change

Mar 2, 5 Drugs 2 (Ch11), Forensic Toxicology (Ch 12)

Mar 9,12 Bloodstain pattern analysis (Ch10); Fire Investigation (Ch 16)

Mar 16, 19 Guest lecture Entomology; Biological Stain Analysis: DNA (Ch 15)

Mar 23, 26 Biocrime / Microbial Forensics

Overview

Introduction

Chemistry of Fire

Investigating fire origins

Laboratory analysis of arson evidence

Explosives

Investigating scenes of explosions

Lab analysis of explosion evidence

Introduction

- Arsons are often difficult to investigate since the perpetrator thoroughly planned the act, is not present during the act, and the destruction is so extensive.
- The forensic scientist's function is limited to detecting and identifying relevant chemical materials collected at the scene and reconstructing and identifying igniter mechanisms.
- Ultimately the determination of the cause of a fire must be made by an investigator whose training and knowledge have been augmented by the experience of fire investigation.
- This may not be an easy task

Police and firefighters are using special machines that pump out hot air at 300 degrees Celsius to melt the thick ice coating the structure. - Jennifer Tyron/Global News, Jan 30, 2014

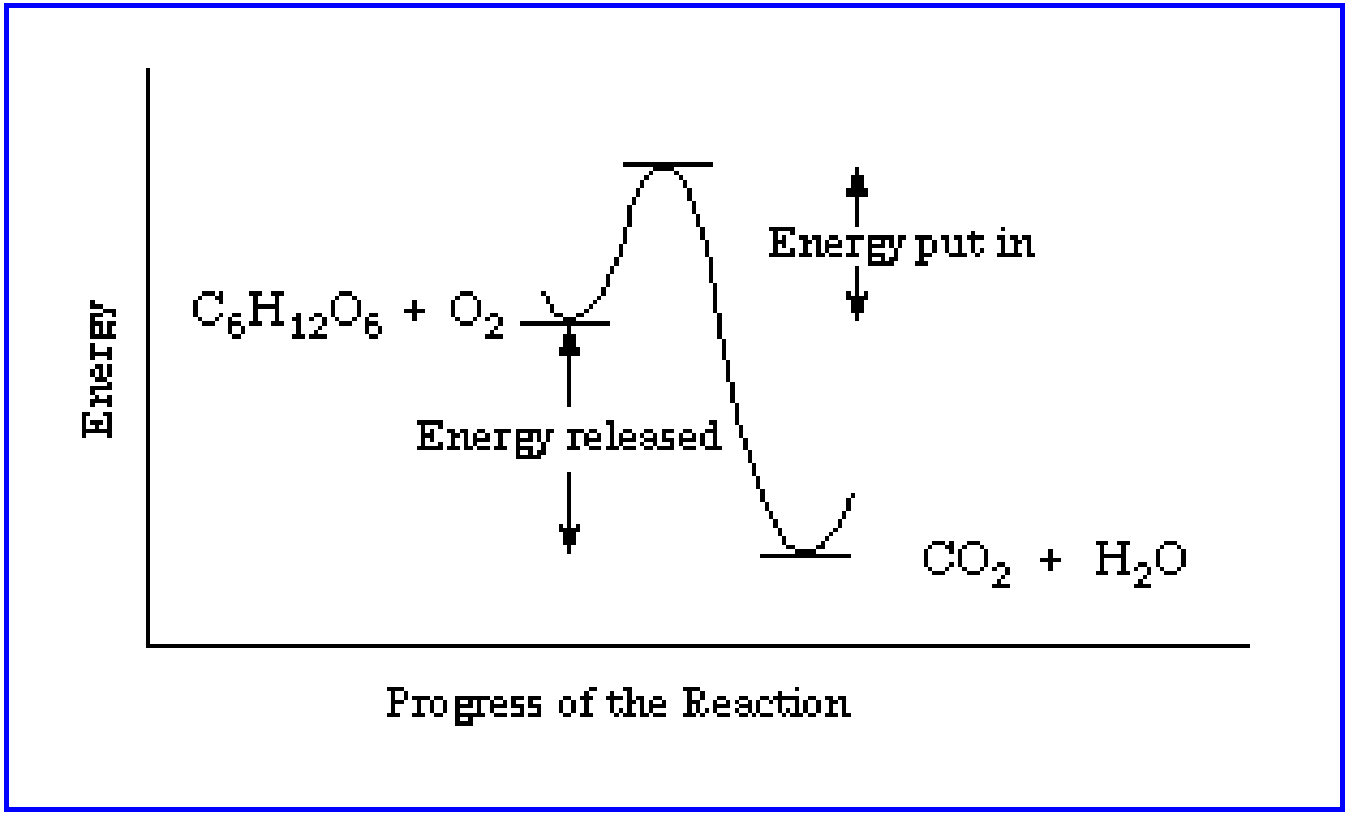
Oxidation

- Chemically, fire is a type of oxidation, which is the combination of oxygen with other substances to produce new substances.
  - Not all oxidation reactions proceed in a manner that one associates with a fire; e.g., rusting.
  - An oxidation reaction is associated with the concept of energy. Energy is associated with the ability of a system to do work. Steam can turn a turbine to generate electrical energy. Energy takes many forms; e.g., heat and light.
  - All oxidation reactions are examples in which more energy is liberated than what is required to initiate the reaction. These are known as exothermic reactions.

Combustion

- To start fire, the ignition temperature must be reached – which is the minimum temperature needed to spontaneously ignite fuel.
- The heat involved when a substance burns is known as heat of combustion.
- Once combustion starts energy in the form of heat and light (flame) is liberated.
- Fire is a chain reaction since a portion of the energy liberated by combustion is used to sustain the fire

Activation Energy and Oxidation



http://www.biologie.uni-hamburg.de/b-online/library/newton/Chy251_253/Lectures/Reactions/ReactionProfiles.html

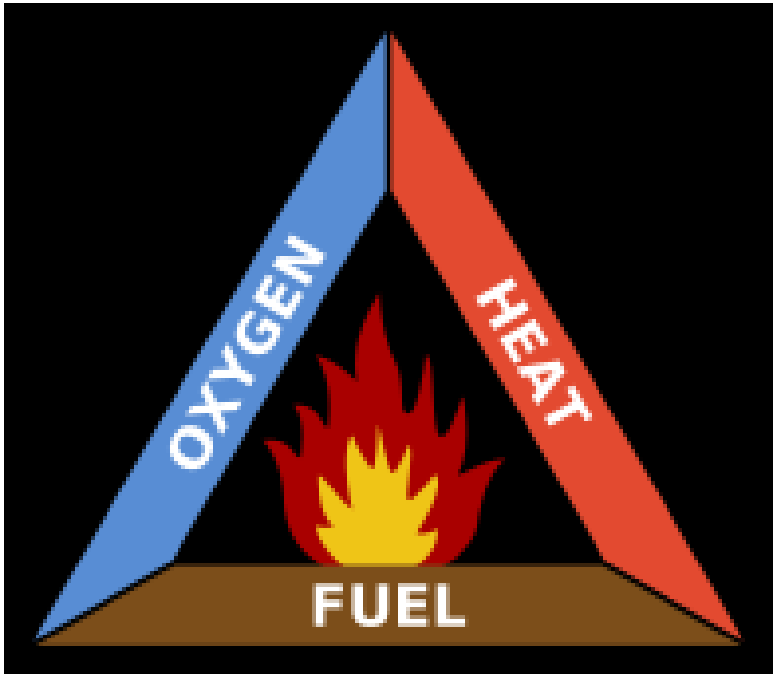
Combustion

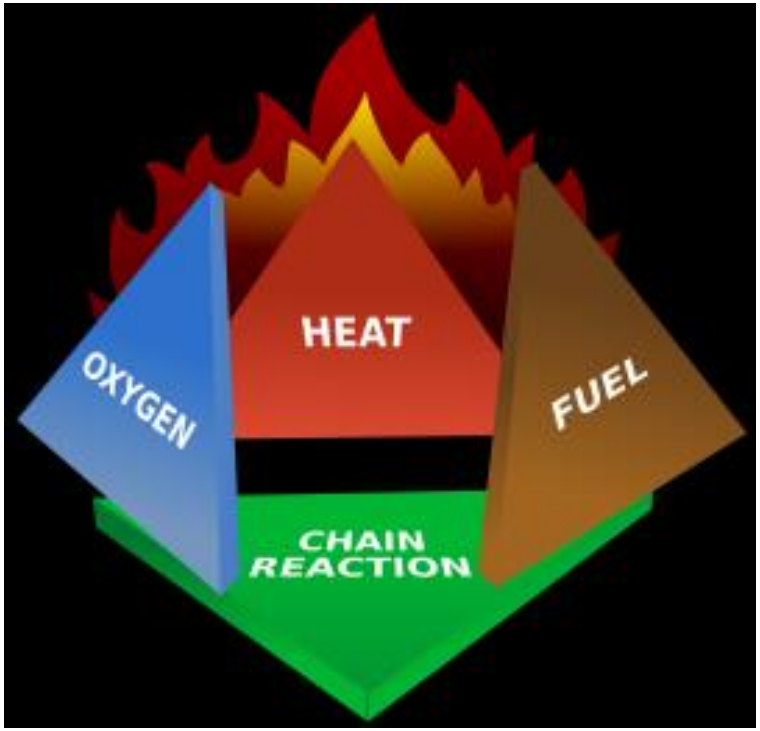
To initiate and sustain a fire, the following are required:

- A fuel (vapor) must be present.
- Oxygen must be available in sufficient quantity to combine with the fuel.
- Heat must be applied to initiate the combustion, and sufficient heat must be generated to sustain the reaction.

Memory Aids

Combustion triangle and fire tetrahedron





http://en.wikipedia.org/wiki/Fire_triangle

Physical State of the Fuel

- A fuel achieves a reaction rate with oxygen sufficient to produce a flame only when it is in the gaseous state. Thus, rusting will not be accompanied by a flame.

- A liquid burns when the temperature is high enough to vaporize the fuel. The flash point is the lowest temperature at which a liquid produces enough vapor to burn.

- A solid such as wood burns only when exposed to heat hot enough to decompose it into gaseous products (pyrolysis).

- Glowing combustion or smoldering is burning at the fuel-air interface, such as a cigarette, the embers of a wood fire, or a charcoal fire.

http://www.businessinsider.com/photos-from-the-investigation-into-the-quebec-train-crash-2013-7?op=1

http://en.wikipedia.org/wiki/Smouldering

http://bgfons.com/download/3931

The Fire Scene

- The arson investigator needs to begin examining a fire scene for signs of arson as soon as the fire has been extinguished.

- Experience shows that most arsons are started with petroleum-based accelerants.

- The search of the fire scene must focus on finding the fire's origin, which may be most productive in any search for an accelerant or ignition device.

Indicators of Arson

- Some telltale signs of arson include evidence of separate and unconnected fires, the use of “streamers” to spread the fire from one area to another.
- An irregularly shaped pattern on the floor resulting from the pouring of accelerant onto the surface.
- Normally, a fire has a tendency to move in an upward direction, and thus the probable origin will most likely be the lowest point showing the most intense characteristics of burning.

Indicators of Arson Continued

- Evidence of severe burning found on the floor (as opposed to the ceiling) of a structure is indicative of a flammable liquid.
- Discovery of an ignition device: The most common igniter is a match, but arsonists can construct many other types of devices to start a fire, including burning cigarettes, firearms, ammunition, a mechanical match-striker, electrical sparking devices, and a “Molotov cocktail.”
- Fortunately, combustible liquids are rarely entirely consumed during a fire.

Students in the class study the fire behavior indicators after having grid-searched the specific point of origin and located the cause of the fire (a firework located near the ruler at the bottom of the burn).

http://www.blm.gov/mt/st/en/info/newsroom/steward/07summer/fire.html

Collection of Fire Scene Evidence

At the suspected point of origin of a fire, ash and soot, along with porous materials which may contain excess accelerant, should be collected and stored in airtight containers such as new paint cans or wide-mouth glass jars, leaving an airspace to remove samples. Never use plastic containers to store fire scene evidence.

Traces of flammable liquid residues

may be located with a vapor detector

(sniffer) or a trained canine.

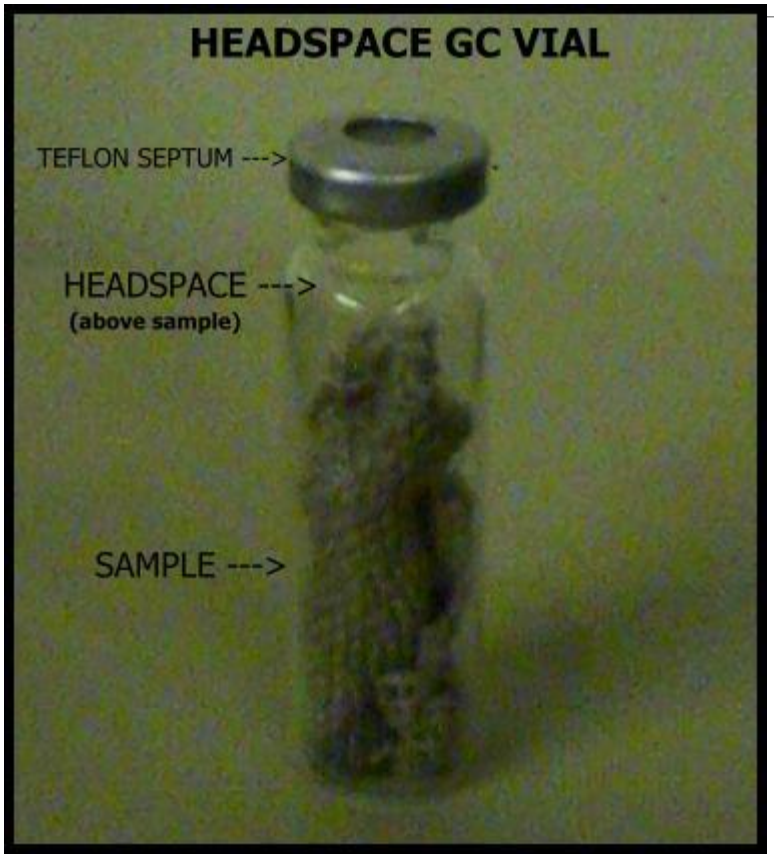
http://www.calgarycitynews.com/2013/12/the-calgary-fire-department-graduates.html

The collection of all materials suspected of containing volatile liquids must be accompanied by a thorough sampling of similar but uncontaminated control specimens from another area of the fire scene, called a substrate control.

Laboratory Recovery of Flammable Residues

- The easiest way to recover accelerant residues from fire-scene debris is to heat the airtight container in which the sample is sent to the laboratory.
- When the container is heated, any volatile residue in the debris is driven off and trapped in the container's enclosed airspace.
- The vapor or *headspace* is then removed with a syringe.
- When the vapor is injected into the gas chromatograph, it is separated into its components, and each peak is recorded on the chromatogram.

Accelerant Analysis



http://www.angelfire.com/tx/Miket/accelerant2.html

http://www.tcforensic.com.au/docs/masters.html

Laboratory Recovery of Flammable Residues

In the *vapor concentration* technique, a charcoal strip is placed in the airtight debris container when it is heated.

- The charcoal strip absorbs much of the vapors during heating.
- The strip is washed with a solvent which will recover the accelerant vapors.
- The solvent is then injected into the gas chromatograph for analysis.

Gas Chromatography

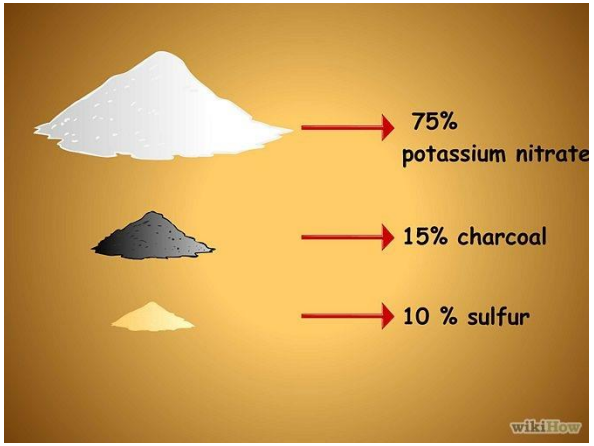
- In the laboratory, the gas chromatograph is the most sensitive and reliable instrument for detecting and characterizing flammable residues.
- The vast majority of arsons are initiated by petroleum distillates such as gasoline and kerosene.
- The gas chromatograph separates the hydrocarbon components and produces a chromatographic pattern characteristic of a particular petroleum product.
- By comparing select gas chromatographic peaks recovered from fire-scene debris to known flammable liquids, a forensic analyst may be able to identify the accelerant used to initiate the fire. The chromatographic pattern of the unknown is compared to patterns produced by known petroleum products.

Explosions

Explosions

- Explosives are substances that undergo a rapid oxidation reaction with the production of large quantities of gases.
- It is this sudden buildup of gas pressure that constitutes the nature of an explosion.
- The speed at which explosives decompose permits their classification as high or low explosives.

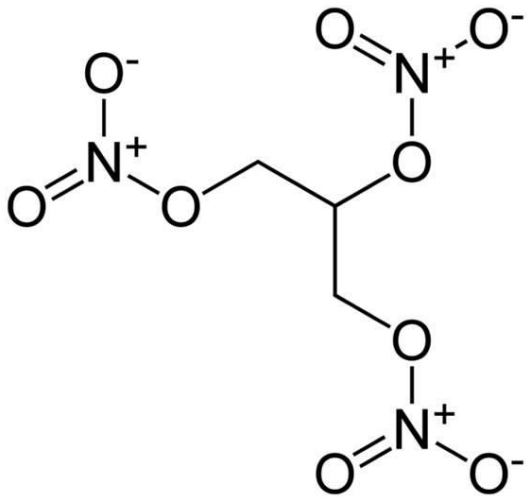
Low Explosives



http://www.wikihow.com/Make-Black-Powder

The most widely used explosives in the low-explosive group are black powder and smokeless powder.

- Black powder is a mixture of potassium or sodium nitrate, charcoal, and sulfur.
- Smokeless powder consists of nitrated cotton (nitrocellulose) or nitroglycerin and nitrocellulose.



Low explosives can be confined to a container like a pipe. The speed of decomposition is called deflagration causing the walls of the container to fragment and fly outward in all directions.

http://chemistry.about.com/od/factsstructures/ig/Chemical-Structures---N/Nitroglycerin---Nitroglycerine.htm

High Explosives

Among the high explosives:

- Primary explosives are ultra-sensitive to heat, shock, or friction and provide the major ingredients found in blasting caps or primers used to detonate other explosives.
- Secondary explosives are relatively insensitive to heat, shock, or friction and will normally burn rather than detonate if ignited in small quantities in the open air.

This group comprises the majority of commercial and military blasting, such as dynamite, TNT, PETN, and RDX.

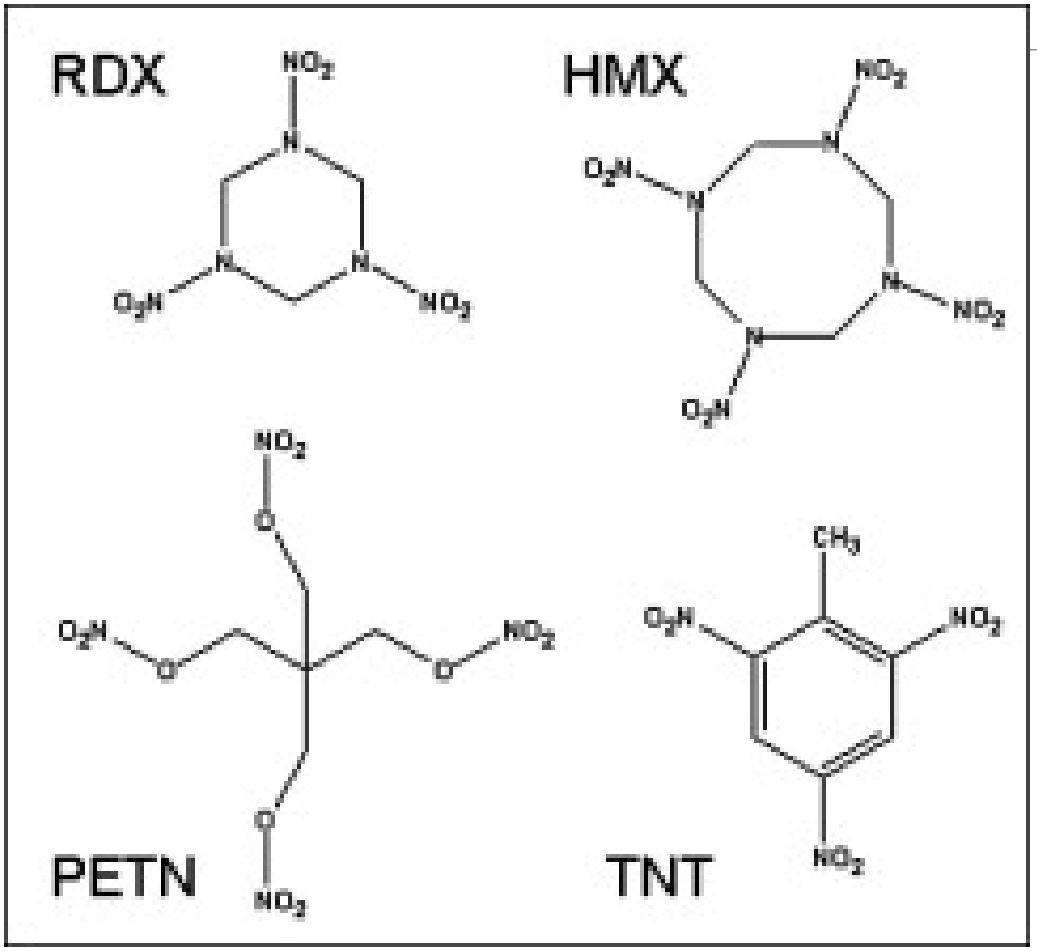
High Explosives

- Secondary explosives must be detonated by a primary explosive.

- The speed of decomposition is known as detonation. It is extremely rapid producing a supersonic shock wave creating a blast effect with an outward rush of gases at speeds as high as 7,000 miles per hour.

- In recent years, nitroglycerin-based dynamite has all but disappeared from the industrial explosive market and has been replaced by ammonium nitrate-based explosives.

Explosive compounds react rapidly because they contain an oxygen source



http://www.sciencedirect.com/science/journal/00092614/443

RDX = Research Department eXplosive;

HMX = His/Her Majesty's Explosive also called Octogen;

PETN= Pentaerythritol tetranitrate also known as PENT, PENTA, TEN, corpent, penthrite

Military and Peroxide Explosives

In many countries outside the United States, the accessibility of military high explosives to terrorist organizations makes them very common constituents of homemade bombs.

RDX is the most popular and powerful of the military explosives, often encountered in the form of pliable plastic known as C-4.

Triacetone triperoxide (TATP) is a homemade explosive that has been used by terrorist organizations.

- TATP can be made by combining acetone and peroxide in the presence of an acid.
- Its existence has led to the banning of most liquids on commercial aircraft.

Collection and Analysis

- The entire bomb site must be systematically searched with great care given to recovering any trace of a detonating mechanism or any other item foreign to the explosion site.

- Objects located at or near the origin of the explosion must be collected for laboratory examination.

- Often a crater is located at the origin and loose soil and other debris must be preserved from its interior for laboratory analysis.

Collection and Analysis

- All materials collected for the examination by the laboratory must be placed in sealed air-tight containers and labeled with all pertinent information.
- Debris and articles collected from different areas are to be packaged in separate air-tight containers.
- It has been demonstrated that some explosives can diffuse through plastic and contaminate nearby containers.

Lab Analysis

- Typically, in the laboratory, debris collected at explosion scenes will be examined microscopically for unconsumed explosive particles.
- Recovered debris may also be thoroughly rinsed with organic solvents and analyzed by testing procedures that include color spot tests, thin-layer chromatography, and gas chromatography/mass spectrometry.
- Confirmatory identification tests may be performed on unexploded materials by infrared spectrophotometry.

Recap

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