by auto-suggestion, external influence, suggestions, descriptions and opinions of others and rationalisation. Oral evidence, therefore, is coloured, whereas material evidence is free from these infirmities.

But the material evidence can be manipulated:

1. A person is killed in an accidental firing. The relatives want to implicate their opponents. They procure an unlicensed firearm, fire a cartridge, place it at the scene and plant the firearm on the opponent.

   The police recover the shell and the firearm. The shell is married to the firearm. The police prosecute the person.

2. A person is in the armed forces. He is seen carrying out duty up to 1 A.M. in the unit. He slips through the guarded premises, goes about a hundred miles , commits a murder, returns to his unit, enters into the guarded premises secretly and is present on the duty at 7.30 A.M.

   By circumstantial evidence he proves his presence in the unit throughout the night.

3. A threatens B with death. The next day B is found murdered. B had no other enemies except A. Police suspects A as the murderer. He is not found anywhere. He is declared a proclaimed offender. Soon after ' A ' appears before a magistrate and says he had gone on a pilgrimage, but checking at the allegedly visited places, his visits to the places are not established. He is arrested and prosecuted. In defence, he produces the jail record. He was behind the bars at the relevant time. He escapes sentence.

1.6 TOOLS AND TECHNIQUES

The tools and techniques of forensic science are oriented to meet the following exacting demands in an analysis:

- Sensitivity
- Specificity
- Rapidity

The instruments and technique should be highly sensitive because the quantities of materials involved are extremely small, often in micro, sub-micro or microscopic ranges. For example, a few milligrams of certain poisons are sufficient to kill a person. The quantity is distributed in the whole body. Only few hundred grams of the body matter is provided for analysis. The sample contains quantities of the poison only in micro or nanogram ranges. It must be identified and estimated correctly. In recent times the quantities involved in some crimes like offences under drug acts have gone infinitesimally small, for example the LSD's dose in micrograms and designer's drugs like Fentanyl, are used in nanogram ranges only.

Paints, soils, dusts, inks and body fluids are some times met with in sub-micro quantities.

A clue material has to be identified positively; otherwise the evidentiary value of the clue is limited. The instruments and techniques must, therefore, be

highly specific. In a poisoning case it is not sufficient to identify the killer drug as a barbiturate but it is necessary to find out which one it is, so that its source could be traced and linked to the criminal.

The number of cases requiring evaluation of clues is increasing every day. The techniques and instruments should, therefore, be rapid. In classical examination of viscera and organs for poisoning are subjected to lengthy processes of extracting purification, identification and estimation. The results are checked and crossed checked for mistakes. Modern techniques may eliminate most of these steps. The poison is extracted from the convenient body part (say blood, urine, lungs, or kidneys) and identified through chromatography (paper, column and thin layer). The quantity is estimated through ultra-violet-spectro-photometry and specific poison is identified through infrared spectro-photometry, FTIR or mass spectrography. The classical method needs days and weeks for the complete analysis, whereas the above procedure identifies and estimates the clue material in a few hours. Similarly, blood alcohol in a sample (a drop of blood or less is sufficient) may be identified and estimated through gas chromatography in a few minutes.

The tools and techniques currently used in modern forensic science laboratories belong to both the classical and modern categories.

1.6.1 Measurements

Examination of clue materials requires various types of measurements. Determination of dimensions (length, breadth, height, depth, curvature, and diameter) angles, melting point (including mixed melting points), boiling points (including boiling point curves and ranges), (densities, refractive indices, briefings and fluorescence are daily routine. They require elementary knowledge of science, yet they fix the identity of a material in a number of cases.

Refinement of techniques has improved efficiency and accuracy of the determination considerably in recent times. For example, density gradient tubes have permitted density determination of very small amounts with high accuracy. Likewise, using a hot stage, in Beckline method, small differences in refractive indices can be determined very accurately.

1.6.2 Microscopy

A microscope is the most important tool of a forensic science laboratory. It is needed in all branches of forensic science.

A microscope in its simplest form is a magnifying lens. Continuous improvement and inventions have given a variety of microscopes suitable for different purposes. Compound microscopes, stereomicroscopes, comparison microscopes, fluorescence microscopes, phase contrast microscopes and metallurgical microscopes are common items in forensic science laboratory.

The use of infrared rays for microscopy (by using an image converter) and electron microscopy (where magnification of the order 10^5 or above can be achieved) are comparatively additional recent innovations in the field. They have an important impact on forensic science. For example, scanning electron microscope is becoming indispensable in Forensic Ballistics, Micro-Trace Analysis, etc.

1.6.3 Photography

The investigating officers and others concerned with the administration of justice are familiar with the photographs of the scene of occurrence and of the criminals. Photography is also being used to demonstrate invisible traces, visually unrecognisable clues, stains and the like. Photography with ultra-violet rays, infrared rays, X-rays and coloured filters, macro-photography (magnified photographs), photomicrography (photograph of microscopic evidence taken in conjunction with a microscope), microphotography (miniature photography), cine photography, digital photography and photogrammetry have great importance in criminal investigation work.

The variety of cameras used is very large.

Holography is a recent innovation. Here photographs (holograms) are taken with the help of a laser beam. The technique can photograph prints and impressions even on carpets and grass.

1.6.4 Invisible Rays

The use of ultra-violet rays in criminal investigation is well known. The use of infrared and X-rays are comparatively later additions and are making their impact increasingly.

Some materials absorb ultra-violet rays. Some of their energy is consumed in the process. The rays of lower energy content are emitted. They have greater wavelength and are in the visible range. Thus, objects invisible in the dark start giving light. The phenomenon is called fluorescence. The absorption power of different materials varies greatly. Even small differences in the surface structures of an item are detected through differences in fluorescence. It helps in the identification and differentiation of stains, sealing waxes, papers, inks, dyes, paints, varnishes and more importantly forged and genuine currency notes.

Infrared rays have greater wavelength than the visible light. They also have penetration power and, pass through some materials. They are useful in the examination of documents, clothes, stains and the like.

X-rays have the shortest wavelength of the three types of rays. They have greater penetration power and give fluorescence under suitable conditions (*e.g.*, on a specially coated screen). They are useful in the study of paintings, documents, bullet holes, and fractures and for locating metal objects in sealed containers (or foreign objects in a body).

1.6.5 Chromatography

Chromatographic techniques have assumed great importance in forensic science. All its forms: column chromatography, Thin Layer Chromatography, High Performance Liquid Chromatography and Gas Chromatography are handy tools. They are used to separate, identify and estimate clue materials even in sub-microgram quantities. The impurities do not substantially interfere during the analyses.

1.6.5.1 Column Chromatography

Column chromatography is mainly used to isolate and purify a substance. The material is dissolved in a suitable solvent and pass through a suitable

stationary phase, packed in a column. The substance is then eluted with one or more solvents. The required material, due to difference in absorption power, is eluted out of the column in a pure form before or after the impurities, depending upon their solubility and adsorption powers.

Paper chromatography is similar in principle and action. Paper's cellulose fibre and water absorbed by the paper constitute the stationary phase. Two dimensional and reversed phase chromatography are additional innovations in paper chromatography.

Paper chromatography is used for identification in addition to isolation and purification of the clue materials. For this purpose the ratio of the distance travelled by the material and the solvent is found, which is characteristic of the substance. It is called R_f value of the substance for the system. Circular paper chromatography is handier for the purpose. However Thin Layer Chromatography (TLC) has almost completely replaced the paper chromatography technique. The latter gives better separation and less tailing. It is quicker also.

1.6.5.2 Thin Layer Chromatography

Thin layer chromatography is very convenient. A thin even layer of the solid stationary (*e.g.*, silica or alumina) is deposited on a glass plate. The substance to be identified is processed as in paper chromatography. The results are quicker and more accurate. The stationary phase and the mobile phases can be varied at will. TLC is a method of choice for most of the preliminary investigations, purification and identifications of narcotics, drugs and poisons. It is equally effective for the purposes for other chemicals, especially in small amounts.

1.6.5.3 Gas Liquid Chromatography (GLC)

Gas chromatography is one of the most important tools in forensic science. The three criteria mentioned for a technique are admirably met with by this technique. It requires minute quantities and gives qualitative results within minutes.

The technique is applied in the analysis of gases, liquids, vaporisable solids and for substances which pyrolyze to give identifiable volatile products. Petrol, kerosene oil, liquors, perfumes, lacquers, varnishes, paints, barbiturates, soaps and organic insecticides are being analysed by this technique. The field of application is being extended every day.

The technique is simple in principle and practice. In general, a liquid or a solid stationary phase supported on small chips or other similar material is packed in the column. Or, some material coated on the inner surface of the column. The column is maintained at a convenient temperature or, the temperature is increased progressively to the final temperature. The variety of the material and the length and diameter of columns vary tremendously depending upon the nature of the material being analysed. Capillary columns are also being used with advantage.

The material to be processed (for purification, identification and or estimation) is passed through the column with the help of a carrier gas like nitrogen, helium, argon, or hydrogen. The sample in its passage through the column is fractionated. Different constituents come out of the column at different intervals and pass through the detector. A large variety of detectors with varying degree of sensitivities are available. Some of them are sample specific. They are detected by changes in the current of a circuit fitted therein. A recorder records these changes on a graph paper. Comparison of the graph with similar graphs of known products permits identification and estimation of the constituents.

If the out-coming gas or vapours are collected in fractions at intervals indicated by the peaks and troughs of the graph, the separation of constituents is obtained.

1.6.5.4 High Performance Liquid Chromatography (HPLC)

The principles on which the HPLC functions are the same as in the case of GLC. The basic difference is that the mobile phase in this case is liquid, a solvent. The solution of the sample is passed through the column under pressure. Adsorption and elution of the constituents take place differentially. The separated constituents are detected/collected at the end of the column.

1.6.5.5 GC-MS/LC-MS

In modern analytical techniques, GLC and HPLC have been used in combination with a Mass Spectrograph. The separated constituents, by either of the instruments, are subjected to mass spectrographic analysis. All these instruments are computer controlled. They give both qualitative and quantitative analyses. The analytical work is thus greatly facilitated. Most of the modern Forensic Science Laboratories are using the combination with excellent results.

1.6.6 Electrophoresis

The technique is particularly useful for colloidal or other materials like proteins, inks, paints and pigments having residual charge on the molecules. The technique is being extensively used in the study of blood and other proteinous matter.

The material to be analysed is take on a paper strip (or gel). The two end of the strip are dipped in an appropriate buffer solution. An electric current of appropriate voltage is applied to the strip. The charged molecules move in either direction depending upon their residual charge. The speeds of the molecules vary with the charge and the weight of the molecules and the absorption power of the medium. Thus, different molecules get separated into bands. The position of a band on the strip identifies the molecule. Electrophoresis has proved a boom in DNA profiling, the new technique of identifying human beings and other evidence in recent times. The fragments of the DNA molecules are subjected to electrophoresis and the patterns of the fragments from the authentic and suspect sources are compared to find the common source or otherwise.

1.6.7 Spectrography

Spectrography is the oldest modern technique used in the analysis of clue materials. Its use is limited to elemental analysis of some elements and their compounds.

A flame, an arc or a spark vapourises a small amount of the materials. The light emitted is passed through a diffraction grating or a prism (both glass and quartz prisms have been used, the latter is preferable). They split the light into its various wavelengths. A photograph of split up light is taken and studied. The position and number of lines depend upon the nature of the substance giving the light. Comparison with standard spectrograms (photographs of the spectrum) gives the nature of the constituents of the sample analysed.

The quantitative estimates are made by studying the densities of the various lines.

1.6.8 Laser Microprobe

A recent innovation of the spectrographic technique is laser spectrography. A small narrow beam of intense light (laser beam) is used to vapourise the material. The wavelengths of the light so produced are studied in the usual way.

The technique has not been extensively used in forensic work so far. But it has a bright future, as the sample required is small. A small spot from the object is vapourised. There is no noticeable damage to the object. The analysis is ' non-destructive ' for all practical purposes. The technique is being utilised to 'fingerprint' valuable paintings, statues, ancient items of national heritage and other works of art etc.

1.6.9 Mass Spectrometry

Mass spectrometry permits identifications of all substances which can be vapourised into charged particles (most of the materials). The samples required for the analysis are virtually in the molecular (or atomic) range.

Both qualitative and quantitative estimation can be made. The technique is being used extensively in forensic work.

Mass Spectrography, because of its extremely highly sensitivity and versatility, has become a technique of choice especially for highly complex and materials in minute quantities like designer drugs. The ''Unknown' substances can also be identified through various fragments which are formed in the process.

1.6.10 Spectrophotometry

One of the most important techniques in forensic work is spectrophotometry. It is sensitive, specific and rapid. In addition, it is versatile and useful for both qualitative and quantitative analyses. It is simple in principle. The equipment is, however, sophisticated and costly. A beam of electromagnetic rays of selected wavelengths (from ultraviolet, visible or infrared range) is passed through the material. The material absorbs some of the energy of these rays (at a particular wavelength). The residual rays fall upon a photoelectric cell and produce changes in the current of the circuit. The changes are recorded on a graph paper. The comparison of the graphs with those of the known materials permits identification of the unknown material. Quantitative estimation is possible from the peak area.

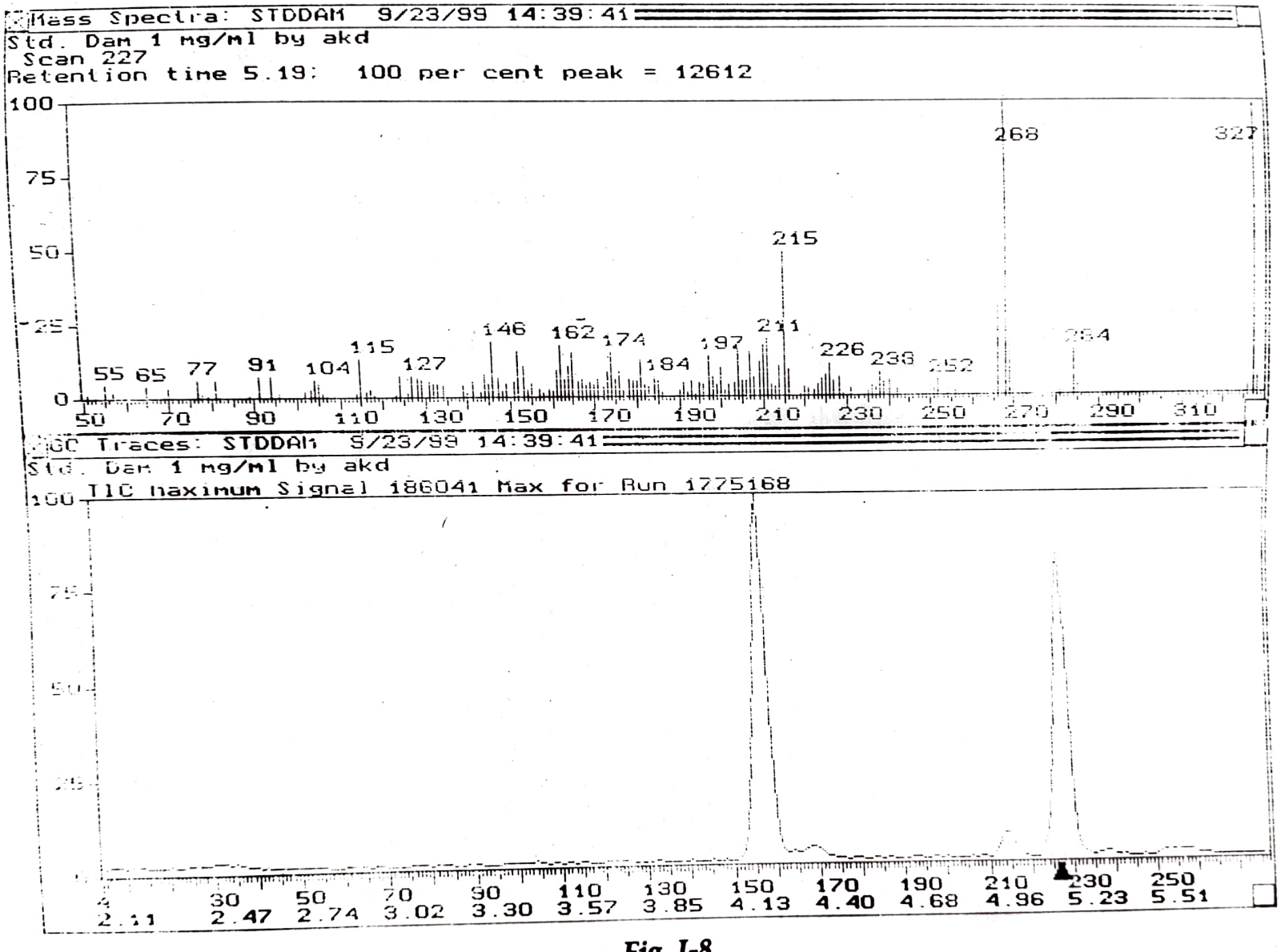

Fig. I-8

Mass Spectra of Heroin.

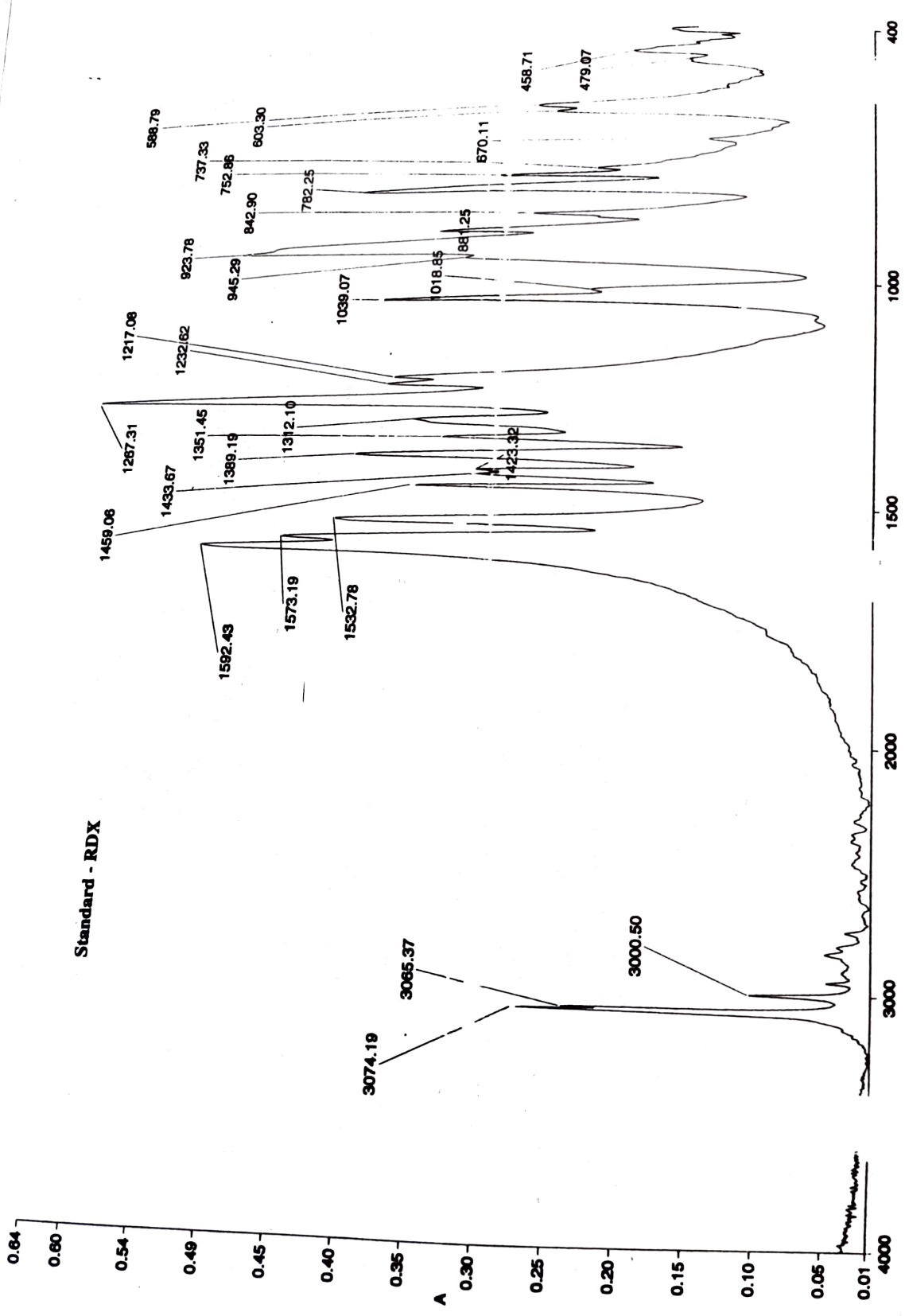

Fig. I-9
IR Spectrim of RDX.

The technique is extensively used in the identification of sedatives, drugs, poisons, narcotics and intoxicants. It is also useful in the identification of liquids and gases.

UV, IR, NIR, FTIR Spectrophotometers form part of the well-equipped laboratories.

1.6.11 Neutron Activation Analysis

Most of the elements can be made radioactive. The radioactivity is characteristic of the element and is studied by spectrometry. The substance is placed in an atomic reactor where it is subjected to high flux neutron bombardment. Neutron sources other than atomic reactors have been developed but they have not been found so useful in forensic work.

The technique is one of the most sensitive and specific techniques so far known. It has been utilised in the examination of projectile materials, hair, plant, soils, dust and other clue materials.

The neutron activation analysis has not become a routine technique. Nor it is likely to become so, for sometime to come, as high flux neutrons required in the technique are available only in an atomic reactor, which is a complex and costly apparatus.

1.6.12 X-rays Diffraction Analysis

It is a highly sensitive and specific technique for the identification of materials. The materials under study are not destroyed in the process.

A beam of X-rays is passed through the material. The X-rays get diffracted depending upon the arrangement of the various particles in the crystals. The diffracted patterns are photographed and compared with diffraction patterns of known materials whereby the identity of the substance is established. The instrument coupled with a computer can store and compare the data so generated and give the identity or common source of the origin of the material.

The technique is useful in the study of barbiturates, glass fragments, minerals, inorganic substances, paints, pigments, corrosion material, dust and the like.

1.6.13 DTA, NMR, and Polarography

Differential thermal analysis (DTA), nuclear magnetic resonance (NMR) and polarographic techniques are important analytical techniques used in chemical analysis. They are being adopted for forensic work. All these techniques are sensitive and specific.

1.6.14 Scanning Electron Microscopy (SEM)

Scanning Electron Microscope (SEM) is another powerful tool in the hands of forensic scientists. The microscope utilises electron beam for 'observation' of the surfaces. Part of the electron beam is absorbed, part is scattered and part is reflected back. Because of the particle size of the electron, *vis-à-vis* quantum of light, SEM has the following advantages:

- The SEM gives very high resolution. The resolution is increased so much that even the small differences in surface structure are

highlighted. The resolution approaches the molecular level. Thus, it increases the discrimination power tremendously.

- The magnification is increased many folds (100000 times).
- The images obtained have three-dimensional effect.
- The additional gadget (EDX) permits finding the elemental compositions of the surface or the particles thereon.
- Coupled with computers, the instrument is working wonders in Forensic Ballistics where it has facilitated the evaluation of the gunshot residues in all the aspects. The instrument is equally useful in the evaluation of the surface structures and marks thereon.

1.7 FORENSIC SCIENCE INSTITUTIONS

1.7.1 Forensic Science Laboratory

A forensic science laboratory is the main forensic science institution. It is generally divided into the following scientific departments / divisions:

- Chemistry
- Physics
- Biology
- Ballistics
- Explosives
- Toxicology
- Narcotics
- Serology
- DNA Profiling
- Forensic Psychology
- Lie Detector Unit
- Voice Analysis
- Photography
- Instruments
- Computers
- Scene of Crime

Deputy directors having master's degree in their basic specialties ordinarily, head the divisions. They have several years of experience in the expertise and have ample research experience in the specific and related field. The head of the division is assisted by assistant directors, senior and junior scientific officers, senior and junior scientific assistants, laboratory assistants and attendants.

The non-technical staff carries out clerical work, maintenance of stores and supplies and other non-scientific duties.

The laboratory is properly guarded against theft and loss of exhibits.

A director who has scientific training and has several years of experience of working in a forensic science laboratory heads the laboratory. In big laboratory an additional/joint director (technical) and an administrative officer (non-technical) assist the director.

The laboratories, in India, by and large are well equipped. They have both the classical and modern equipment. Most of them are using the techniques mentioned above. Sophisticated equipment for techniques like comparison microscopy, spectrography, spectrophotometry, atomic absorption spectrometry, all type of chromatography, electrophoresis, mass spectrography, laser techniques, X-ray diffraction analysis, nuclear magnetic resonance, high performance liquid chromatography and polarography is increasingly being used in the investigation of crime.

1.7.1.1 Services

The efficiency of a scientist is greatly affected by the services at his disposal. He should have ample working space: search table, chemical benches, lighting arrangement and regular supply of water, gas and electricity.

There should be adequate storage space for incoming and outgoing exhibits. They are kept in separate rooms. Each police district is given a separate storage rack so that the exhibits do not get misplaced or intermixed.

The storekeeper for the exhibits handles only sealed packets of the exhibits.

A small workshop greatly adds to the efficiency of the worker, as slight modification to the equipment and apparatus can be made conveniently in the workshop.

1.7.1.2 Library

It is not possible to subscribe to all the important journals in various scientific disciplines. This deficiency is overcome by locating the laboratory near a university. Here in addition to library and laboratory facilities, consultations with university staff are also possible.

Forensic science literature has been developing during the past few decades. Most of the countries publish one or two journals exclusively dealing with the subject. They should be subscribed for. The journals carry papers on forensic science.

There are not many books on the subject. Therefore, all available books should be collected. The bibliography given after the chapters indicate most of the books in English language. In addition reference works in chemistry, toxicology, physics and biology prove useful. They should be purchased.

Modern internet, as source of literature has come up and may ultimately replace libraries in the usual sense. The computerised literature is located at a centralised place and can be shared on time sharing basis through telephone/ internet. Most of the literature is now available internationally through this mode.

1.7.1.3 Functions

The main function of a forensic science laboratory is the examination of clue materials involved in crimes. In addition, the laboratories help in the photography and examination of the scene of occurrence, gives lectures and demonstration to police trainees, prosecutors and judges. They carry out research in forensic science. The laboratories controlled by police also provide

photographic facilities to their criminal investigation, including photographic coverage of the scenes of crimes.

The experts appear in courts whenever required to explain and prove their findings.

In addition to forensic science laboratories, the institutions which provide scientific assistance in dissemination of justice are:

1.7.2 Other Institutions

1.7.2.1 Fingerprint Bureau

All the major state in India, have fingerprint bureaus. In addition the central government has also a central finger print bureau located at Delhi under the Department of National Crime Record Bureau. The fingerprint record at the national level has been digitised and computerised. Any police force in India can utilise its services.

Fingerprint bureau perform the following main functions:

- Collect, classify and store the record.
- Eliminate the record of the dead persons.
- Search and locate the fingerprints records of a given person if it exists.
- Compare the fingerprints.
- Visit the scene of crime to locate; collect and ultimately compare the fingerprints.
- found at the scene.
- Give evidence in courts (or on commission) whenever required.

1.7.2.2 Government Examiners of Documents

Some state governments and central departments have institutions, which examine disputed documents exclusively. For example Bureau of Police Research and Development has three such institutions, known as Government Examiner of Questioned Documents. The oldest is located at Shimla (partly shifted to Chandigarh and likely to be located finally there). It started functioning somewhere in 1906. The other two institutions are at Kolkata and Hyderabad . These institutions cater to the zonal needs of not only central government departments but also to the state governments' needs. Some states have named their own document examining institutions as Document Bureaux. Most of the states and even central government, have organised the document examination in their Forensic Science Laboratories.

1.7.2.3 Mobile Laboratories

Most of the states have mobile forensic science laboratory units. They vary in number and also in the administrative control. The main function of the mobile laboratories is to help the police investigation at the scene of occurrence to locate, collect and preserve the evidence. These teams also provide photographic facilities to record the scene, the evidence, etc. The team also guides the investigation to collect adequate and correct sample for comparison and provide leads for further investigation.

1.7.2.4 Scientific CID Sections

Some police forces have scientific division which help the department with technical photography, scientific surveillance and investigations and other technical needs.

1.7.2.5 Computer Divisions

There is hardly any police organisation now that does not have computer division. The use of computers, in the police forces in India is yet limited. The use, however, is growing fast.

1.7.3 Practical Aspects

The fate of the accused persons often depends upon the findings of Forensic Science. It has to be insured that the facility providers do not intentionally, negligently or otherwise give wrong results. A number of steps are undertaken to do so:

1. Accreditation of the Laboratory and the Experts.
2. Quality Assurance of the processes, tools and output of the expertise.
3. Standardisation of the tools and the techniques and the basic data sufficient for the various conclusions.
4. Automation to reduce the human error and to increase the overall efficiency of the forensic work.

All the steps are essential to streamline the working of forensic science service. However in India only the last has come up. The others are crying for their induction.

1.8 PROBLEMS OF PROOF

1.8.1 General

Problems of proof in linking the criminal with the crime include investigative, scientific and legal aspects. It shall be worthwhile to understand these problems and their causes to facilitate the utilisation of science and scientific techniques in the dissemination of justice.

The evidence against the criminal may be the evidence of the eyewitness or of the victim, it may be confession of the culprit, an incriminating statement of a co-criminal, circumstantial evidence or scientific evidence. Till recently the courts in India, had to depend mostly on non-scientific evidence mainly on the eyewitness accounts. Logically the evidence of the eyewitnesses appears to be the best evidence. If a person has witnessed the occurrence, the same should be the best evidence against the culprits. However, it has been proved time and again that this evidence suffers from a number of infirmities:

- The eyewitness observes the occurrence for an extremely short period.
- He may not have observe the complete occurrence.
- He is often uncertain about the identities of the culprits unless he knows them.
- He may intermingle the acts of various individual in the occurrence.
- He may be biased in favour of the victim or of the culprit.