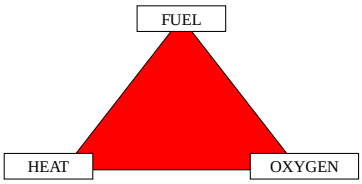
Forensic Science:
Arson and Fire Investigation
(Chapters 14-15)

Fire Investigation Terms

- **Fire -** Produced when a substance undergoes rapid oxidation involving heat and light.
- **Fire Triangle** – Shows the three elements needed to produce and sustain a fire.
- **Flash Point** – The lowest temperature to which a substance must be heated in order for the substance to give off vapors which will burn when exposed to a flame or ignition source.
- **Point of Origin** – The location where the fire started.
- **Burn patterns** –Noticeable patterns created by the fire as it burns.
- **Accelerants** – Substances, such as gasoline, paint thinner, and alcohol, that accelerate the burning process.
- **Arson** – A fire started deliberately.
- **Modus Operandi** – an offender's pattern of operation
- **Exothermic Reaction –** Heat energy is given off
- **Endothermic Reaction -** Heat energy is absorbed from the surroundings

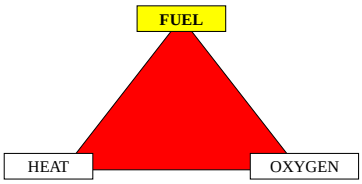
Fuel + Oxygen + Heat = Fire

The **FIRE TRIANGLE** represents the **three** elements needed for fire to occur: heat, fuel, and oxygen.

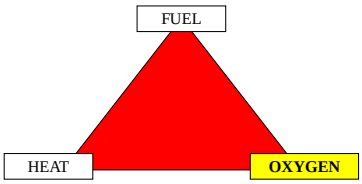


Fuel can be any **combustible material** in **any state of matter** - solid, liquid, or gas. Most solids and liquids become a **vapor or gas** before they will burn.

Examples:
CLOTHING
FURNITURE
CURTAINS
FLAMMABLE LIQUIDS



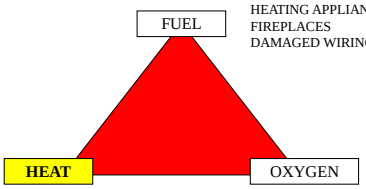
The air we breathe is about **21% oxygen**. Fire requires an atmosphere with at least **16% oxygen**.



Remember: Fuel + Oxygen + Heat = Fire

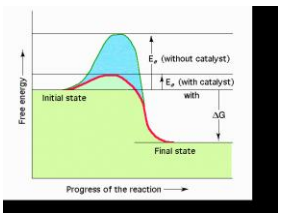
Heat is the energy necessary to **increase the temperature of the fuel** to a point where sufficient vapors are given off for **ignition** to occur.

Examples:
STOVES
HEATING APPLIANCES
FIREPLACES
DAMAGED WIRING



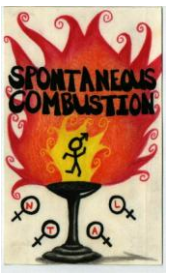
Requirement for Combustion

- **Ignition temp** is the minimum temperature at which fuel vapor will ignite



Spontaneous Combustion

- A **natural heat-producing process** that may give rise to a fire in the presence of sufficient air & fuel
  - Ex. hay stored in barns growing medium for bacteria which generate heat
  - Ex. rags soaked w/ highly unsaturated oils, such as linseed oil



Fire Clues

- **Point of Origin –** Burn patterns and other damage can help determine the point of origin, or the location where the fire started.
- **Char Patterns** – Created by very hot fires that burn very quickly and move fast along its path, so that there can be sharp lines between what is burned and what isn't.
  - A char pattern on a door would help an investigator determine which side of the door the fire was on.
  - A char pattern on the floor would help investigators determine the use of an accelerant and its path.
- **V-Patterns** - Fire burns up, in a V-shaped pattern, so a fire that starts at an outlet against a wall leaves a char pattern that points to the origin.
  - A very narrow V-shape might indicate a fire that was hotter than normal, such as one helped along by an accelerant.
  - A wide V-shape might indicate a fire that was slow burning.
  - A U-shape could indicate that there was a "pool of origin" rather than a point of origin, such as might be caused by, say, a puddle of gasoline.
- **Glass -** Glass fragments, windows, and light bulbs can provide clues to a fire.
  - Light bulbs tend to melt toward the heat source, so the "direction of melt" can indicate the direction of the fire.
  - A dark soot layer on the glass could indicate a slow, smoldering fire.
  - Clear glass with an abnormal pattern of cracking could imply a very hot fire, possibly due to an accelerant.
- **Chimney Effect** - Since fire burns upwards, there can be a "chimney effect" where the fire ignites at a point, the superheated gases rise upward and form a fireball, which continues straight up to burn a hole in the ceiling. If the roof is not entirely burnt, and the fire investigator finds such a hole, the origin of the fire could be directly underneath.
- **Color of smoke** – Determine what type material was burning
- **Color of flames** – Indicates at what temperature the fire was burning.

Fire Investigation Basics

- Work from the least damaged areas to the most heavily damaged areas.
- In accidental fires, floor damage is limited in respect to ceiling damage
- Document with notes, photographs, and videos.
- Collect evidence
- Interview witnesses
- Determine the point of origin.
- Determine the heat source(s).

Evidence of Accelerant Use

- Large amounts of damage
- Unusual burn patterns
- High heat stress
- Multiple sites of origin

Tools at fire scene

- Portable gas chromatographs
- Chemical tests
- Canines
- Portable detectors (“sniffer”)

- Dogs can detect 0.01 µL of 50% evaporated gasoline 100% of the time.
- 0.01 µL is about the size of one thousandth of a drop.

Steps to Recover and Identify Accelerants

- Collect samples (both questionable and substrate controls)
- Extract the fire debris and obtain a sample for instrumental analysis
- Carry out instrumental analysis (usually GC/MS but TLC also used as screening tool)
- Interpret the results

Evidence Containers

- The evidence container should have the following qualities:
  - Air tight
  - Highly resistant to breakage
  - Prevents cross-contamination
  - Good integrity seal

OHT 10.5

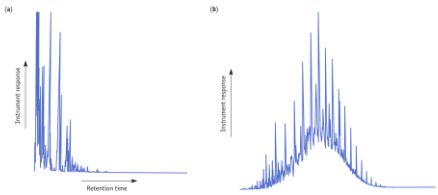


Figure 10.9 Typical gas chromatograms of (a) petrol and (b) diesel oil, note that these were recorded under identical conditions

Supplied by Neil Lamont, Staffordshire University, UK.

Jackson & Jackson: *Forensic Science* © Andrew R. W. Jackson and Julie M. Jackson 2004

Accident or Arson?

- **Accidental Nature**
  - Heating System
  - Electrical appliances
  - Lightning
  - Children playing with matches
  - Smoking
- **Non-Accident**
  - Odors – Gas, kerosene, or other accelerants
  - Furnishing – Removal of personal objects and valuables
  - Clothing – Check debris for buttons, zippers, etc
  - Locked windows, blocked doors
  - Two or more points of origin
  - Look for inverted v-patterns (can be a sign that an accelerant was used)
  - Floors charred –Can indicate use of an accelerant
  - Trailers that lead the fire from one place to another

Image: Havana Rural Fire Department

Arson Facts in America

According to the FBI Crime Index, juvenile and adult arson cause an annual average of 560,000 fires, 750 deaths, 3,700 injuries, and $1.5 billion in property loss. 55% of all arson arrests in the US are children under 18.

What are Common Motives for Arson?

- **Crime concealment**: To conceal another crime such as murder, burglary, or vehicle.
- **Revenge or spite**: To get back at someone for a perceived injustice.
- **Monetary Gain**: Arson-for-Profit fires are set to burn a building, vehicle, or some other object in order to gain profit from the fire. The profit may come in several forms; from insurance coverage on the property, or from putting a competitor out of business.
- **Malicious Vandalism**: Fire set to someone's property, just to destroy it. Malicious vandalism fires account for the largest percentage of arson fires. These fires are frequently set by juveniles.
- **Mentally Disturbed**: Some persons have been found to have an irresistible impulse to set fires.

Source: http://www.state.il.us/osfm/Arson/ArsonIsAFelonyCrime.htm

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.

Explosives

Explosives are classified as high and low explosives based on their speed of decomposition.

- In a high explosive, it is called the speed of detonation.
  - ✓ Detonation refers to the creation of a supersonic shock wave within the explosive charge. This leads to the new instantaneous buildup of heat and gases.
- In a low explosive, is called the speed of deflagration (burning).
  - ✓ very rapid oxidation that produces heat, light, & a subsonic pressure wave.

High Explosives

• Detonate almost instantaneously
• Categorized into Primary or Secondary Explosives

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

• Comprises the majority of commercial and military blasting
  - **PETN** (pentaerythritol tetranitrate)
  - **TNT** (trinitrotoluene)
  - **Dynamite**
  - **RDX** (cyclotrimethylenetrinitramine) - the most powerful & popular for military use (known as **C-4**)

Low Explosives

- Explosive with a velocity less than 1,000 meters per second.
- Produce a throwing or propelling action (useful for ammunition and skyrockets)

- **Black powder:**
  - ✓ a mixture of *potassium nitrate, carbon & sulfur* in a 75/15/10 ratio
  - ✓ Commonly used in safety fuses to carry a flame
- **Smokeless powder**
  - ✓ nitrocellulose or nitroglycerin/nitrocellulose mixture

- The only ingredients required are fuel and a good oxidizing agent (substance that supplies oxygen to a chemical rxn.)
  - ✓ Potassium chlorate + sugar is popular

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 examination.

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