

# (1) Unit 5 - Arson, Explosives, Ballistics, & Impressions

## I. Arson

### A. The Chemistry of Fire

#1

1. Combustion - rapid combination of oxygen w/ another substance, accompanied by noticeable heat & light

#2

2. 3 Requirements to Initiate & Sustain Combustion

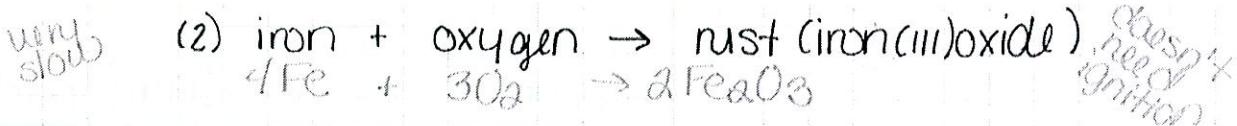
(A) A fuel must be present.

(B) Oxygen must be available in sufficient quantity to combine w/ the fuel.

(C) Heat must be applied to initiate the combustion & sufficient heat must be generated to sustain the reaction.

3. Combustion is a form of oxidation - reaction of a substance w/oxygen ( $O_2$ ) to form new products.

(A) All fire begins w/ oxidation

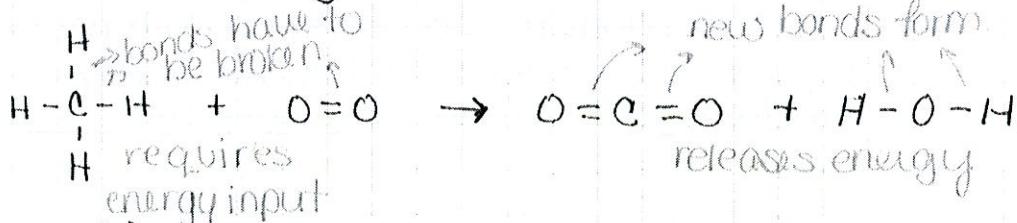


4. Energy - the ability or potential of a system or material to do work

(A) Energy takes many forms: heat, electrical, mechanical, nuclear, light, & chemical.

(B) combustion converts chemical energy to heat & light energy

(1) The amount of heat from a chemical reaction comes from the difference in energy of breaking & forming chemical bonds.



(2) exothermic reactions - more energy is released than was initially needed to break bonds & start the reaction

(a) heat of combustion - the excess energy released

(3) endothermic reactions - reaction requires more energy to break bonds than it releases when forming new bonds

## ② 5. Heat

#4 (A) ignition temperature - minimum temperature at which a fuel spontaneously ignites.

(i) once combustion starts, enough heat is released to keep the reaction going, like a chain reaction. It will continue until either the fuel or oxygen run out.

## b. Speed (Rate) of Reaction of Combustion

(A) The faster the molecules move, the greater the # of collisions between them, & the faster the reaction.

### (B) Factors Affecting Rate of Combustion

(i) Physical state of fuel - The only state of matter that has a rate fast enough to produce a flame is the gas state. #10

(a) Liquid and solid fuels have to become gases to burn!

#### (2) Fuel temperature

(a) Liquids - the temperature must be high enough to vaporize the fuel.

(i) The vapor (gas) mixes w/ O<sub>2</sub> and combusts

(ii) flash point - lowest temperature at which a

#7 liquid gives off enough vapor to support combustion. Flash point is always lower than ignition temperature  
Ex) gasoline: f.p. = -50°F i.t. = 495°F

(b) Solids - only burn when exposed to heat intense enough to decompose the solid into gas, called pyrolysis.

(c) The rate increases when the temperature is raised for most reactions - an 18°F (10°C) increase in temperature will double or triple the rate

(3) Fuel-Air mixture - combustion will occur only if there is the correct fuel to air (oxygen) ratio

#9 (a) flammable range - the range of possible gas/vapor fuel concentrations in air that are capable of burning

Ex) gasoline - 1.3-6.0%

(d) Glowing Combustion - combustion only on the surface of a solid fuel in the absence of heat high enough to pyrolyze the solid

Ex) glowing, red hot charcoals

(3)

#11

(5) Spontaneous Combustion - fire caused by a natural, heat-producing process in the presence of enough air and fuel.

Ex) hay, grain silos, oil soaked rags in an improperly ventilated container.

## 7. Heat Transfer

(A) Conduction - movement of heat through a solid object in which electrons and atoms within the heated object collide w/one another & transfer the heat energy.

- (1) metals - contain loosely held electrons, conduct heat well  
wood - tightly held electrons, poor conductors of heat, called insulators

(2) reconstruction of a fire scene

(a) heat will be conducted thru beams, nails, & bolts to places far from the heat source. Any fuel in contact w/ these things will ignite.

(b) paper, wood, & plastic are poor conductors. Heat will not spread well or cause ignition far from the initial heat source

(B) Radiation. - transfer of heat energy from a heated surface to a cooler one by electromagnetic (em) radiation. EM radiation moves in a straight line from one surface to another.

(1) plays a key role in understanding how fire spreads through a structure.

Ex) All surfaces that face a fire are exposed to radiant heat & burst into flame when the surface reaches ignition temperature. In large fires, nearby structures & cars can be ignited at a distance.

#14

(C) Convection. - transfer of heat by molecules moving within a liquid or gas.

Ex) In a structural fire, hot gaseous products of combustion expand & move to upper portions of the structure, becoming another source of heat & radiating the heat onto exposed surfaces that pyrolyze, releasing more gaseous products

#15

(1) Flashover - all combustible fuels spontaneously ignite, engulfing the entire structure in flame.

(4)

### 6. Searching the Fire Scene

1. Arson investigators begin examining the scene as soon as the fire has been extinguished

#16

(A) most arsons start w/ petroleum based accelerants - material used to start or sustain a fire, like gasoline or kerosene

(B) Look for containers that held the accelerant, ignition devices (candles to time-delay devices), & irregularly shaped pattern on the floor or ground (from pouring accelerant on the surface). Also look for signs of breaking & entering, theft

(C) Interview eyewitnesses

2. Timelines of Investigation - Arson investigators do NOT need a search warrant to investigate or collect evidence (by Supreme Court decision)

#16  
too

(A) accelerant residue can evaporate within hours or days

### 3. Locating the Fire's Origin

(A) Focus on search for an accelerant or ignition device

(B) May find evidence of separate & unconnected fires or the use of "streamer" to spread fire from 1 area to another.

#17

(C) Since fires spread upward, probable origin is most likely closest to the lowest point that shows the most intense characteristics of burning

(1) V-shaped pattern can form along a vertical wall

(2) If a liquid accelerant was used, charring will be most intense at bottom of object since liquids flow down.

(D) Air flow currents can direct the movement of the fire

(E) other considerations

(1) prevailing drafts & winds

(2) secondary fires due to collapsing floors & roofs

(3) physical arrangement of structure

(4) stairways & elevator shafts

(5) holes in floor, wall, or roof

(6) effects of fire fighter suppressing the fire

(F) Once origin is located, point of origin needs to be protected. Nothing should be moved. Sketches made & photos taken.

#18

(5)

#### 4. Searching for Accelerants

(A) Enough liquid accelerant may remain unchanged as it seeped into porous surfaces: cracks in the floor, upholstery, rags, plaster, wallboards, or carpet.

#19  
good  
screening  
device

(B) Portable hydrocarbon detector or "sniffer" - looks for traces of accelerant residues.

(1) sucks in air surrounding questioned sample, passed over a heated element. If combustible vapor is present, it oxidizes & increases temperature of filament which registers on the detector's meter

#### 5. Collection & Preservation of Arson Evidence

(A) 2-3 quarts of ash & soot debris is collected from the point of origin

(1) contains all porous materials & other substances thought to contain flammable residues.

(B) Packaging & Preservation

(1) immediately in air tight containers so residue is not lost to evaporation - clean, new paint cans with friction lids are often used. or wide-mouth glass jars w/air-tight lids.

(a) fill  $\frac{1}{2}$  -  $\frac{2}{3}$  full

(2) fluids in open bottles or cans should be collected & sealed, even if they appear empty

(C) Substrate control - uncontaminated control samples collected from another area of the fire scene

(D) Igniters and Other Evidence

(1) most common igniter - a match

(2) other igniters

(a) burning cigarette (d) mechanical match striker

(b) firearms

(e) electrical sparking devices

(c) ammunition

(f) molotov cocktail

(E) Also collect the clothing of the suspected perpetrator.

(6) C. Analysis of Flammable Residues (hydrocarbons)

disadvantage - limit to the vapor volume

(1) The Headspace Technique *that can be removed*

- (A) Heat the air-tight container containing the sample, the volatile residue vaporizes & is trapped in the container's headspace. The vapor is then removed with a syringe.
- (B) Vapor is injected into a gas chromatograph & separated into its components, which are shown as peaks on a chromatogram.
- (C) Classify components by comparing the chromatogram w/ ones of known accelerants.

(ILRC - The Ignitable Liquids Reference Collection  
ilrc.ucf.edu - over 500 liquids)

(2) Vapor Concentration

- (A) A charcoal-coated strip is placed in container w/ debris. Heated to 140°F (60°C) for an hour. A significant quantity of accelerant vaporizes & is absorbed by the strip. Strip is washed w/ a small amount of carbon disulfide & then that solvent is injected into the gas chromatograph.
- (i) increases detection at least 100x's over headspace technique.

#22

(3) mass spectrometry - sometimes gas chromatography isn't useful

- (A) Pass the separated component from gas chromatographic column through a mass spectrometer
- (i) fragments samples into ions. Analyst controls which ions will be detected or ignored. Eliminates extraneous peaks in the gas chromatogram.

## II Forensic Investigation of Explosion

### A. Explosives and Explosions

#### 1. The Chemistry of Fire

a. Explosions are similar to combustion, the only difference is the speed (rate) of the reaction.

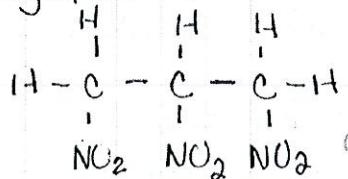
Explosions are extremely fast, producing large amounts of gas, building up high pressure

(1) Detonation occurs so fast, oxygen in the air cannot be used for the reaction. So many explosives must have their own source of oxygen, called oxidizing agents.

Ex) black powder - a mixture:

75% potassium nitrate ( $KNO_3$ ) when ignited, the oxygen is liberated & combines to form  $O_2(g)$  which builds up lots of pressure.  
 15% charcoal (C)  
 10% sulfur (S)

#### nitroglycerin



Oxygen is embedded w/i one molecule

#### 2. Types of Explosives

##### a. Low explosives

#23 (1) decompose at relatively slow rates, less than 1000 m/s, called deflagration - generate low-intensity pressure wave that can disrupt the surroundings

(2) when confined to small spaces, can explode w/ lethal force

##### (3) Types

###### #23 (a) black powder -

- (i) one of two most widely used explosives
- (ii) accessible to the public &/or relatively easy to make

(iii) mix of  $KNO_3$ , C, & S - see above

- unconfined: it just burns

- used in safety fuses - black powder infused cord that burns slow enough to allow people enough time to leave site.

#25

#23

(b) smokeless powder

- (i) other most widely used explosives  
 (ii) made of nitrocellulose (single-base powder)  
 or nitroglycerin mixed w/ nitrocellulose  
 (double-base powder)

pic pg 102

#23

(c) chlorate mixtures

- (i)  $KClO_3$  + sugar

+ C  
+ S  
+ starch  
+ P  
+ mg filings

#23

(d) Gas-Air Mixtures

- (i) only works w/i the flammable range of fuel-air concentrations  
 ex. gasoline 1.3-6% natural gas 5.3-13.9%

#26 b. High Explosives

- (1) decompose at relatively large rates, greater than  $1000 \text{ m/s}$ , called detonation - accompanied by a violent disruptive effect & an intense, high-speed pressure shock wave.

blw  
1000 m/s  
1000 m/s  
2000 m/s

- (2) do not have to be contained to cause damage

- (3) primary explosives - a high explosive that is easily detonated by heat, shock, or friction

- (a) used to detonate other explosives thru a chain reaction, referred to as primers

as blasting caps

pic pg 104

(b) lead azide

lead styphnate #26a

diazodinitrophenol

#27

- (4) secondary explosives - a high explosive that is

- relatively insensitive to heat, shock, & friction, normally burn rather than detonate in small quantities in open air

#26b  
pic pg 104  
all but dynamite  
per industrial  
explosives  
made

- (a) dynamite - also known as straight dynamite is rated by the weight % of nitroglycerin in the formula - nitroglycerin, pulp,  $NaNO_3$ , &  $CaCO_3$  stabilizer

Ex 40% str dynamite 60% str dynamite

modern

(blasting power is not directly proportional to %)

#26b  
pic pg 104  
made in 1867  
nitro glycerin  
a type of dynamite  
explosives

- (b) ammonium nitrate explosives ( $NH_4NO_3$ ) - mix oxygen-rich  $NH_4NO_3$  with a fuel to form a low cost, stable explosive

- #26b (i) water gel - resembles gel - toothpaste (3)  
- water-resistant → good in wet conditions  
-  $\text{NH}_4\text{NO}_3$  &  $\text{NaNO}_3$  gelled w/ guar gum & mixed with a combustible material like aluminum (fuel)
- #26b (ii) emulsion explosives - have 2 distinct phases - an oil phase & a water phase.  
- a droplet of supersaturated solution of  $\text{NH}_4\text{NO}_3$  surrounded by a hydrocarbon fuel.  
- typical emulsion is water, 1 or more inorganic nitrate oxidizers, oil, & emulsifying agents, & micron-sized glass, resin, or ceramic spheres - microspheres / microballoons
- #26b (iii) ANFO -  $\text{NH}_4\text{NO}_3$  soaked in fuel oil  
- inexpensive → form of fertilizer  
- easy to handle  
- wide applications in the mining industry  
- 1993 - NYC World Trade Center bombing
- #26b (iv) TATP - triacetone triperoxide  
- homemade explosive used as an improvised explosive by terrorist organizations in Israel & other Middle Eastern countries  
- prepared by reacting acetone &  $\text{H}_2\text{O}_2$  in the presence of an acid catalyst, like  $\text{HCl}$ .  
- friction & impact-insensitive & extremely powerful when confined.  
- 2005 London transit bombings
- (v) military High Explosives
- #26b - RDX - most popular & powerful, usually in the form of a pliable plastic, C-4
- #26b - TNT - trinitrotoluene - "military dynamite"  
↳ produced & used in large-scale during WWII.  
↳ wide application in shells, bombs, grenades, demolition explosives, & propellants.  
↳ contains no nitroglycerin  
↳ rarely encountered in bombings in US.
- #26b - PETN  
↳ used for small-caliber projectiles & grenades.  
↳ used commercially as a detonating core in a detonating cord (primacord) - connects a series of explosive charges so they all blow at once

## B. Collection & Analysis of Evidence of Explosions

1. Detecting and Recovering Evidence of Explosives
  - a. most obvious characteristic - presence of a crater at the origin of the blast.
    - (1) All loose soil and other debris must immediately be removed from interior of the hole & preserved.
    - (2) Porous materials near the pt. of origin are good sources for explosive residue
    - (3) Nonporous objects, like metal, can have residue on their surface
    - (4) any material blown away from the blast's origin
    - (5) search entire area for any trace of detonating mechanism or any other foreign object
      - (a) wire-mesh screens for sifting
      - (b) personnel should wear overalls, gloves, & shoe coverings
  - b. Ion mobility spectrometer (IMS) can be used - similar to arson machine, to detect explosives residue.
    - (a) preliminary id of residues
    - (b) can id plastic explosives & commercial & military explosives
  - c. Collection & Packaging
    - (1) airtight, sealed containers - materials
    - (2) soil & loose materials - metal paint cans
    - (3) no plastic bags, residues can escape

## C. Analysis of Evidence Explosives

1. 1<sup>st</sup> examined microscopically for unconsumed explosive
2. Then rinsed w/ acetone. If a water gel or a low explosive is suspected, rinse w/ H<sub>2</sub>O
3. Color tests run for presence of organic & inorganic explosives

### #29 4. Screening & Confirmation Tests

- a. color spot tests
  - b. thin-layer chromatography (TLC)
  - c. high-performance liquid chromatography (HPLC)
  - d. gas chromatogram/mass spectrometry
  - e. infrared spectrophotometry
  - f. x-ray diffraction
- } screening
- } confirm

#30