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1. Learning Outcomes

After studying this module, you shall be able to learn about

- Explosives.
- Explosion and its different types.
- Types of explosives.
- Different types of improvised explosive devices(IEDs)
- Manufacture and Composition of some explosives.

2. Introduction: Explosives

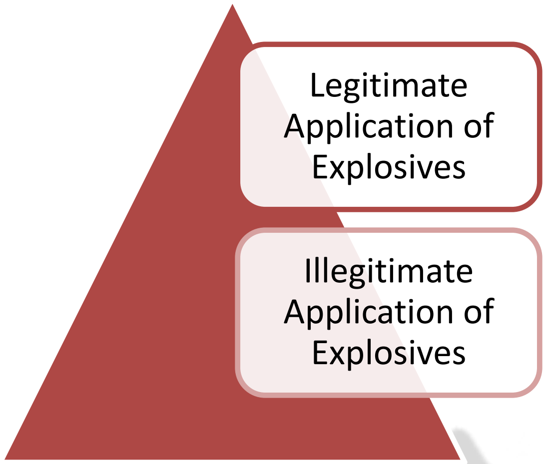
An explosive is a substance, an element, a compound or a mixture, which is capable of exerting pressure on its surroundings on explosion/transformation.

Role of Forensic Science in Explosives Examination

Forensic Science plays a role in relation to explosives. Explosives studied by forensic personnel mainly relate to mass destruction episodes wherein bombs are used for illicit activities. The explosive residues collected from the crime scene are examined for such causes specially as the constitution the explosive material, the source and intention of explosion.

2.1 Applications of Explosives

An explosive have many applications, which are legal and do not cause harm to any human, animal or any other living being.



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Legitimate Uses: An explosive might be used in blasting rocks for mining, oil explorations, in satellite and space craft propulsions, in constructing roads, railway line etc, in firework displays, and may also be used for military purposes which we will discuss latter.

Illegitimate Uses: The criminals are using the explosives for causing destruction to individuals or a nation by blasting bombs. The illegitimate use of explosives cause large scale destruction, as well as a threat to the integrity of any nation and is severely punishable under Indian Penal Code, Explosive Act and The Explosives Substance Act.

Some common examples of explosives are RDX, TNT, TETN, ANFO, and Dynamite etc.

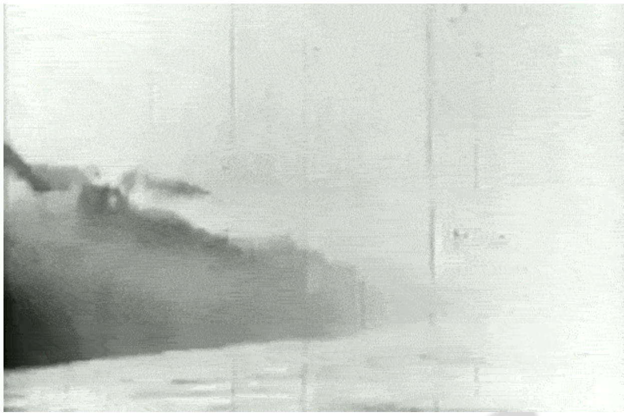


Figure:-1 Ripple Rock, British Columbia, Canada

Ripple Rock was an underwater, twin-peaked mountain, hazardous to ships passing through the Seymour Narrows of the Discovery Passage in British Columbia, Canada. It was destroyed with the help of 1,270 metric tons of Nitramex 2H explosives.

3. Role of Forensic Science in Explosives

Forensics plays an important role in the investigation of explosions where explosive substances/materials are the main ingredients. Explosives can be detected prior to explosions (during trafficking) and also after the explosion by forensic spot tests and also by hi-tech forensic analytical tools.

4. Explosion

In simplest term we can define an explosion as a rapid increase in volume of gaseous substances and release of energy along with the generation of high temperature and release of gases.

4.1 Types of Explosion

An explosion may be exotic or chemical. The common examples of exotic explosion is nuclear explosion and the use of high intensity laser arc to heat a substance to its plasma state. Laser and electric energy are presently used only to start reactions rathar than producing energy.

Due to the existence of organic compounds containing $-NO_2$, $-ONO_2$ and $-NHNO_2$ groups and others an explosion is a impulsive chemical reaction which is driven by enormous release of heat and energy. This type of eruption is known as chemical explosion.The chemical explosion is of three types: Decomposition, deflagration and detonation.

The chemical decomposition of an explosive is a gentler process which occurs during its storage. This can happen over years or days or hours or may be within a fraction of a second. Deflagration and Detonation are two spontaneous types of Chemical decomposition.

Deflagration of the explosive substance is proliferated by a blaze front which travels gradually through the explosive substance. Low explosive experiences the process of Deflagration.

In Detonation, the explosion is propagated by shock waves navigating through the explosive material. Detonation happens in high explosives.

5. Classification of Explosives

The Explosives can be classified on the basis of composition, velocity, sensitivity and physical forms. But broadly explosives are of three types: Low explosives, high explosives and miscellaneous. The latter sub-divided into homemade explosives, nuclear explosives.

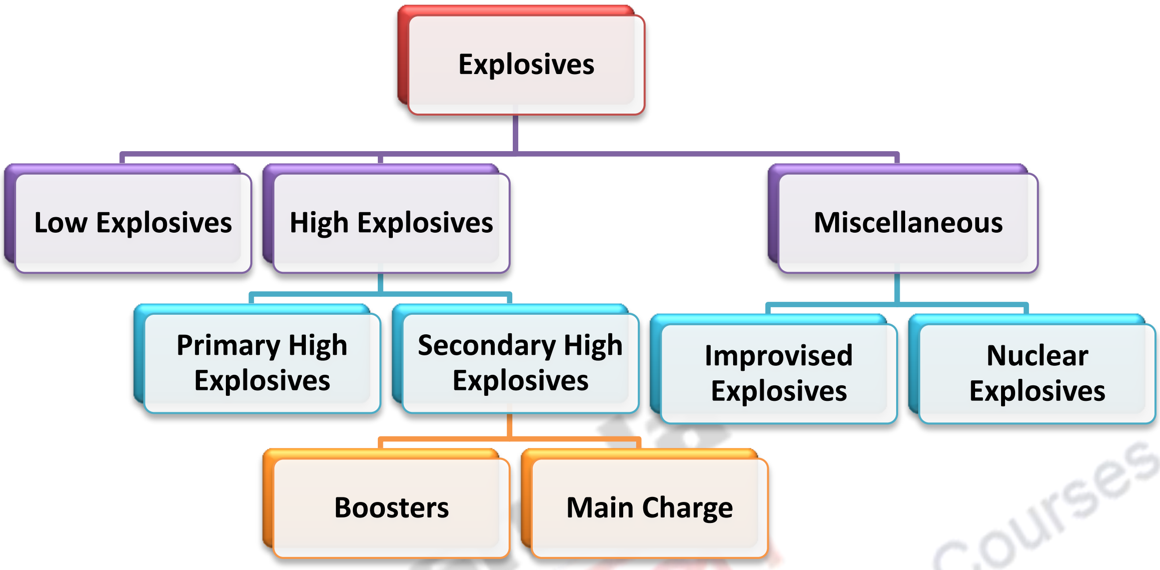


Figure:-2 Classification of Explosives

6. Low Explosives

Low explosives are solid flammable materials that deflagrate. Low explosives liberate enormous quantity of gases that generate sufficient pressure to force a projectile in a specific direction upon ignition and decomposition. The proportion of burning of explosive depends on combustion gas pressure, grain size and form, and composition.

Low explosives experience deflagration at amounts that fluctuate from a few centimeters per second to about 400 metres per second. Gunpowder or black powder, smokeless powder, flash powder, Pyrotechnics are few common examples of low explosives.

6.1 Gun Powder

Gunpowder was the first chemical explosive. Gunpowder is an admixture of sulfur, charcoal, and potassium nitrate. The sulfur and charcoal acts as fuels, while the potassium nitrate works as an oxidizer. Gunpowder has been extensively used as a propellant in firearms and as a pyrotechnic composition in fireworks owing to the extent of heat and gas volume that it produces.

6.2 Pyrotechnics

Pyrotechnics is a methodical technique involving the use of constituents skilled of undertaking self-contained and self-sustained exothermic chemical reactions for the generation of heat, light, gas, smoke and/or sound. Pyrotechnics has the propensity to change a fire into either a burst of striking fireworks or a dense cloud of clogging smoke. The fireworks are a blinking, fiery, short-lived burst of glowing, colored aerial lights.

Figure:-3 Fireworks

7. High Explosives

The explosives that detonate, meaning that the explosive shock front passes through the material at a supersonic speed. These are commonly used in carrying out the activities involving mining, destruction, and military applications. The high explosives may be further grouped into primary and secondary high explosives. High explosives experience detonation with explosive velocity ranging from 3 to 9 km/s.

RDX, PETN, TNT, ANFO are the examples of high explosives.

7.1 Primary High Explosives

The explosives which are extremely sensitive to mechanical shock, friction, and heat, to which they will respond by burning rapidly or detonating are known as primary high explosives. Lead Azide, lead styphnate, DDNP and tetrazene are some of the examples of primary high explosives.

7.1.1 Mercury Fulminate

Mercury fulminate is prepared by dissolving mercury in nitric acid and then pouring into ethanol. A vigorous reaction takes place, which is accompanied by the evolution of white fumes, followed by brownish red fumes and finally again by white fumes. At the same time crystals of mercury fulminate are formed. The grayish colored crystals are recovered and washed with water until all of the acid is removed.

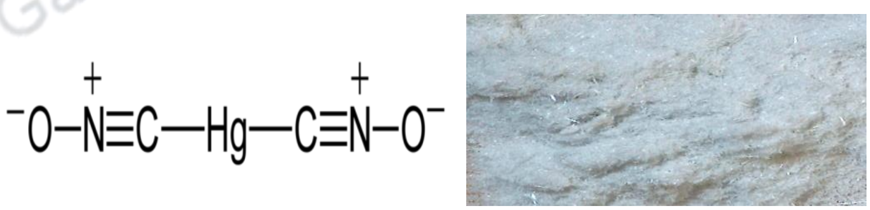


Figure 4: Mercury Fulminate

The mechanism for the formation of mercury fulminate and the intermediate steps are as follows:

1) **Oxidation of ethanol to ethanal**

$$CH_3CH_2OH + HNO_3 \longrightarrow CH_3CHO+HNO_2H_2O$$

2) **Formation of nitrosoethanal (nitrosation)**

$$CH_3CHO + HNO_2 \longrightarrow NOCH_2CHO+H_2O$$

3) **Isomerization of nitrosoethanal to isonitrosoethanal**

$$NOCH_2CHO \longrightarrow HON{=}CH\text{-}CHO$$

4) **Oxidation of isonitrosoethanal to isonitrosoethanoic acid**

$$HON{=}CH\text{-}CHO \longrightarrow HON{=}CH\text{-}COOH$$

5) **Decomposition of isonitrosoethanoic acid to fulminic acid and methanoic acid**

$$HON{=}CH\text{-}COOH \longrightarrow C{=}NOH + HCOOH$$

6) **Formation of mercury fulminate**

$$2C{+}NOH + Hg(NO_3)_2 \longrightarrow C{=}NO)_2Hg+2HNO_3$$

7.1.2 Lead Azide

Lead Azide is a form of primary explosive. It is prepared by dissolving lead nitrate in a solution containing dextrin, with the pH adjusted to 5 by adding one or two drops of sodium hydroxide. This solution is heated to 60-65 degree Celsius and stirred. Sodium azide dissolved in a solution of sodium hydroxide is then added drop wise to the lead nitrate solution. The mixture is then left to cool to room temperature with continuous stirring. Lead azide crystals are filtered, washed with water and dried.

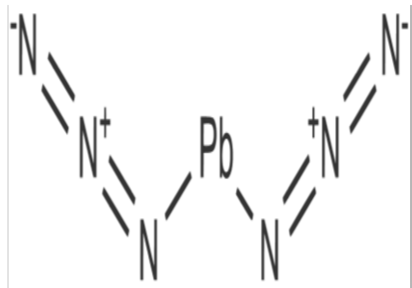


Fig 5: Lead Azide

7.2 Secondary explosives

Secondary high explosives are also known as base explosives. They are comparatively unresponsive to shock, resistance, and heat. They may ignite when exposed to heat or flame in trivial, liberated quantities. These are sometimes added in small amounts to blasting caps to boost their power. The secondary high explosives may further divide into boosters and main charge.

Secondary High Explosive	
Boosters	**Main Charge**
RDX	Dynamite

Figure:-6 Classification of Secondary High Explosives

Secondary High Explosives- Boosters

An explosive booster acts as a bridge between a low energy explosive and a low sensitivity explosive such as TNT. It increases the explosive shockwave from an initiating explosive to the degree sufficient to detonate the secondary charge. PETN and RDX are categorized as Boosters.

7.2.1 PETN (Pentaerythritol tetranitrate)

PETN is prepared by nitrating pentaerythritol, which in turn is made by mixing formaldehyde with calcium hydroxide in an aqueous solution held at 65-70 degree Celsius. Nitration of pentaerythritol is achieved by adding it to concentrated nitric acid at 25-30 degree Celsius to form PETN. The crude PETN is then removed by filtration, washed with water and then neutralized with sodium carbonate solution and finally recrystallized from acetone. This results in 95% yield of PETN.

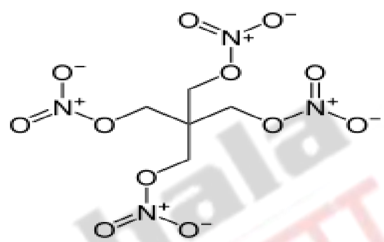


Fig 7: PETN

7.2.2 RDX (Cyclotrimethylenetrinitramine, 1,3,5-Trinitroperhydro-1,3,5-triazine)

RDX is synthesized by adding hexamethylenetetramine to excess concentrated nitric acid at 25 degree Celsius and warming it to 55 degree Celsius. RDX is precipitated with cold water and the mixture is then boiled to remove any soluble impurities. Finally purification of RDX is carried out by recrystallization from acetone.

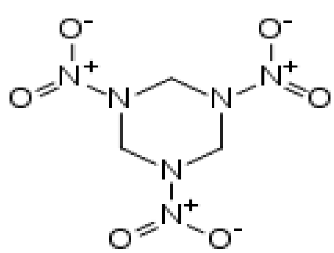


Fig 8: RDX

RDX preparation processes

RDX is also formed by various other preparation techniques such as SH Process which was invented by Schnurr, K process patented by Knoffler, W process patented by Wolfram, E process patented by Erbele, KA method also known as Bachmann process which was invented by Knoffler and Apel.

SH process involves continuous nitration of hexamethylenetetramine by concentrated nitric acid, with the production of nitrous gas. The RDX is filtered from the residual acid and stabilized by boiling in water under pressure and purified by re-crystallization from acetone.

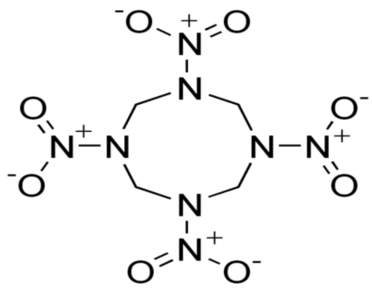
In the K process, RDX is formed by reacting ammonium nitrate with a mixture of hexamethylenetetramine and nitric acid, and warmed.

The W process is based on the condensation of potassium amidosulfonate with formaldehyde, and the nitration of the condensation product. Potassium amidosulfonate and formaldehyde are reacted together to produce potassium methyleneamidosulfonate. This product is nitrated to RDX by a mixture of nitric and sulfuric acids.

In the E process paraformaldehyde and ammonium nitrate undergo dehydration by acetic anhydride solution resulting in the formation of RDX. KA process is based on the reaction between hexamethylenetetramine di-nitrate and ammonium nitrate with a small amount of nitric acid in an acetic anhydride solution.

7.2.3 HMX (cyclotetramethylenetetranitramine)

HMX is formed as a by-product during the manufacture of RDX by the Bachman process. Hexamethylenetetramine, acetic acid, acetic anhydride, ammonium nitrate and nitric acid are mixed together and heated at 45 degree Celsius for 10 minutes. Ammonium nitrate, nitric acid and acetic anhydride are then slowly added and left on a steam bath for 12 hour. A precipitate forms which contains 27% RDX and 73% HMX.



7.2.4 HNS (Hexanitrostilbene)/ 1,1'-(1,2-ethenediyl) bis [2,4,6-trinitrobenzene]

HNS stands for hexanitrostilbene and can be prepared by many methods. For example:

- By the reaction of nitro derivatives of toluene with benzaldehyde, by the reaction of nitro derivatives of benzyl halgenides with alkaline agents
- By removing hydrogen halogenide and also
- By the oxidation of nitro derivatives of toluene

1)The first reaction involves heating a mixture of trinitrotoluene with trinitrobenzaldehyde at 160-170 degree Celsius and then cooling the mixture for 2 hours. The product is a low yield of HNS explosive. The increased yield of HNS can be achieved by reacting 2,4,6-trinitrobenzyl halogenide with potassium hydroxide in methanol.

2) Another method of forming HNS is the oxidation of TNT with sodium hypochlorite. Ten parts of 5% sodium hypocholride solutions are mixed with a chilled solution of one part TNT in ten parts methanol. The solution is then allowed to stand at ambient temperature until HNS precipitates as a fine crystalline product. The HNS precipitate is then recrystallized from nitrobenzene to give pale yellow-colored needles.

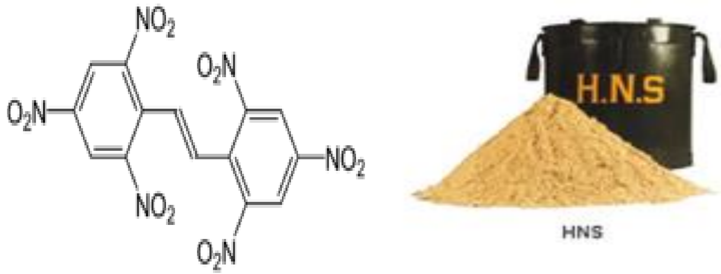


Fig 9: The image of HNS

7.2.5 Ammonium Nitrate

Ammonium Nitrate is formed by injecting gaseous ammonia into 40-60% nitric acid at 150 degree Celsius. Dense ammonium nitrate crystals are formed by spraying droplets of molten ammonium nitrate solution (>99.6%) down a short tower. The spray produces spherical particles known as ‘prills’. These crystals are non-absorbent and used in conjunction with nitroglycerine.

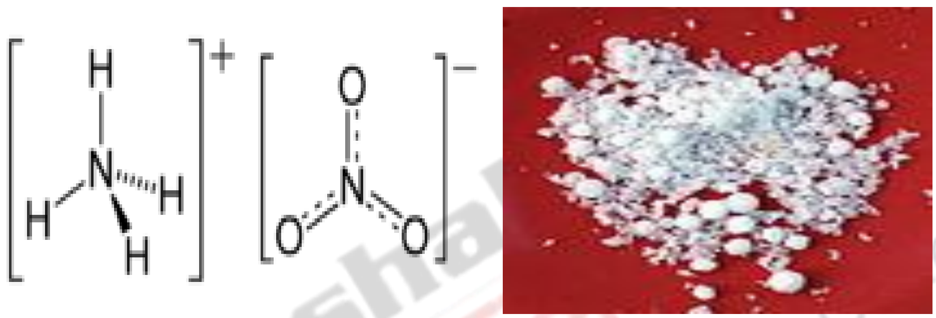


Fig 10: Ammonium nitrate

7.2.6 TATB- 1,3,5-Triamino-2,4,6-trinitrobenzene

Another explosive formed by C-nitration process is TATB. It is produced by the nitration of 1,3,5-trichloro-2,4,6-trinitrobenzene, where, 1,3,5-trichloro-2,4,6-trinitrobenzene is prepared by the nitration of tri-chlorobenzene with a mixture of nitric acid and sulfuric acid. 1,3,5-trichloro-2,4,6-trinitrobenzene is then converted to 1,3,5-trinitro-2,4,6-triaminobenzene (TATB) by nitrating with ammonia. The yellow brown crystals of TATB are filtered and washed with water.

Fig 11: The image of TATB crystals under scanning electron microscope

7.2.7 TNT-(2,4,6-trinitrotoluene)

TNT is also produced by the C-nitration process. It is formed by the nitration of toluene with mixture nitric and sulphuric acids. Toluene is first nitrated to mono-nitrotoluene and then to di-nitrotoluene and finally it gets converted to crude tri-nitrotoluene.

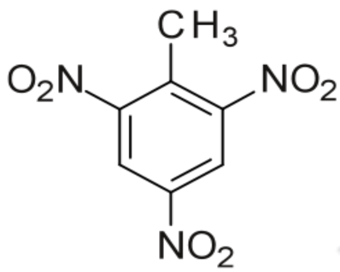


Fig 12: TNT

7.2.8 Dynamite

Dynamite is basically divided into gelatine and non-gelatine classification. Gelatine dynamite is prepared by dissolving nitrocellulose in nitroglycerine at 45-50 degree Celsius to form a gel. The mixture is stirred by large, vertical mixer blades. Once the gel is formed the other ingredients are added. The explosives mixture is then extruded or pressed into long rods, which are cut into smaller pieces and packaged into paper cartridges coated with paraffin. The manufacture of non-gelatine dynamite is similar to gelatine dynamite except that nitrocellulose is not used in the formulations.

Gelatine dynamites are basically of four types:

- Gelatine dynamite
- Semi gelatine dynamite
- Gelignite and
- Ammonia gelignite

Gelatine dynamite, gelignite and ammonia gelignite contains 25-55% Nitroglycerine, 1% to 5% nitrocellulose, woodmeal as a fuel whereas semi gelatine dynamite contains 15-20% nitroglycerine, 1-5% nitrocellulose and woodmeal act as a fuel. They all differ in the use of oxidizer. Inorganic nitrates are the oxidizer in gelatine dynamite and Semi-gelatine dynamite whereas sodium/ potassium nitrate and ammonium nitrate act as an oxidizer in gelignite and ammonia respectively.

Non gelatine dynamite are of following two types:

- Non gelatine dynamite and
- Ammonia Dynamite

Non gelatine and ammonia dynamite both have 10 to 50 percent nitroglycerine and wood meal. In Non-gelatine dynamite sodium nitrate or potassium nitrate act as an oxidizer whereas in Ammonia Dynamite, oxidizer is ammonium nitrate.

8. Homemade Explosives-Molotov Cocktail

A Molotov cocktail consists of a glass bottle semi-filled with flammable liquid, usually gasoline (petrol) or alcohol (generally methanol or ethanol); the mouth of the bottle is fitted with a cork or other type of airtight stoppes (rubber, glass, or plastic), and a cloth rag fixed securely around the mouth.

The weapon is used by first soaking the rag in a flammable liquid immediately prior to using it, lighting the rag and throwing the bottle at the target. The bottle shatters on impact, spilling the flammable liquid over the target, which is then ignited by the burning rag.

9.Improvised Explosive Devices-Briefcase Bomb

An improvised explosive device(IED) is a product, assembled in contravention to the existing rules of law of nation adopting unconventional or semi-conventional methods of formulating ammunition/explosives, with a criminal/anti-national intention. IED is also known as homemade bomb. For example- roadside bombs, letter bomb, bombs incorporated in briefcase/vehicle etc

9.1 Letter Bomb

A letter bomb is defined as an explosive device sent via postal service, and designed with an intention to injure or kill the recipient when opened. They have been used in terrorist attacks also.

They are usually designed to explode immediately on opening, with the intention of seriously injuring or killing the recipient (who may or may not be the person to whom the bomb was addressed).

10. Components of an IED

IED's are formed by incorporating destructive, lethal, and noxious, pyrotechnics or incendiary chemicals. An IED is basically composed of explosives, a detonator, a power source (battery) and an Initiation mechanism (switch).

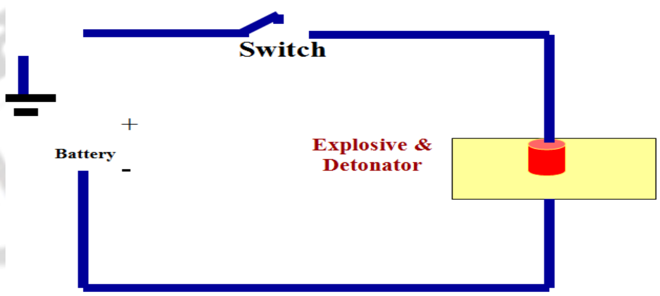


Figure:-13 Schematic Diagram of an IED's Component

11. Search Procedures for Locating an IED

The following do's and Don'ts' should be followed while searching for an IED:

1. Don't touch or handle suspicious object
2. Don't assume that merely one device is planted
3. Use maximum two persons per room or for all area up to 250 Sq. ft.
4. Clearly mark the area to be searched
5. Trust nothing and assume nothing to be safe

6. Obtain maximum information about the device
7. Carefully listen to any unusual voice/ sound before entering a room
8. Be careful from any hidden danger, at the entrance itself and also at other places and throughout the search
9. Make a visual survey of the entire area of the room
10. Search the area back to back
11. Immediately report regarding the area and the suspected material
12. Ask for help from expert

12. Booby Trap

In simplest terms we can define a booby trap is as a device, which is made with an intention to startle,surprise, attack, harm or kill an individual. A booby trap is generally trigerred accidentally by the presence or movements of the victim. Booby Trap often has some form of entice to attract the victim towards it. Sometimes the booby trap is planted on busy roads or is triggered when the victim performs some action like opening a door, picking up something, switching something on or off etc.

Figure:-14 Booby Traps

13. Precautions with Letter Bomb

Following are some precautions that one needs to taken when encountered with a Letter bomb:

1. Evacuate all persons
2. Stop admission into the room
3. Do not open letter using hand
4. Do not smoke near the bomb
5. Do not cut any distended wire
6. Do not jerk the letter
7. Put letter through mail bomb detector

14.Nuclear Explosives

A nuclear explosive is an unstable device that stems its energy from nuclear reactions. Virtually all-nuclear explosive devices that have been devised and produced are nuclear weapons anticipated for warfare. Atom bomb is an example of nuclear explosive.

14.1 Dirty Bomb

It is generally known as radiological dispersion device (RDD). A dirty bomb is a radiological weapon, which is a combination of radioactive material with conventional explosives such as dynamite. A dirty bomb is basically used to contaminate the affected area with radioactive material. The main purpose of a dirty bomb is to frighten people. It may also cause people to be exposed to radioactive material.

15. Characteristics of Explosives

The following are some of the important characteristics of an explosive which are very important to determine whether the explosive is suitable for a particular use:

- Availability and cost
- Sensitivity
- Sensitivity to initiation
- Velocity of detonation
- Stability
- Power, performance, and strength
- Brisance
- Density
- Volatility
- Toxicity
- Explosive train
- Oxygen balance (OB% or Ω)
- Chemical composition
  - Chemically pure compounds
  - Mixture of oxidizer and fuel

Availability and Cost:- These include availability of raw materials, its cost, complexity and its safety for manufacturing operations.

Sensitivity:- Sensitivity is the ease with which an explosive can be detonated or ignited. An explosive is sensitive to shock, friction or heat. Sensitivity should be considered in selecting an explosive suitable to its particular use.

Sensitivity to initiation:-Sensitivity to initiation is defined by the power of the detonator which is certain to prime the explosive to a sustained and continuous detonation.

Velocity of detonation:-It is that speed with which the reaction process spreads in the mass of the explosive, which is a significant feature of explosive and differs according to the kind of explosive.

Stability:- One of the main characteristic of explosive is its ability to be stored without detonation which is known as stability. The stability is affected by temperature of its storage, chemical constitution of explosive, exposure to sunlight and its electrical discharge.

Power, functioning, and potency:- The power or functioning of an explosive is its ability to do work which is determined by some tests to measure the substance for its proposed use.

Brisance :- Brisance is defined as the shattering effect (break) which is notable and separate from their total work capacity. Brisance regulates the efficacy of an explosion in disintegrating shells, bomb casings, and grenades. The swiftness with which an explosive touches its peak power is a degree of its brisance. The brisance is tested by sand crush test.

Density:- Density is the mass of an explosive per unit volume.

Volatility:- Volatility of an explosive is the promptness with which it vaporizes. It influences the chemical composition of explosive followed by reduction of stability, which increases the hazard of handling.

Toxicity:- Some of the explosives are toxic to that extent which requires special handling due to hazards caused by them. Besides explosives some of their derivatives, decomposition products, residues, and released gases can also be toxic. The harmful product may be any heavy metal (such as lead, mercury etc), nitric oxides released from TNT and others.

Explosive Train:- Explosive material may be slotted in the explosive train of a device or system. For example pyrotechnic leads to the ignition of booster, which causes the main charge to detonate. Now let's understand what an Explosive Train is. It can be defined as a triggering chain of events that ultimately lead up to the detonation of explosives.

Oxygen Balance:- Oxygen balance is the degree to which an explosive can be oxidized. The sensitivity, strength, and brisance of an explosive depends on oxygen balance to some extent and approach to their maxima as oxygen balance approaches zero. If an explosive contains oxygen to convert all of its carbon to carbon dioxide, all of its hydrogen to water, and all of its metal to metal oxide with no excess molecules, the molecule is said to have a zero oxygen balance. The molecule is said to have a positive oxygen balance if it contains more oxygen than is needed and a negative oxygen balance if it contains less oxygen than is needed.

Chemical Composition:- An explosive can be characterized based on their Chemical composition which is either a chemically pure compound, such as nitroglycerin, or a mixture of a fuel and an oxidizer, such as black powder or grain dust and air.

a) **Chemically pure compounds:-** Some chemical compounds are unstable. Every molecule of the compound separates into two or more new molecules (mostly gases) with the liberation of energy e.g. Nitroglycerin, Acetone peroxide, organic peroxide TNT, Nitrocellulose, RDX, PETN, HMX.

b) **Mixture of oxidizer and fuel:-** An oxidizer is a pure substance (molecule) that in a chemical reaction can contribute some atoms of one or more oxidizing elements, in which the fuel component of the explosive burns. On the simplest level, the oxidizer may itself be an oxidizing element, such as gaseous or liquid oxygen. e.g. Black powder (Potassium nitrate, charcoal and sulfur), Flash powder, Ammonal, Armstrong's mixture, Sprengel explosives, ANFO, Cheddites. Oxyliquits, Panclastites.

16. Summary

- Explosives are the substances, elements, compounds or mixture capable of exerting pressure on its surroundings on explosion/transformation.
- Explosives can be used legitimately such as blasting rocks for mining, in space craft propulsions etc and can be used for illegal purposes such as in blast for causing destruction to individual or nation.
- The explosives can be classified as low, high or miscellaneous.
- Low explosives experience deflagration at degrees that can vary from a few centimeters per second to about 400 meters per second.
- High explosives undergo detonation with explosive velocity ranging from 3 to 9 km/s.
- Gunpowder, is a admixture of sulfur, charcoal and potassium nitrate and is the first chemical explosive
- Primary high explosives are extremely sensitive to mechanical shock, friction, and heat.
- Secondary high (base) explosives are relatively insensitive to shock, friction, and heat.
- RDX is also formed by various preparation techniques such as SH Process, K process, W process, E process, KA method (Bachmann process).
- HMX is formed as a by-product during the manufacture of RDX by the Bachman process.
- The rate of detonation of Dynamite is 4,900 to 25,400 feet per second.

- A glass bottle half- filled with inflammable liquid and whose mouth is closed with a cork or any airtight plug like a cloth rag fixed securely around the mouth is known as a Molotov Cocktail.
- An IED is basically composed of an explosive, a detonator, a power source (battery) and an initiation mechanism (switch).
- The manufacture of non-gelatine dynamite is similar to gelatine dynamite except that nitrocellulose is not used in its formulation.