APPLICATIONS OF GC-MS: A REVIEW

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***Abstract*- A technique called gas chromatography-mass spectrometry (GC-MS) combines the advantages of mass spectrometry and gas-liquid chromatography to identify various compounds in a test sample. The creation and validation of analytical methods are critical steps in the pharmaceutical industry's drug discovery, development, and manufacturing processes. Method development is the process of demonstrating that an analytical technique is appropriate for use in determining the concentration of an API in a particular compounded dosage form, allowing for the use of streamlined procedures to confirm that an analysis procedure will reliably deliver an accurate measurement of an active ingredient in a compounded preparation.**

***Keywords*: GC-MS, API**

INTRODUCTION:

Gas Chromatography-Mass Spectrometry (GC-MS) is a hyphenated analytical technique that combines mass spectrometry detection capabilities with gas-liquid chromatography separation capabilities to distinguish between various compounds in a test sample. Gas Chromatography-Mass Spectrometry (GC-MS) is a hyphenated analytical technique that combines mass spectrometry detection capabilities with gas-liquid chromatography separation capabilities to distinguish between various compounds in a test sample. [1-3] Any molecule that can pass through a gas chromatograph may be turned into ions in a mass spectrometer, making it a universal detector for gas chromatographs. However, the mass spectrometer is a particularly effective tool because of the mass spectrum's very precise nature. A particular gas chromatographic detector. While mass spectrometry excels at identification, gas chromatography is the perfect separator. Complex mixtures can be effectively separated by GC, and these compounds can be found by MS. Because both GC and MS can operate in the gaseous state, they can be coupled, making the combination of the two more popular. Directly, and the user interface is fairly straightforward. In a nutshell, GC-MS performance is stable, and repeatability is good. An interface setup aims to operate both a gas chromatograph and a mass spectrometer without compromising each instrument's performance. Compatibility is a problem. The different operating pressures needed for a gas chromatograph and a mass spectrometer provide an incompatibility issue. The latter is made to function at high vacuum, whilst the former operates at high pressures. The abundance of carrier gas and lack of sample in the gas chromatograph's effluent is a related issue. The mass spectrometer's vacuum would be lost if the gas chromatograph used a packed column and the flow of carrier gas exceeded 30 ml/min. Consequently, the carrier gas needs to be significantly reduced and different designs must be created.[4]

The gas chromatograph and the mass spectrometer are the two main components that make up the GC-MS. In the gas chromatograph, a capillary is used. The column is influenced by the phase qualities (for example, 5% phenyl polysiloxane) and the column's size (length, diameter, film thickness). As the sample moves down the column, the various molecules in a mixture will get separated due to differences in their chemical characteristics. As the molecules are maintained by the column and elute (come off of) from the column at various periods (referred to as the retention time), the mass spectrometer downstream is able to catch, ionize, and analyze the molecules. The ionized molecules are independently accelerated, deflected, and detected. Diagram of a GC-MS: When these two parts are utilized together, a far finer level of material identification is possible than when they are employed alone. There is no way to accurately identify a specific chemical using just gas chromatography or mass spectrometry. While gas chromatography with a traditional detector, such as a flame ionization detector, cannot distinguish between multiple molecules that just so happen to take the same amount of time to travel through the column (i.e., have the same retention time), two or more molecules that co-elute9, the mass spectrometry process typically requires a very pure sample. In a mass spectrometer (mass spectrum), two distinct molecules may occasionally exhibit a similar pattern of ionized particles. Combining the two procedures lessens the chance of mistakes.[4]

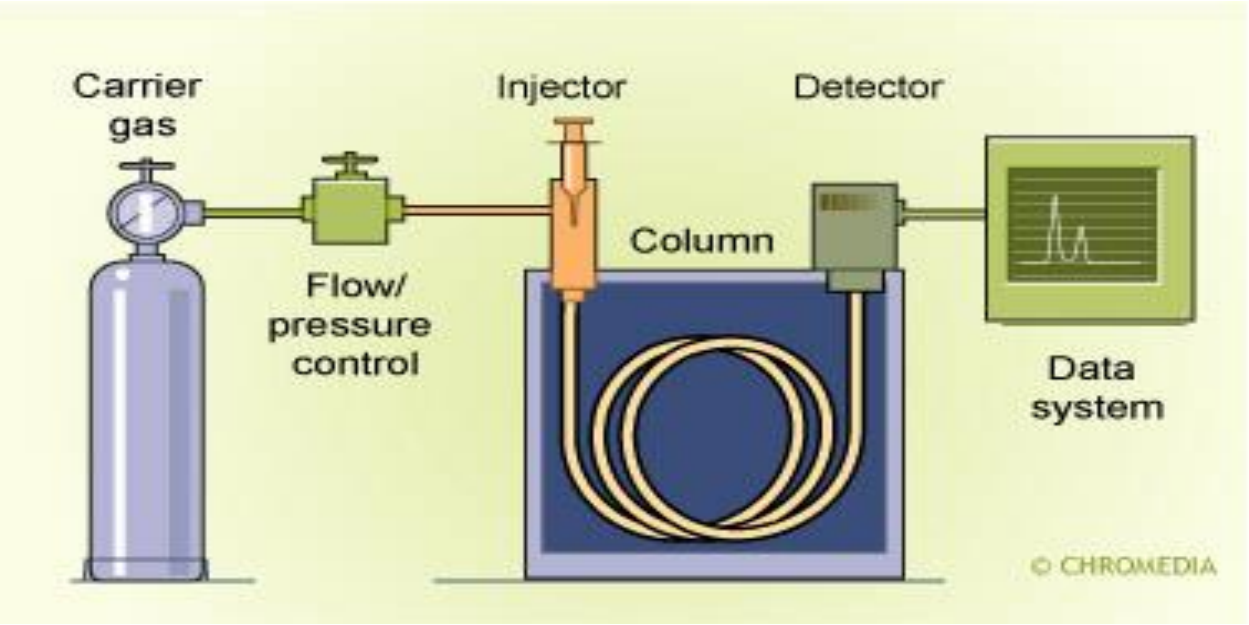

Figure 1: GC/MS.

Purge and trap GC-MS: A purge and trap (P&T) concentrator system may be utilized to introduce samples for the analysis of volatile chemicals. The desired analytes include placed into an airtight chamber after being removed, and mixed with water. Purging is the process of bubbling an inert gas through water, such as nitrogen (N2). The volatile substances travel into the headspace above the water and are pulled out of the chamber along a pressure gradient (produced by the addition of the purge gas). Onto a "trap," the volatile substances are dragged along a hotline. The chemicals are held in the trap by being returned to the liquid phase in a column of adsorbent material that is at room temperature. The trap is heated after that.

Types of mass spectrometer detectors: The most common type of mass spectrometer (MS) associated with a gas chromatograph (GC) is the quadrupole mass spectrometer, sometimes referred to by the Hewlett-Packard (now Agilent) trade name "Mass Selective Detector" (MSD). Another relatively common detector is the ion trap mass spectrometer. Additionally, one may find a magnetic sector mass spectrometer, however, these particular instruments are expensive and bulky and not typically found in high throughput service laboratories. Other detectors may be encountered such as time of flight (TOF), and tandem quadrupoles.

Ionization: After the molecules travel the length of the column, pass through the transfer line and enter into the mass spectrometer they are ionized by various methods with typically only one method being used at any given time12. Once the sample is fragmented it will then be detected, usually by an electron multiplier diode, which essentially turns the ionized mass fragment into an electrical signal that is then detected.

Electron ionization: In electron ionization (EI) the molecules enter into the MS (the source is a quadrupole or the ion trap itself in an ion trap MS) where they are bombarded with free electrons emitted from a filament, not unlike the filament one would find in a standard light bulb. The electrons bombard the molecules, causing the molecule to fragment in a characteristic and reproducible way. This "hard ionization" technique results in the creation of more fragments of low mass-to-charge ratio (m/z). Hard ionization is considered by mass Spectro metrists as the employ of molecular electron bombardment, whereas "soft ionization" is charged by molecular collision with an introduced gas. The molecular fragmentation pattern is dependent upon the electron energy applied to the system, typically 70 eV (electron Volts). The use of 70 eV facilitates the comparison of generated spectra with library spectra using manufacturer-supplied software or software developed by the National Institute of Standards (NIST-USA).[4]

Chemical ionization: In chemical ionization a reagent gas, typically methane or ammonia is introduced into the mass spectrometer. Depending on the technique (positive CI or negative CI) chosen, this reagent gas will interact with the electrons and analyte and cause a 'soft' ionization of the molecule. A softer ionization fragments the molecule to a lower degree than the hard ionization of EI. One of the main benefits of using chemical ionization is that a mass fragment closely corresponding to the molecular weight of the analyte of interest is produced. In positive chemical ionization (PCI) the reagent gas interacts with the target molecule, most often with a proton exchange. This produces the species in relatively high amounts.[4]

Applications of GC-MS:

Environmental monitoring

A highly suggested technology for tracking and monitoring organic contaminants in the environment is GC-MS. Equipment for GCMS has become less expensive while significantly improving in reliability. By using this method, it is very practical to screen for chlorophenols in water and soil, polycyclic aromatic hydrocarbons (PAH), unleaded petrol, dioxins, and dibenzofurans as well as organochlorine pesticides, herbicides, phenols, halogenated pesticides, and Sulphur in the air. It can be used to check for pesticides in spinach and lignin degradation products in biomass studies. Without the need for derivatization, it is possible to analyze decacyclene, ovalene, and even C60 degradation of carbamazepine and its metabolites in treated sewage water and steroids. [5-7]

Food, beverage, flavor, and fragrance analysis

Numerous aromatic chemicals are present in foods and beverages either naturally or as byproducts of processing. The examination of esters, fatty acids, alcohols, aldehydes, terpenes, etc. is the sole usage of GC-MS. Additionally, GC-MS is used to measure and detect pollutants, food spoilage, and adulteration in oil, butter, and ghee that should be examined and managed in accordance with legal requirements. Piperine , spearmint oil, lavender oil, essential oil, fragrance reference standards, perfumes, chiral compounds in essential oils, fragrances, menthol, allergens, olive oil, lemon oil, peppermint oil, yang oil, strawberry syrup, butter triglycerides, residual pesticides in food, and wine are all examples of substances that can be analyzed using this method.[8-9]

Forensic and criminal cases

The suspect's particles can be analyzed by GC-MS to determine his involvement in the case. The American Society for Testing Materials (ASTM) standard for fire debris analysis can be used to establish the analysis of fire debris using GC-MS. It is the main instrument used in anti-doping labs for athletes to check urine samples for illegal performance-enhancing substances like anabolic steroids. Forensic toxicology, it is frequently employed to identify poisons and steroids in biological samples taken from suspects, victims, or the deceased. [10-11]

Biological and pesticides detections

In order to detect the presence of anesthetics, anticonvulsants, antihistamines, anti-epileptic medications, sedative-hypnotics, narcotics, and dietary items in blood and urine, GC-MS is only utilized in this process. The detection of adulterations, fatty acid profiling in microorganisms, the presence of free steroids, blood pollutants, metabolites in serum, organochlorine pesticides in drinking water, soft drinks by headspace, pesticides in sunflower oil, and other things may be done with this technique. [12]

Security and chemical warfare agent detection

All airports in the United States now have explosive detection systems, and the GC-MS is a crucial component of the chemical analysis unit. 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 close to real-time detection of chemical warfare agents (CWA) like sarin, soman, and VX. This has improved capability in homeland security and public health preparedness. [13]

Medicine and Pharmaceutical Applications

The use of screening tests utilizing gas chromatography-mass spectrometry has made it possible to identify dozens of congenital metabolic illnesses known as inborn errors of metabolism in newborns. Even in urine with low concentrations, chemicals can be identified by GC-MS. These substances are generally absent; however, they do show up in people with metabolic problems. Similar to how a urine test at birth can be used to determine inherited metabolic abnormalities, this method is simple, effective, and efficient. The GCMS is used to assess metabolic activity along with isotopic labeling of metabolites. The majority of applications rely on the measurement of 13C-12C ratios using an isotope ratio mass spectrometer (IRMS), which is an MS with a detector made to test a small number of specific ions and return values as

For analytical research and development, quality assurance, production, and pilot plant departments for active pharmaceutical ingredients (API), bulk pharmaceuticals, and formulations, GC-MS is frequently employed in the pharmaceutical industry. It is employed in the creation of procedures and methods as well as the detection of API contaminants. It is a crucial component of studies in medicinal chemistry (compound synthesis and characterization), pharmaceutical analysis (impurity profiling, stability testing), pharmacognosy, process control in the pharmaceutical industry, pharmaceutical biotechnology, etc. [14-16]

Petrochemical and hydrocarbons analysis

The GC-MS is a very useful technique since it consistently detects significantly increased molecular ions, has isomer- and structurally relevant mass spectrum peaks, and can analyze a wide range of low volatile hydrocarbons, including waxes up to C74H150. By using GC-MS, a wide variety of petrochemicals, fuels, and hydrocarbon mixtures can be analyzed, including a wide range of geochemical materials, petrol, kerosene, naphthenic acids, diesel, different types of oil, transformer oil, biodiesel, wax, many other hydrocarbons. [17-19]

Clinical Toxicology

The key appealing characteristics of clinical toxicology include improved molecular ions, an expanded choice of drugs that may be analyzed, higher sensitivity for substances, and faster analysis. By using GC-MS, the toxin and venoms are detected. Clinical toxicology makes great use of it.

Academic research

The uncommon chance to perform the analysis of new compounds for characterization and identification of synthesized or derivatized compounds is made possible by the GC-MS's unique and potent technology. It is frequently employed in both pure and practical sciences, including chemistry, polymers, nanotechnology, and biotechnology, among others. It produces valuable data that can be applied in worldwide research publications. [20-22]

Industrial applications

The examination of aromatic solvents, inorganic gases, amino alcohol in water, contaminants in styrene, glycol, diols, and xylene, allergens in cosmetics, etc. are all carried out in industries using GC-MS. Formic acid in acetic acid is characterized by GC-MS for industrial use. Acetic acid is a crucial step in the chemical production of coal in the industrial sector. It is employed in the creation of synthetic fibers and fabrics as well as polyethylene, and cellulose acetate.[23]

Energy and fuel applications

Aromatic solvents, sulfur, contaminants in polypropylene, sulfur in methane, natural gases, 1,3 butadiene, ethylene, petrol oil, unleaded petrol, polyethylene, diesel, modified biomass, grafted polymers, etc. are all analyzed using GC-MS. Due to its numerous applications, GC-MS has opened up a brand-new field of study and elevated the impactful presentation and characterization of substances to new heights. [25]

Conclusion:

In this chapter, we review the basic principle of GC-MS, as well as the broader criteria for selecting GC-MS conditions and their application. Gas chromatography-mass spectrometry (GC-MS) combines the advantages of mass spectrometry and gas-liquid chromatography to identify various compounds in a test sample. The GC-MS is a very useful technique since it consistently detects significantly increased molecular ions, and has isomer and structurally relevant mass spectrum peaks.

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