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Gas chromatography-Mass spectrometry-A Review

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ABSTRACT

This small critique discusses the analytical technique on gas chromatography mass spectrometry specifically basic principles and instrumentations. The applications of GC-MS to a number of studies for determining organic compounds from around the world are presented and highlight its universal use and acceptance. GC-MS is an integral and complimentary part of many field studies involving organic compound detection and determination.GC/MS is limited to analytes that are not only volatile and thermally labile but can also withstand the harsh partitioning condition of the gas chromatograph. Extensive fragmentation experienced during electron ionisation(EI), in positive & negative mode. There are many compounds that produce unique patterns that can be used in conjunction with gas chromatographic time data for an univocal identification.Considering that GC evolved as popular technology almost six decades ago & given the standardisation methods using the retention index & kovats index.

Keywords: Gas Chromatography-Mass Spectrometry, Spectrum, Interpretation.

INTRODUCTION

Spectroscopy is the measurement and interpretation of Electro Magnetic Radiation (EMR) absorbed or emitted when the molecules or atom or ions of a sample are more from one energy state to another energy state. Electromagnetic radiation is made up of discrete particles called photons. Analytical instruments exploit spectroscopy for both

identification (qualitative analysis) and measurement (quantitative analysis) of atoms, ions and molecules.

Spectroscopy and spectrography are terms used to refer to the measurement of radiation intensity as a function of wavelength and are often used to describe experimental spectroscopic methods. Spectral measurement devices are referred to as spectrometers, spectrophotometers, spectrographs or spectral analysers. Daily observations of colour can be related to spectroscopy. Neon lighting is a direct application of atomic spectroscopy.

Spectroscopy is used in physical and analytical chemistry because atoms and molecules have unique spectra. As a result, these spectra can be used to detect, identify and quantify information about the atoms and molecules. Spectroscopy is also used in astronomy and remote sensing on Earth. Most research telescopes have spectrographs. The measured spectra are used to determine the chemical composition and physical properties of astronomical objects (such as their temperature and velocity).[1,2]

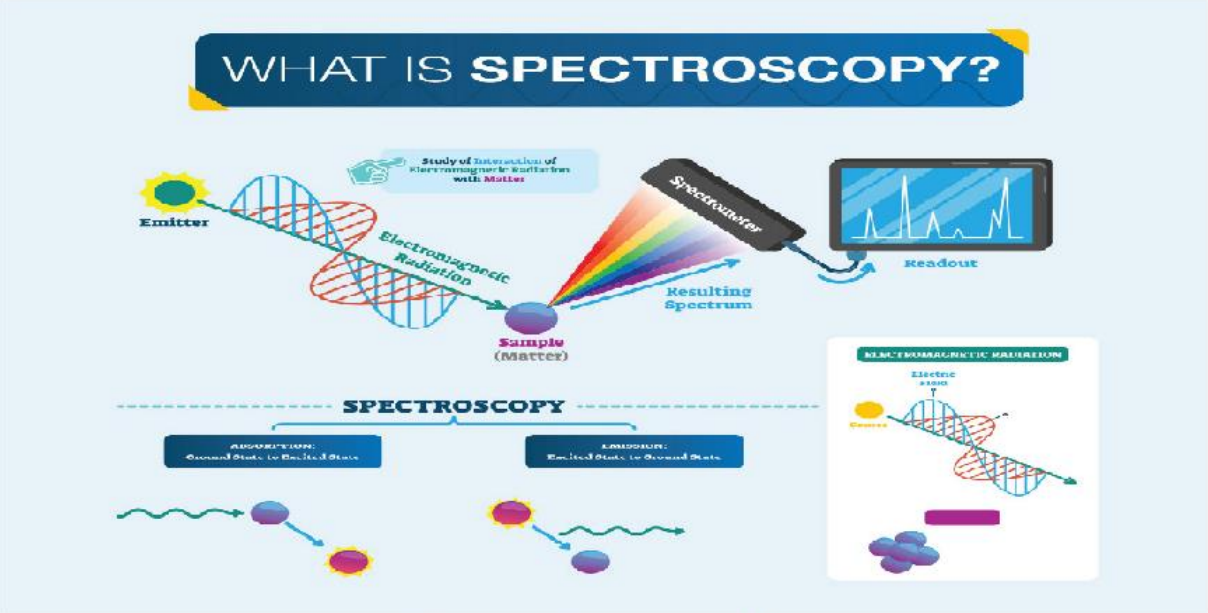


Figure: (1) Spectroscopy[12]

SPECTRUM

A plot of the response as a function of wavelength or more commonly frequency is referred to as a spectrum.

SPECTROMETRY

It is the measurement of these responses and an instrument which performs such measurements is a Spectrometer (or) Spectrograph.

SPECTROMETER

An instrument that can measure radiation intensity as a function of Energy(E), Frequency(V), Wavelength(λ), wave number(σ), etc. in order to obtain a spectrum.

SPECTROPHOTOMETER

A spectrometer that uses a photon detector to measure the ratio of the radiant power incident on (P_o) and emergent power from (P) a sample of matter, as a function of photon Wavelength(λ), Frequency(V), Wave number(σ), or energy (E photon).[1]

CLASSIFICATION OF SPECTROSCOPY

- ❖ Atomic or Molecular Spectroscopy
- ❖ Absorption or Emission Spectroscopy
- ❖ Electronic or Magnetic Spectroscopy

1.ATOMIC (OR) MOLECULAR SPECTROSCOPY

a) Atomic spectroscopy

Where the changes in energy take place at atomic level.

Ex: Atomic absorption spectroscopy.

b) Molecular Spectroscopy

Where the changes in energy take place at molecular level.

Ex: UV Spectroscopy, Colorimetry etc.

2.ABSORPTION (OR) EMISSION SPECTROSCOPY

a) Absorption Spectroscopy

Where absorption of radiation is being studied.

Ex: Spectroscopy, Infrared spectroscopy etc.

b) Emission Spectroscopy

Where emission of radiation is being studied.

Ex: Flame photometry, Fluorimetry.

3.ELECTRONIC (OR) MAGNETIC SPECTROSCOPY

a) Electronic spectroscopy

Ex: UV Spectroscopy, Colorimetry.

b) Magnetic Spectroscopy

Ex: NMR Spectroscopy, ESR Spectroscopy.[1,21]

PRINCIPLE OF SPECTROSCOPY

The principle is based on the measurement of spectrum of two sample containing atoms/molecules. Spectrum is a grapy of intensity of absorbed or emitted radiation by sample verses frequency(V) or wavelength(λ). Spectrometer is an instrument design to measure the spectrum of a compound.

□ Absorption Spectroscopy

□ Emission Spectroscopy

ABSORPTION SPECTROSCOPY

- ❖ It is the measure of energy absorbed by an excited atom or molecular and the spectroscopic analysis of the energy gives the absorption spectrum.
- ❖ It also represents the energy absorbed relative to the energy of given frequency of electromagnetic radiation.

Ex: UV (185-400nm) / Visible (400-800nm) Spectroscopy, IR Spectroscopy (0.76-15μm).

EMISSION SPECTROSCOPY

- ❖ It is the measure of emitted light and spectroscopic analysis of this emitted light gives the emission spectrum.
- ❖ An emission spectrum thus obtained gives the information about the light source under study.
- ❖ This phenomenon is primarily caused by excitation of atoms by the thermal or electrical means, absorbed energy causes electron in the ground state to be promoted to the state of higher energy where they are short lived and will return to the ground state by emitting the radiation.

Ex: Flame Spectroscopy, Flourimetry.[1]

COMMON TYPRS OF THE SPECTROSCOPY

- ➢ Visible Spectroscopy (Colorimetry)
- ➢ Ultraviolet Spectroscopy
- ➢ Fluorimetry
- ➢ Nephelometry and Turbidimetry
- ➢ NMR Spectroscopy
- ➢ ESR Spectroscopy
- ➢ Mass Spectrometry
- ➢ IR Spectroscopy

UV / VISIBLE SPECTROSCOPY

Ultraviolet and Visible Spectroscopy deals with the recording of the absorption of radiation in the UV and Visible region of the electromagnetic spectrum.

- UV region extends from 10-400nm.
- Near UV (quartz) region 200-400nm.
- Far or Vacuum UV region 10-200nm.
- The visible region extends from 400-800nm.

FLOURIMETRY

Fluorescence is the phenomena of emission of radiation when there is transition from singlet excited state to singlet ground state. The wavelength of absorbed radiation is called as excitation wavelength and that of emitted radiation is called as emission wavelength.

NEPHLOMETRY AND TURBIDIMETRY SPECTROSCOPY

Nephlometry Spectroscopy

It is the measurement of scattered light as a function of concentration of suspended particles less than approximately 100mg/ litre. Nephlometry is a technique used in immunology to determine the levels of several blood plasma protein.

Turbidimetry spectroscopy

It is the measurement of transmitted light as a function of concentration of suspended particles more than 100mg/litre, high concentration.

NMR- (Nuclear Magnetic Resonance) SPECTROSCOPY

Nuclear Magnetic Resonance (NMR) Spectroscopy is a technique that is used to determine the types, number and relative position of certain atoms in a molecules. The radio-frequency region of roughly 4 to 900 MHz.

ESR- (Electro Spin Resonance) SPECTROSCOPY

It is also called as Electro Paramagnetic Resonance (EPR). ESR Spectroscopy is the study of spin changes at the electron level when a microwave frequency is absorbed in the presence of a magnetic field.

GAS CHROMATOGRAPHY

Gas chromatography is a separation technique. Small amount of sample for example 1ml of air, microliter of the solution either liquid and solids in the solution are injected into a instrument. The machine is called gas chromatography. This machine by using injection port, column and detector generates a written record of analysis a series peak. Series of peak are called chromatogram. Chromatogram is simple a written recod of the analysis performed by gas chromatography.

MASS SPECTROMETRY

A mass spectrometer works by generating charged molecules or molecular fragments either in a high vacuum or immediately prior to the sample entering the high vacuum region. The ionised molecules have to be generated in the gas phase. In classical mass spectrometry there was only one methods of producing the charged molecules but now there are quite a number of alternatives. Once the molecules are charged and in the gas phase they can be manipilated by the application of either electric or magnetic fields to enable the determination of their molecular weight and the molecular weight of any fragments which are produced by the molecule breaking up.[22]

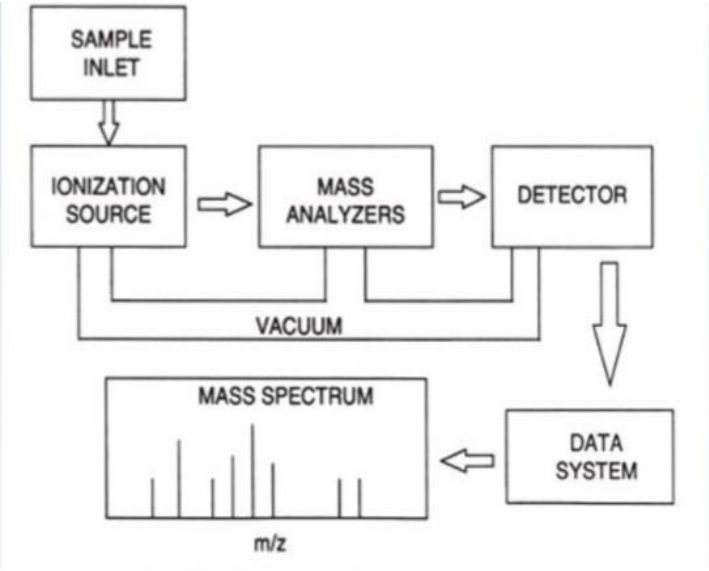


Fig 2: The Schematic diagram of Mass Spectrometry

GAS CHROMATOGRAPHY-MASS SPECTROMETRY

Gas Chromatography-Mass Spectrometry (GC-MS) is a hyphenated analytical technique that combines the separation properties of gas-liquid chromatography with the detection feature of mass spectrometry to identify different substances within a test sample. GC is used to separate the volatile and thermally stable substitutes in a sample where as GC-MS fragments the analyte to be identified on the basis of its mass. The further addition of mass spectrometer in it leads to GC-MS/MS. Superior performance is achieved by single and triple quadrupole modes.[3]

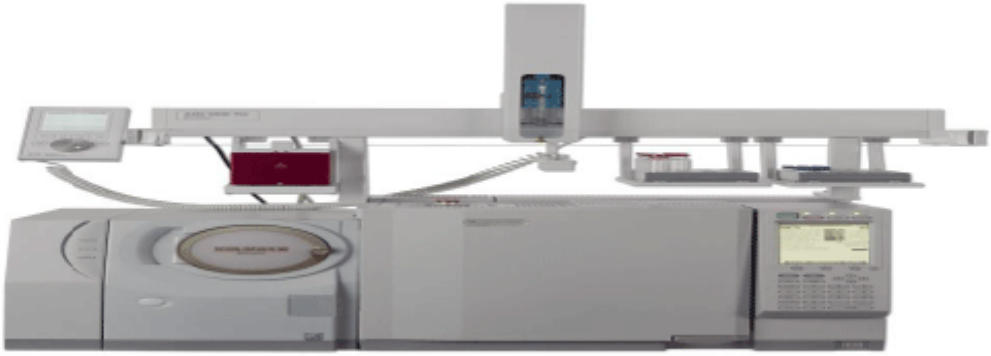
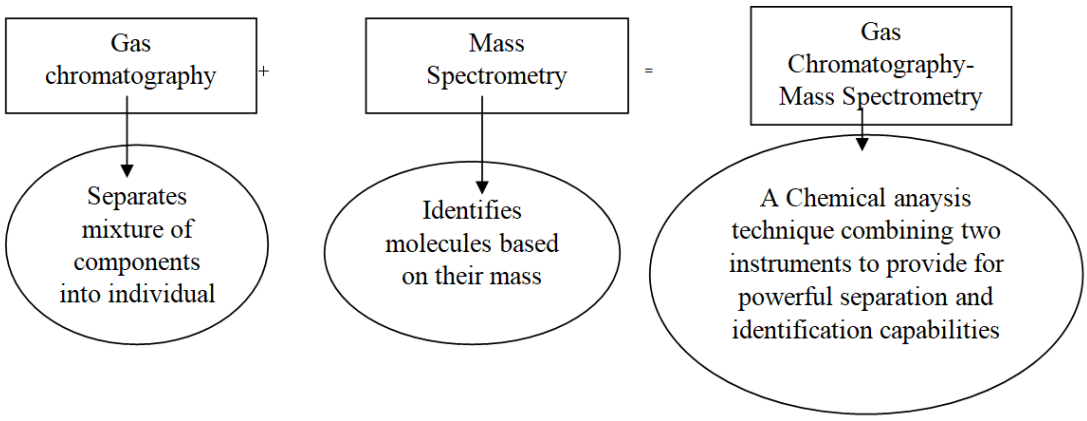


Fig 3: A typical GC-MS with head space of shimadzu company[13]

PRINCIPLE

The mass spectrometer is a universal detector for gas chromatographs since any compound that can pass through a gas chromatograph is converted into ions in mass spectrometer. At the same time, the highly specific nature of mass spectrum makes the mass spectrometer a very specific gas chromatographic detector. Gas chromatography is an ideal separator, whereas mass spectrometry is excellent for identification. The aim of an interfacing arrangement is to operate both a gas chromatograph and a mass spectrometer without degrading the performance of either instrument. The problem is compatibility. One incompatibility problem is the difference in pressure required for the operation of a gas chromatograph and the mass spectrometer. Whereas the former operates at high pressures, the latter is designed to run under high vacuum. An associated problem is the presence of much carrier gas and little sample in the effluent from the gas chromatograph. If the gas chromatograph is using packed column the flow of carrier gas may be in excess of 30ml/min, which would collapse the vacuum of the mass spectrometer. Therefore, carrier gas must be substantially removed and various designs have to be developed.[4]

FLOW CHART



TYPES OF GC-MS[5]

Different analytical tasks require different detection abilities. While the gas chromatography system may remain the same, different types of mass spectrometers may be required for different types of analyses depending on the level of selectivity and sensitivity required.

- Single quadrupole GC-MS
- Triple quadrupole GC-MS/MS
- HRAM GC-MS/MS

SINGLE QUADRUPOLE GC-MS

When gas chromatography is combined with a mass spectrometer that includes just one quadrupole, it is often referred to simply as GC-MS. GC-MS is well suited to the everyday analysis of samples where either targeted or untargeted analysis using selected ion monitoring (SIM) acquisition. Typical applications include pesticide analysis in food and environmental samples, analysis of biological samples for drugs of abuse and analysis of volatile organic compounds in water samples.

TRIPLE QUADRUPOLE GC-MS

Gas chromatography combined with triple quadrapole mass spectrometry system is referred to us GC-MS.The triple quadrapole MS operated in selective reaction monitoring (SRM) mode provides a higher level of selectivity and is best suited to analyses where the highest sensitivity is required. This is often the case when quantitating pesticides in food or environmental contaminants.

Fig 4: Triple Quandrupole GC-MS[14]

HRAM GC-MS

For comprehensive characterization of samples in a single analysis with high-confidence compound discovery, identification and quantisation, a GC system can be combined with a high-resolution accurate mass (HRAM) mass spectrometer.

INSTRUMENTATION OF GC-MS

The GC-MS is composed of two major building blocks the gas chromatography and the mass spectrometer. The gas chromatography utilizes a capillary column whose properties regarding molecule separation depend on the column's dimensions (length, diameter, film thickness) as well as the phase properties (e.g. 5% phenyl polysiloxane). The difference in the chemical properties between different molecules in a mixture and their relative affinity for the stationary phase of the column will promote separation of the molecules as the sample travels the length of the column. The molecules are retained by the column and then elute (come off) from the column at different times (called the retention time), and this allows the mass spectrometer downstream to capture, ionize, accelerate, deflect, and detect the ionized

molecules separately. The mass spectrometer does this by breaking each molecules into ionized fragments and detecting these fragments using their mass-to-charge ratio. Sometimes two different molecules can also have a similar pattern of ionized fragments in a mass spectrometer (mass spectrum). Combining the two processes reduces the possibility of error, as it is extremely unlikely that two different molecules will behave in the same way in both a gas chromatography and a mass spectrometer.

- ❖ Gas Chromatography
- ❖ Interface
- ❖ Mass Spectrometer
- ❖ Data System

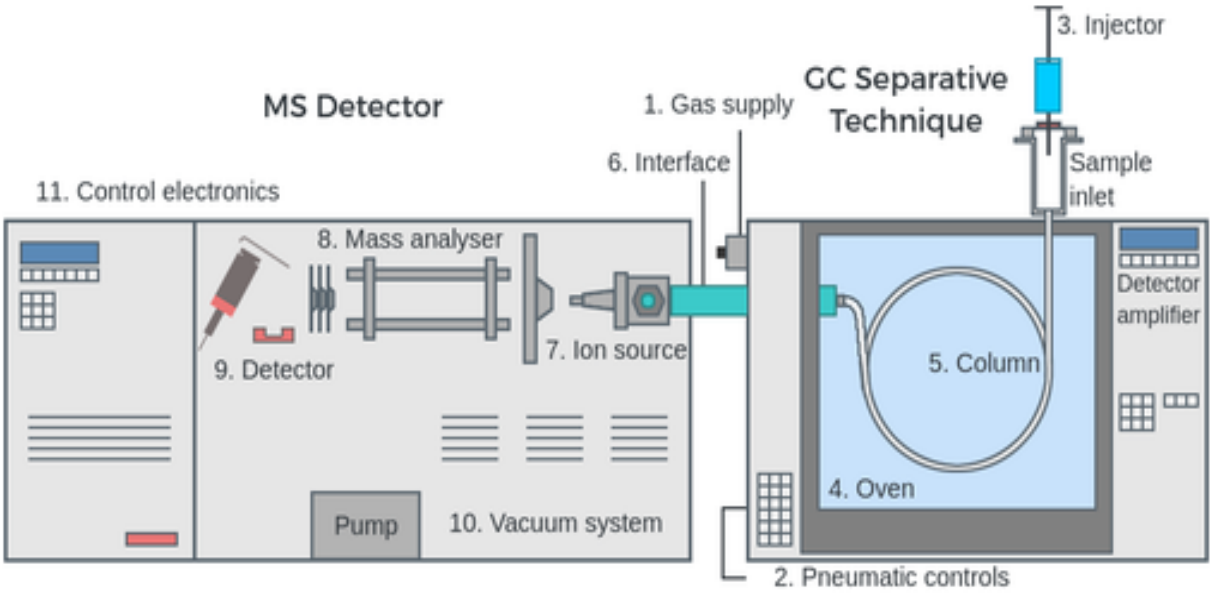


Fig 5: A Typical GC-MS System[15]

GAS CHROMATOGRAPHY

- Carrier gas
- Pneumatic control
- Injector
- Column
- Oven

CARRIER GAS

The Sample solution is injected into the GC inlet where it is vapourised and swept onto a chromatographic coloumn by the carrier gas (helium). Carrier gas served as mobile phase supplied in the steel tank under high pressure. At pressure of 40-80 psi this passes into flow controllers. **E.g.:** Nitrogen, helium; hydrogen and argon Can also be used

Fig 6: Carrier Gas[16]

Requirements

- Inert
- Column requirements
- Purity-better than 99.995%
- Cost effective & avaliable

SAMPLE SELECTION[33]

- Sample should be organic must be volatile and semivolatile thermaly stable.
- Compound may be require chemical modification (derivatization) to eliminate adsorption effects that would affect the qulity of the data sample are usually analysed as organic solution materaial of interst (eg:soils, sediment, tissues and etc…) extracted and the extract subjected to various chemical techniques before GC-MS analysis is possible.
- For organics and volatile organics,the sample preparation procedures can be named as extraction, cleanup, derivatisation ,transfer to vapour phase and concentrated.

Solid samples

- In order to treat solid sample and separate a purpose analyte, some enhanced solvent extraction method include pressurised liquid extraction, microwave–sonic wave assisted extraction, superheated water extraction.

Liquid samples

- Extraction of analyte into a liquid phase can be achieved by membrane extraction,single drop micro extraction [SDME],purge trap.

Gas samples

- For trapping analytes form vapour sample ,head space analysis are used.
- Depending upon the ionisation method analytical sensitivity of 1 to 100 pages per component are routine.

PNEUMATIC CONTROL

Gas supply is regulated to the correct pressure and then fed to the required part of instrument. Older instruments-manual pressure control via regulators. Modern GC instruments-electronic pneumatic pressure controller.

OVEN

Temperature programmable, typically range from 5°C-400°C but can go as low as -25°C with cryogenic cooling.

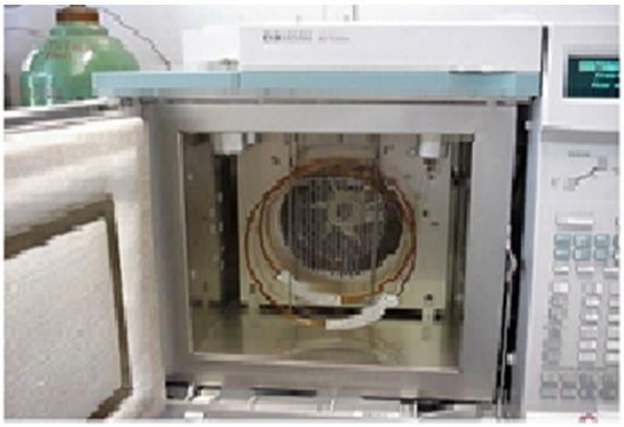


Fig 7: Oven[17]

SAMPLE INJECTION PORT

1. Sample is made to vaporized rapidly before entering to column.
2. Various kind of injection: Packed column injection, Split injection, Spitless injection, programmed split/Spitlessinjection, Programmed On-Column injection.

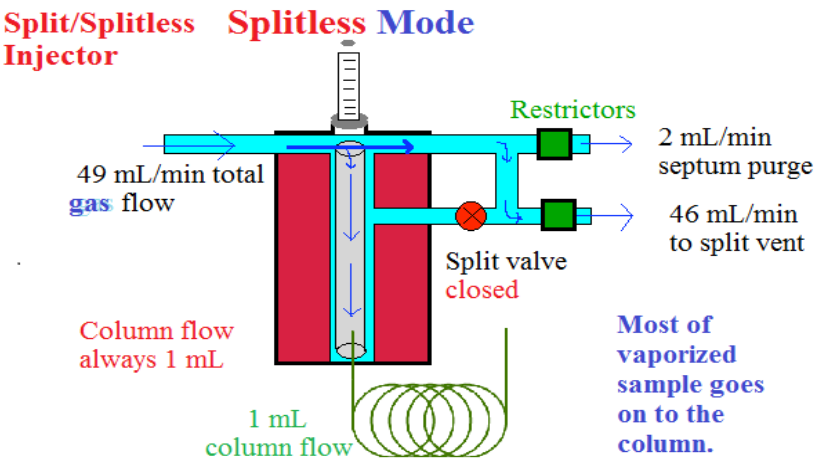


Fig 8: Split - Splitless Injector[20]

COLUMN

Gas chromatography GC-MS utilizes capillary column and stationary phase has been chemically bonded to the fused silica, e.g., DB-5.

- Packed column
- Capillary column

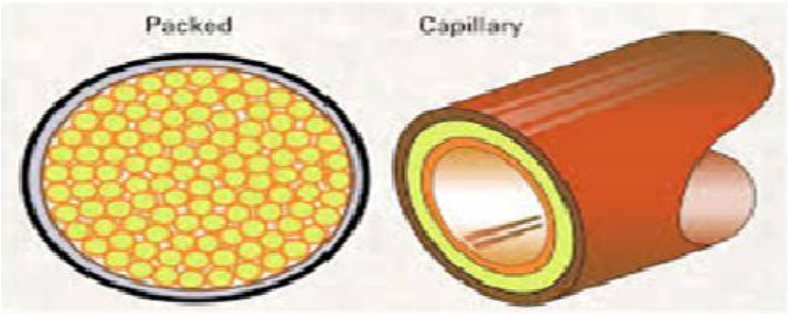


Fig 9: Column[21]

DETECTORS

A chromatography detector is a device used in gas chromatography (GC) or liquid chromatography (LC) to detectcomponents of the mixture being eluted off the chromatography column.

- Simple and reliable
- Sensitive to electronegative groups (halogens)
- Largely non-destructive
- Limited dynamic range (10^2)
- Mass sensitive detectors

a) Thermal Conductive Detectors (TCD)
b) Flame Ionization Detector (FID)
c) Electron Capture Detectors (ECD)
d) Photoionization detectors

PHOTOIONIZATION DETECTORS

The selective determination of aromatic hydrocarbon is the job of the photoionization detectors. Since only a small fraction of analysis molecules are actually ionized in the PID chamber, this is consider to be a non-destructive GC detectors. PID can be cannected to another detectors in series, so that have been separated by the GC column do not broaden out before detection. The available UV lamp energies range from 8.3 to 11.7ev, lambda max ranges from 150nm to 106 nm.

A Photoionization Reaction

$$R + h\nu \rightarrow R^{+} + e^{-}$$

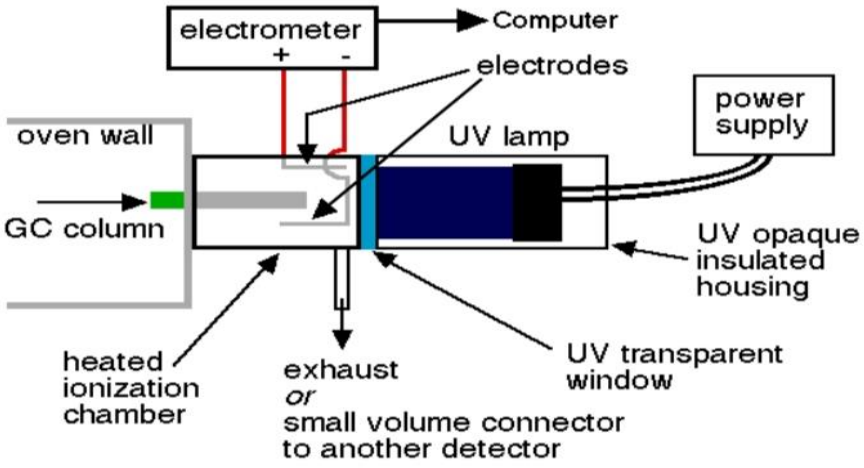


Fig 10: Schematic of Photoionization Detector[32]

INTERFACE

Pressure incompatibility problem between GC and MS was solved by inserting an interface.

- Jet interface
- Direct capillary infusion interface
- Watson-Biemann effusion separator

MASS SPECTROMETER

Mass spectrometry is a technique used for measuring the molecules weight and determining the molecules formula of an organic compound.

- Ion source
- High-vacuum system
- Mass analyzer
- Ion collector

IONIZATION TECHNIQUES

- EI(Electron impact)
- CI(Chemical ionisation)
- FAB(Fast atom bombardment)
- ESI(Electrospray ionisation)
- MALDI(Matrix assisted laser desorption ionisation)
- APCI(Atmospheric pressure chemical ionisation)

ELECTRON IMPACT IONISER

In an electron impact mass spectrometer (EI-MS),a molecule is vaporised and ionised by bombardment with abeam of high- energy electrons. The energy of the electrons is˜ 1600 kcal (or70 eV). The electron beam ionizes the molecule by causing it to eject an electron.

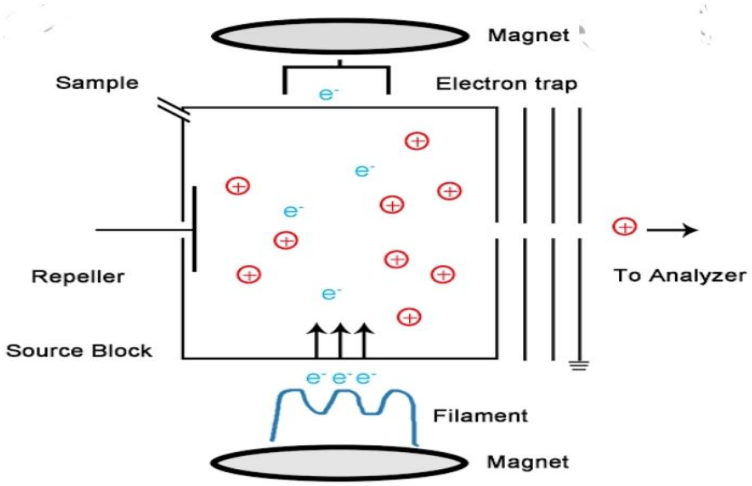
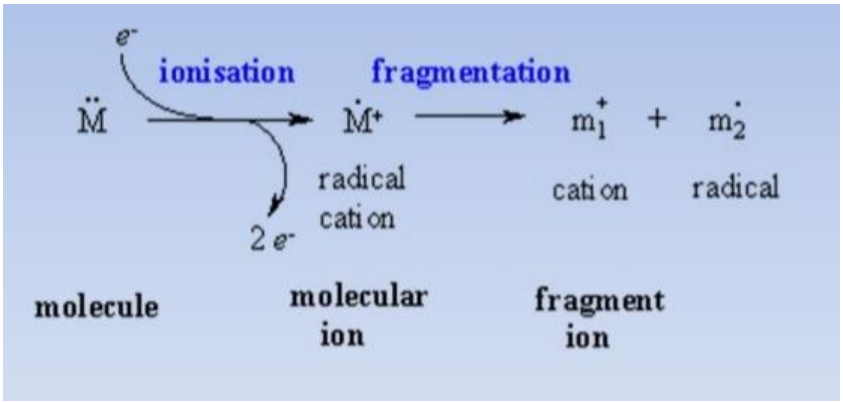


Fig 11: Electron Ionization (EI) Source[31]



Mass analyzer

They deflect ions down a curved tube in a magnetic fieldbased on their kinetic energy determined by the mass, charge and velocity.

- ✓ Quadrupole mass analyzer
- ✓ Ion cyclotron analyzer
- ✓ Time-of-flight mass analyzer
- ✓ Magnetic sector analyzer
- ✓ Quadrupole ion trap mass analyzers

Quadrupole mass analyzer

In quadrupole mass analyzer a set of four rode are arranged parallel to the direction. Only m/z is been determined and stable oscillation takes place. It functions as a mass filter. Ions travels in quadrupole axis with cork screw type of trajectory. It is also known as 'Hewlett-Packard'or 'Mass Selective Detector'.

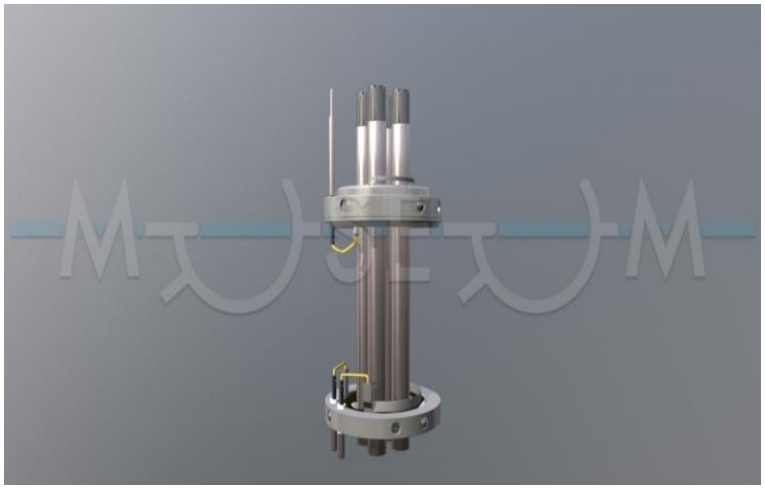


Fig 12: Quadrupole Analyzer[22]

Ion cyclotron analyzer

Ions in a magnetic field move in circular orbits characteristic of their m/z values. If energy is provided at a frequency equal to their precession frequency, and inadirection perpendicular to their plane of precession. Ions will absorb the energy, enabling them to be detected.

Time-of-flight analyzer

The time-of-flight(TOF) analyzer is based on the velocities of two ions are created by uniform electromagnetic force applied toall the ions at same time, causing them to accelerate down a light tube. Lighter on travels faster and strike the detector first so that the m/z ratio ofions is detected.

Magnetic sector analyzer

Single Focusing: A magnetic field is used to focus ions based on their momentum as they areejected from an ion source at high energy.

Double Focusing: It is used differentiale the small mass differences of the fragment. In a double-focusing mass analyzer beam is first passes radial electrostatic field.

Quadrupole ion trap mass analyzers

There are two principal ion trapped mass analyzers. Three-dimensional quadrupole ion traps (″dynamic″ traps), and ion cyclotron resonance mass spectrometers (″static″ traps). Both operate by storing ions by usingDC and RF electric fields.

INTERPRETING GC-MS RESULTS

GC - MS provide distinct complimentary results. These methods were just used in tandem the 19505,and still widely applied in clinics and laboratory worldwide .GC-MS analysis is an effective testing and troubleshooting tool for many manufacturers across industries, helping identify and quantify the materials that make up a sample or uncover contaminants that impact product quality.

GC-MS CHROMATOGRAM OR SPECTRUM DEVELOPMENT:

The GC step comes before MS,the mixture of interest must be gaseous form,the process with conversion of sample to gas ,if necessary.Once in gaseous form it is passed through a column called stationary phase. Then elute at different times and are ionised for MS analysis. These combine into what is show as peaks on a GC-MS chromatogram[27]

The chromatogram are shown as graph,with the X-axis showing ‘retention time’and the Y axis showing ‘intensity counts’.The retention time is the time is taken for the component to reach the detector at the end of the column.Retention time data providing identifying the chemical property of the component can be polarity, volatility, whether certain functional group or not[30]

MS also analysis the mass to charge ratio, which is also added on as X axis component. Therefore output

GC-MS can be depicted as chromatogram with retention time on the X axis or as a spectrum with mass to charge ratio on the X axis.

The Y axis showing intensity counts is a measure of how much quantity of the component is present. Different analytes have different affinities for the detector. Higher affinity larger peak area than other peacks often see in compounds that ionises readily. Many organic compounds will fragments are than read individually for mass (molecules components)are connected. By analysing data from a mass spectrometry spectrum, two key concepts arise parent ion peak and base peak[27].

In addition unknown compounds are identified based on their retention times of known standard with other detectors.

BASE PEAK

The most intense peak in the mass spectrum is called the base peak. Base peak is the highest peak it is assigned a relative inttensity of 100%.

MOLECULAR ION PEAK

The ion formed from a molecule by removal of one electron of lowest ionization potential is known as molecular ion.The molecular ion is detected as mass to charge ratio that corresponds to molecular weight of molecule. The molecular ion peak the molecular weight of the compounds. The molecular ion peak is highest mass number except isotope peak.

FRAGMENT IONS

The ions produced from the molecular ion by cleavage of bonds are called Fragment ion. They have lower masses and as building blocks to reconstruct the molecular structure. Fragmentation of molecular ion cleavage bond occurs in heterolytic and homolytic cleavage.

Examples of Spectrum

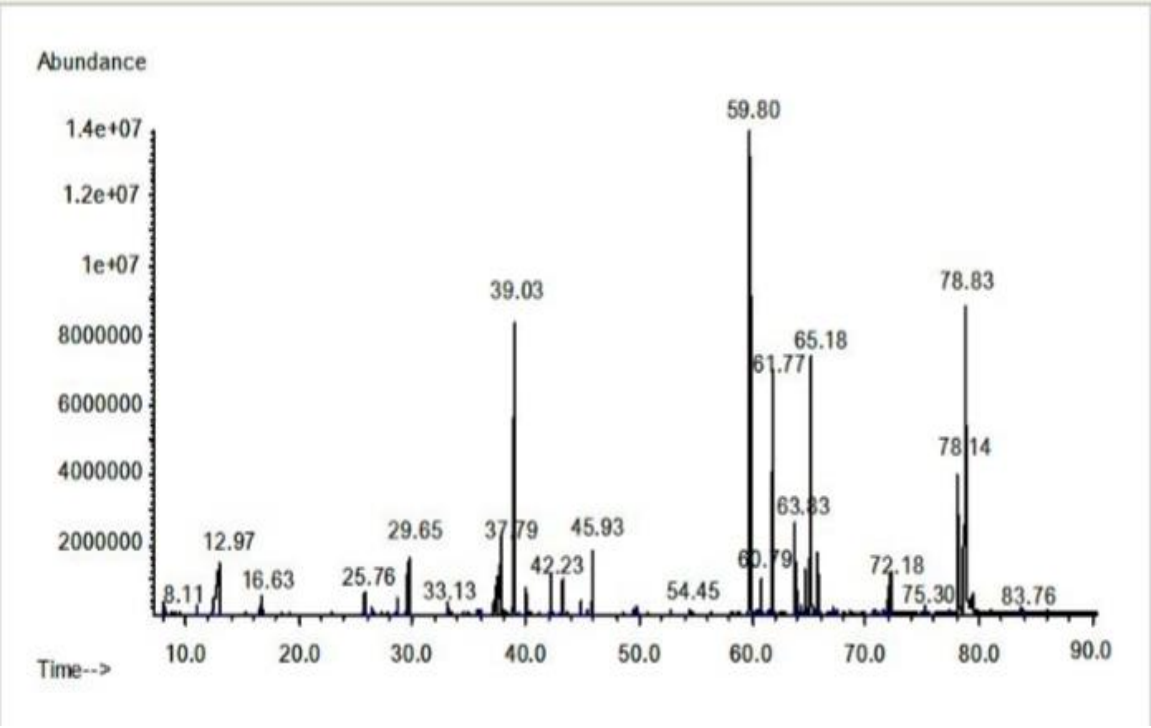


Fig 13: Chromatogram of silylated green tea dry leaf.[23]

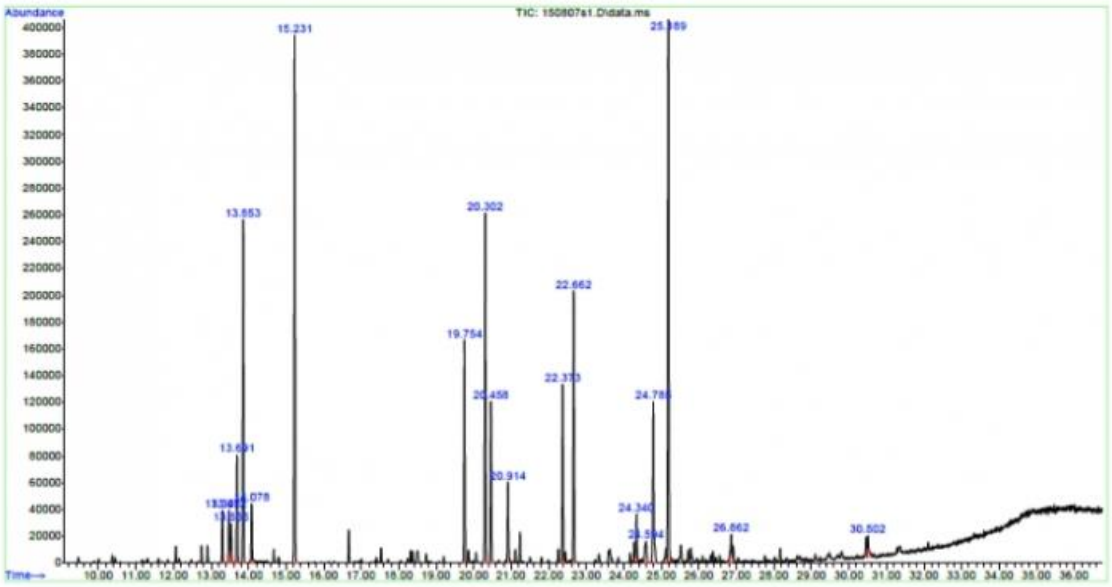


Fig 14: Chromatogram of oil paint sample[24]

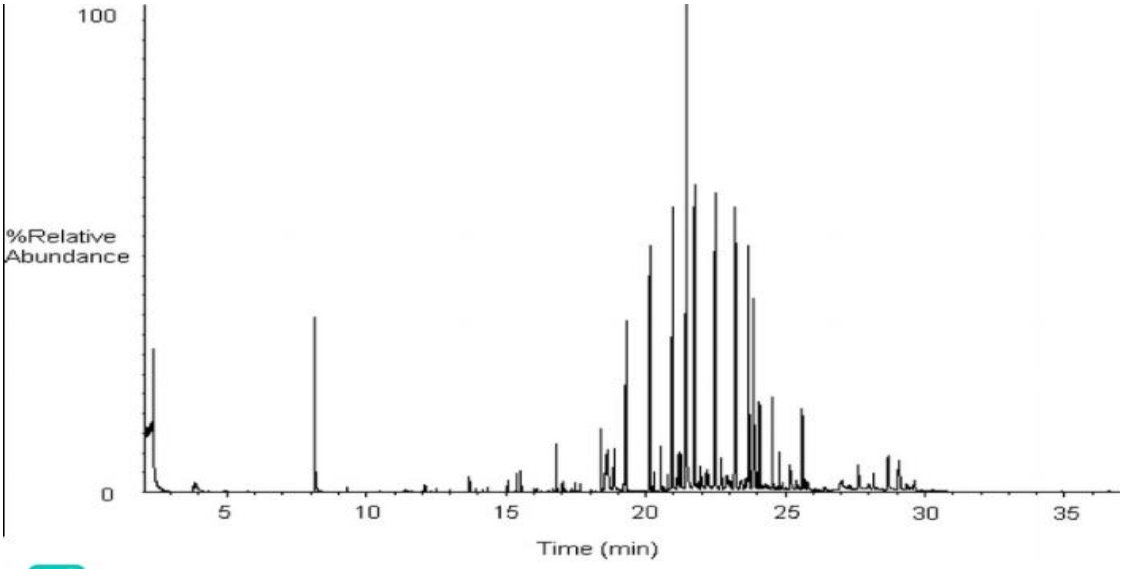


Fig 15: Extractables and leachables in oraly inhaled and nasal drug products[25]

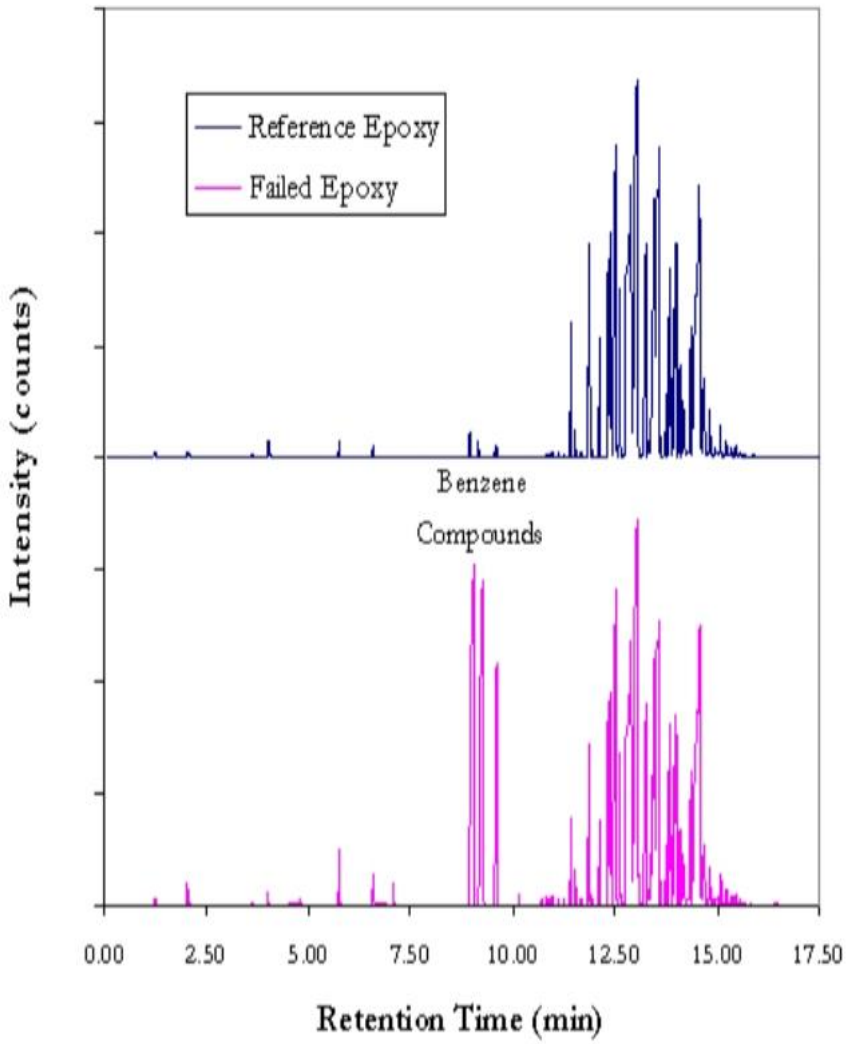


Fig 16: Chromatogram of Epoxy out gassing (Test and reference)[26]

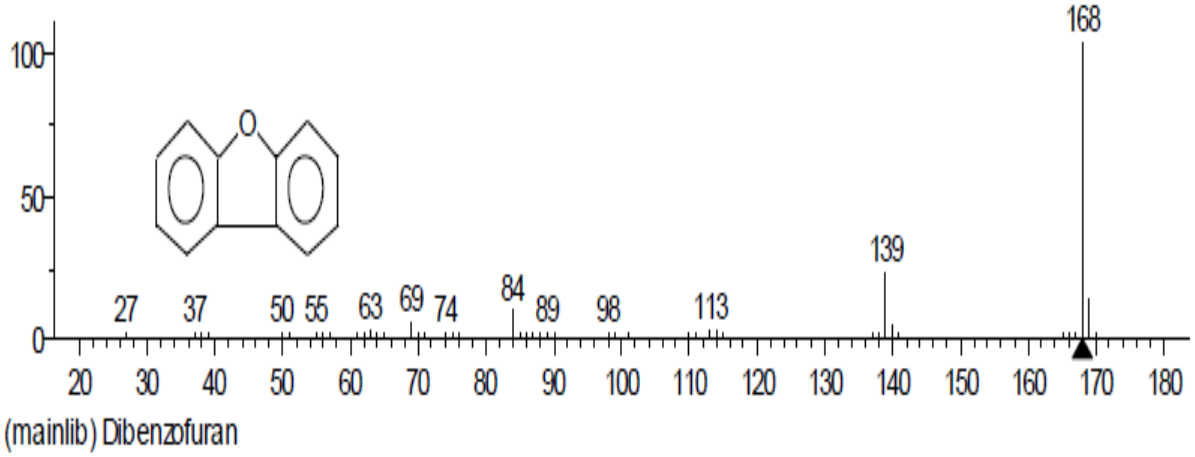


Fig 17: The GC-MS spectrum of Dibenzofuran[28]

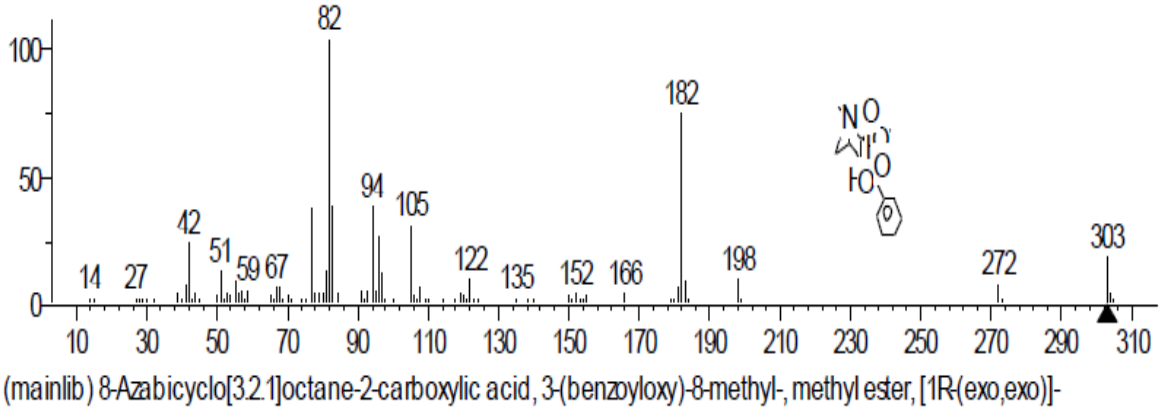


Fig 18: The GC-MS spectrum of cocaine[29]

ADVANTAGES

- Amount of data generated is very large
- It stores every sec for upto 90 min.[3,6,9]

ADVANTAGES OF GC-MS

- ❖ GC requires the analyte to have significant vapour pressure between 30 and 300˚C. GC presents a insufficient proof of the nature of detected compounds.
- ❖ The identification is based on retention time matching that may be inaccurate or misleading
- ❖ GC-MS represents the mass of a given particle (Da) to the number (Z) of electrostatic charge s (E) that the particle carries.
- ❖ The term M/Z is measured in DA/e .GCMS commonly uses electron impact (EI) and chemical ionization (CI) techniques.
- ❖ The main features of enhanced molecular ion, improved confidence in sample identification, significantly increased range of thermally labile and lowvolatility samples amenable for analysis, much faster analysis, improved sensitivity particularly for compounds that are hard to analyze and the many other features and options provide compelling reasons to use the GC-MS in broad range of areas.[7,10,11]

DISADVANTAGE OF GC-MS

- ❖ The major disadvantage of using GC-MS for drug confirmation testing or broad-spectrum drug screening is that GC-MS methods are not capable of directly analyzing drugs that are non-volatile, polar, or thermally labile.
- ❖ Derivatization is required to increase the volatility.
- ❖ This involves derivatizing one or more polar groups on a compound to a less polar group.
- ❖ Derivatization can also be used to achieve increased sensitivity, selectivity, or specificity for a given chromatographic separation.
- ❖ For drug confirmation testing and broad spectrum drug screening, lengthy sample preparations, which include hydrolysis and derivatization, are required prior to GC-MS analysis.
- ❖ This significantly lengthens the time of sample analysis compared to most LC-based methods.[8,10]

APPLICATIONS

CLINICAL TOXICOLOGY

Enhanced molecular ions, extended range of compounds amenable for analysis, superior sensitivity for compounds and faster analysis are the main attractive features of the clinical toxicology. The toxin and venoms are identified by GC-MS. It is extensively used in clinical toxicology.

INDUSTRIAL APPLICATION

GC-MS is used in industries for the analysis of aromatic solvents, inorganic gases, amino alcohol in water, impurities in styrene, glycol, diols, xylene, allergens in cosmetics etc. GC-MS is used for the characterization of formic acid in acetic acid for industrial use. In industries acetic acide is important intermediate in coal chemical synthesis. It is used in

the production of poly ethylene, cellulose acetate and poly vinyl as well as synthesic fiber and fabrics.

ENERGY AND FUEL APPLICATION

GC-MS is also used for the analysis of aromatic solvents, sulphur, impurities in polypropylene, sulphur in methane, natural gases, 1,3 butadiene, ethylene, gas oil, unleaded gasoline, poluethene, diesel . Oil unleaded gasoline, polyethylene, diesl, modified biomass, grafted polymers etc.

FOOD, BEVERAGE, FLAVOR AND FRAGRANCE ANALYSIS

GC-MS is also used to detect and measure contaminants, spoilage and adulteration of food, oil, butter, ghee that could be harmful and should to be controlled and checked as regulated by governmental agencies.

ENVIRONMENTAL MONITORING AND CLEANUP

GC-MS is becoming the tool of choice for tracking organic pollutants in the environment. The cost of GC-MS equipment has decreased significantly, and the reliability has increased at the same time, which has contributed to its increased adoption in environmental studies.

FORENSIC AND CRIMINAL CASES

GC-MS can analyze the particles from a human body in order to help link a criminal to a crime. The analysis of fire debris using GC-MS is well established, and there is even an established American Society for Testing and Materials (ASTM) standard for fire debris analysis. GCMS/MS is especially useful here as samples often contain very complex matrices and results, used in court, need to be highly accurate.

SPORTS ANTI-DOPING ANALYSIS

GC-MS is the main tool used in sports anti-doping laboratories to test athletes' urine samples for prohibited performance-enhancing drugs, for example anabolic steroids.

CHEMICAL WARFARE AGENT DETECTION

As part of the post-September 11 drive towards increased capability in homeland security and public health preparedness, traditional GC-MS units with transmission quadrupole mass spectrometers, as well as those with cylindrical ion trap (CIT-MS) and toroidal ion trap (T-ITMS) mass spectrometers have been modified for field portability and near real-time detection of chemical warfare agents (CWA) such as sarin, soman, and VX.

CHEMICAL ENGINEERING

GC-MS is used for the analysis of unknown organic compound mixtures. One critical use of this technology is the use of GC-MS to determine the composition of bio-oils processed from raw biomass. GC-MS is also utilized in the identification of continuous phase component in a smart material, Magnetorheological (MR) fluid.

MEDICINE

Dozens of congenital metabolic diseases also known as inborn errors of metabolism (IEM) are now detectable by new-born screening tests, especially the testing using gas chromatography–mass spectrometry. GC-MS can determine compounds in urine even in minor concentration.

CONCLUSION

GC-MS is an advanced technique that cannot be compared with other modern analytical equipment but can be complemented by mass spectrophotometer to achieve GC-MS and development pilot plants deportments for API, bulk drugs and formulations. It is used for press and method development, identification of impurities in API. It is an integral part of research associated with medicinal chemistry (synthesis and character of compound) phamaceutical analysis, pharmacognosy, pharmaceutical process control and pharmaceutical biotechnology. Its concise, efficient, automated system gives fast, reproducible and effective results that serve a key role in advancement of Science and Technology. This versatile analytical technique could be explored for before prospects in future.

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