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Review on Current Trends of Gas Chromatography in Pharmaceutical Industry

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Abstract: ***A gas chromatograph (GC) is an analytical tool for determining the composition of distinct segments in a sample. GC may help in recognizing a compound. In preparative chromatography, GC can be used to get ready pure compound from a mixer. A gas chromatograph is a chemical analysis tool that is used to separate compounds from a complex sample mixture. In GC the mobile phase is inert gas and stationary phase is a thin layer of inert fluid on an inert solid support. It has high resolution power compared to other methods. The GC method is highly accurate quantitative analysis typical of 1-5%. It is limited to volatile sample. It requires spectroscopy, usually mass spectroscopy, for conformation of peak identity. The Instrumentation involves sample injection-A sample port is necessary for introducing the sample at the head of the column. Carrier Gas-The carrier gas plays an important role, and varies in the GC used. Helium is most commonly used as carrier gas because it is safer than other gases. Autosamplers-Autosamplers are instruments that automatically take a sample and insert it into the GC for analysis. Columns-columns plays key role in GC there are two main types of columns are Open tubular columns and Packed columns. Detectors-A detector is a device used to detect components of mixture being eluted off the chromatographic column. Two main types of detectors mainly used in GC are Flame Ionization Detector (FID) Thermal Conductivity Detector (TCD).***

Keywords: analytical method, Gas chromatography, instrumentation, detectors, advantages, disadvantages, applications

1. Introduction

A gas chromatograph (GC) is an analytical tool for determining the composition of distinct segments in a sample. Gas chromatography is the study carried out by a gas chromatograph. Gas chromatography (GC) is a type of chromatography that is commonly employed in analytical research to separate and investigate chemicals that may be vaporised without dissolving.

Regular employments of GC are trying to remove the contaminants of a particular substance, or separating of the distinctive segments of a mixers. GC may help in recognizing a compound. In preparative chromatography, GC can be used to get ready pure compound from a mixer.

Gas chromatography principle: The specimens are mixed into the instrument, which then enters a gas stream that transfers the sample into a division tube called a "column. " (As a carrier gas, helium or nitrogen is utilised.) The distinct components are kept separate within the section. The designators take measurements of the part as it exits the section. A standard specimen with a known concentration is mixed into the instrument to quantify an example with an unknown. The test is compared to the standard sample top maintenance time (Retention time) and region in order to group the unknown sample. A gas chromatograph is a chemical analysis tool that is used to separate compounds from a complex sample mixture.

A gas chromatograph uses a column, which is a small tube through which different chemical constituents of a sample are transported in a gas stream (transporter gas, portable stage) at different rates depending on their different chemicals and physical properties and their interaction with a specific column filling, known as the stationary phase. The compounds are recognised and analysed electronically as they leave the end of the column. The stationary stage in the column has the ability to isolate a variety of different components, forcing each component to exit the segment at a separate moment (retention time). The flow rate of the carrier gas, the length of the column, and the temperature are all variables that can be used to alter the order or period of retention.

Gas-liquid chromatography is the most frequent method for separating organic molecules among the numerous types of gas chromatography. In the identification of compounds, the combination of gas chromatography and mass spectrometry is a crucial instrument. An injection port, a column, carrier gas flow control equipment, ovens and heaters for regulating injection port and column temperatures, an integrator chart recorder, and a detector are all part of a conventional gas chromatograph.

In gas-liquid chromatography, a solution sample containing organic compounds of interest is injected into the sample port and vaporised to separate the components. The injected vaporised samples are then carried away by an inert gas, most often helium or nitrogen. This inert gas passes through a liquid-coated glass column filled with silica. The outcome will increase faster for materials that are less soluble in the liquid than for materials that are more soluble. The goal of this section is to provide you a greater grasp of the separation and measurement procedures, as well as how to use them.

In GLC, the liquid stationary phase is adsorbed onto a solid inert packing or immobilized on the capillary tubing walls. The column is considered packed if the glass or metal column tubing is packed with small globular inert supports. The liquid phase adsorbs onto the surface of these beads in a thin layer. In a capillary column, the tubing walls are coated with the stationary phase or an adsorbent layer, which is capable of supporting the liquid phase. However, the method of GSC, has limited application in the laboratory and is rarely used due to severe peak tailing and the minor retention of polar compounds within the column.

The sample is adsorbed in the stationary phase of the column, which is then separated by the polarity of the carrier gas moving through the column. The carrier gas will be a 99.999 percent pure inert gas such as helium or nitrogen. Before being injected into the carrier stream, liquid samples are vaporised. Substances with a higher interaction with the stationary phase are kept in the column for longer periods of time and, as a result, segregate from those with a lower interaction. Detectors detect the chemicals eluted from the column at different periods depending on their polarity. RT varies depending on the polarity of the molecule. The response of such Gas Chromatography detectors is proportional to the analyst concentration in the sample. Flame ionisation detectors (FID), thermal conductivity detectors (TCD), electron capture detectors (EC), nitrogen phosphorous detectors (NPD), and other types of detectors are utilised.

Advantage-

- High resolution power compared to other methods.
- High sensitivity.
- High accuracy and precision.
- Analysis of sample very quickly.
- Small samples needed (µl/µg).
- Requires only very small samples with little preparation.
- Good at separating the complex mixtures into components.
- Results are rapidly obtained (1to100 minutes.
- Only instrument with the sensitivity to detect volatile organic mixtures of low concentration.
- Equipment is not very complex.
- Highly accurate quantitative analysis typical of 1-5%
- Reliable and relatively simple.

Key sources of the competitive advantage of gas chromatography-

To begin, it should be noted that GC and GC-MS are only available for 35 percent of medications, either in their native form (5%) or as volatile derivatives (30%). (own calculation). HPLC or LC-MS/MS are the most often employed techniques for the remaining 65 percent of medicines. In comparison to LC-based approaches, Table 1 outlines the most notable advantages of using GC and GC-MS procedures.

Table 1: Analysis of the key sources of the competitive advantage of GC compared to LC techniques, in relation to its attributes

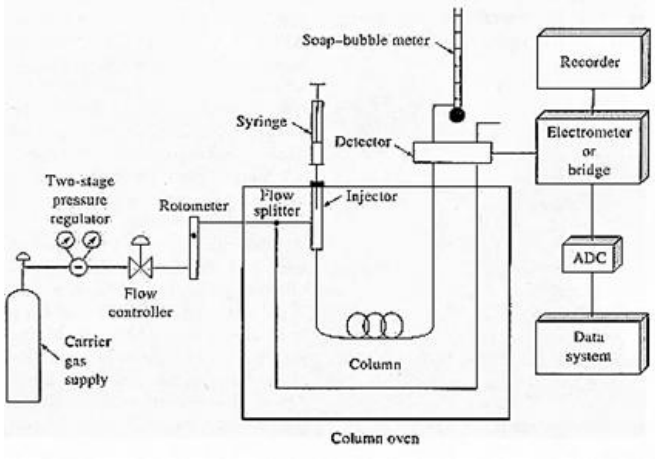
No.	The source of competitive advantage	Rating of the advantage	Characteristic
1	Uniqueness of the service	Significant for 35% of pharmaceuticals	There isn't a lot of demand for GC-based pharmaceutical analysis right now. According to Scopus, 3874 reports on the analyses of pharmaceutical residues using the GC technique and respectively 18137 reports using the LC technique were recorded as of 30.01.2018, indicating a dominant share of the LC technique used in such analyses. It is important to note that when determinations must be made in regulated fields, the choice of measuring technique is governed by legal requirements. In other cases, weather conditions, equipment availability, and employee qualifications are critical. To summarise, few organisations use GC and GC-MS to identify pharmaceutical residuals, therefore the uniqueness of the service's availability for 35 percent of pharmaceuticals can be important.
2	Duration of the analysis	Average	Time of chromatographic ‘run’ depends on the number of analytes taken as targets and MS abilities. When comparing the GC and LC analysis of for example 20 pharmaceuticals, the time of analysis is very comparable. This means that the advantage of the GC and the GC-MS techniques in this area is not significant.
3	Availability of the technique	Average	Because of the widespread availability of GC and GC-MS equipment, as well as HPLC and LC-MS equipment on the market and in laboratories, the predominance of GC-based approaches in this domain is negligible.
4	Accuracy of the result	Significant	In compared to LC-MS analyses, the high accuracy of the acquired result is due to significantly fewer matrix effects affecting the outcomes of final determinations (Caban et al.2012). It has something to do with the ion source approach. Electron Ionization (EI) is less sensitive to matrix effects in GC-MS than Electro-Spray Ionization (ESI) (which is commonly employed in LC-MS) (Biswas and Mitra 2013). Because proper certified reference materials (Certified Reference Materials – CRMs) are virtually unavailable for a substantial portion of the analyses and matrices, having acceptable patterns as well as an appropriately optimised methodology is critical for producing a highly accurate result. In the literature, there are examples of negative matrix impact on chromatographic analysis (Caban et al.2012, Garrido et al.2009). Under general, GC-MS systems that are kept in clean conditions are less influenced by matrix.

5	Detection limits	Average	The GC-MS technique's sensitivity is comparable to that of the LC-MS. It is also sufficient in terms of the expected required concentration ranges (ng/l or ng/kg); however, SPE-GC is associated with a higher sample concentration ratio, e. g., transferring analytes from a 500 ml sample to a 0.1 ml volume (the volume of the derivatising agent) yields a concentration factor of 5000 (Caban et al.2016); for this type of analysis, SPE-LC-MS is most However, the benefit of GC and GC-MS in this field is negligible, and the observed pharmaceutical detection limits are primarily determined by the extraction methodologies used (Lika and Slobodnk 1996).
6	Waste production	Significant	The use of a carrier gas as a mobile phase is associated with little waste output as compared to the LC-MS process. Furthermore, because there is no need to dispose of solvent residues, this process is substantially less expensive and environmentally friendly. Although solvent consumption in HPLC procedures can currently be reduced by up to 90% (Caban et al.2015), the cost of such solutions is many times higher. In chromatography, GC is frequently referred to as the "green" technique (Biswas and Mitra 2013).
7	The rate of implementation in routine analyses	Significant	In compared to LC-MS-based approaches, it is more easier to adopt for routine analysis in environmental and biomedical laboratories. It is due to the decreased cost (see Table 2). Furthermore, due to the easier optimization of this system's operation, the time required to teach a person to run GC-MS equipment is reduced.

Disadvantage-

- Limited to volatile sample.
- Not suitable for thermally labile samples.
- Samples be soluble and don't react with the column.
- During injection of the gaseous sample proper attention is required.
- Requires spectroscopy, usually mass spectroscopy, for conformation of peak identity.
- Some samples require extensive preparation.

Methods and Instruments-



Sample Injection

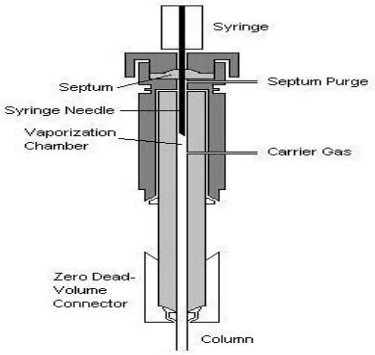


Figure: A cross-sectional view of a microflash vaporizer direct injector

A sample port is necessary for introducing the sample at the head of the column. Modern injection techniques often

employ the use of heated sample ports through which the sample can be injected and vaporized in a near simultaneous fashion. A calibrated microsyringe is used to deliver a sample volume in the range of a few microliters through a rubber septum and into the vaporization chamber. Most separations require only a small fraction of the initial sample volume and a sample splitter is used to direct excess sample to waste. Commercial gas chromatographs often allow for both split and splitless injections when alternating between packed columns and capillary columns. The vaporization chamber is typically heated 50 °C above the lowest boiling point of the sample and subsequently mixed with the carrier gas to transport the sample into the column.

Carrier Gas-

The carrier gas plays an important role, and varies in the GC used. Carrier gas must be dry, free of oxygen and chemically inert mobile-phase employed in gas chromatography. Helium is most commonly used because it is safer than, but comparable to hydrogen in efficiency, has a larger range of flow rates and is compatible with many detectors. Nitrogen, argon, and hydrogen are also used depending upon the desired performance and the detector being used. Both hydrogen and helium, which are commonly used on most traditional detectors such as Flame Ionization (FID), thermal conductivity (TCD) and Electron capture (ECD), provide a shorter analysis time and lower elution temperatures of the sample due to higher flow rates and low molecular weight. For instance, hydrogen or helium as the carrier gas gives the highest sensitivity with TCD because the difference in thermal conductivity between the organic vapour and hydrogen/helium is greater than other carrier gas. Other detectors such as mass spectroscopy, uses nitrogen or argon which has a much better advantage than hydrogen or helium due to their higher molecular weights, in which improve vacuum pump efficiency.

All carrier gasses are available in pressurized tanks and pressure regulators, gages and flow meters are used to meticulously control the flow rate of the gas. Most gas supplies used should fall between 99.995%-99.9995% purity range and contain a low levels (< 0.5 ppm) of oxygen and total hydrocarbons in the tank. The carrier gas system contains a molecular sieve to remove water and other impurities. Traps are another option to keep the system pure and optimum sensitive and removal traces of water and other contaminants. A two stage pressure regulation is required to use to minimize the pressure surges and to monitor the flow rate of the gas. To monitor the flow rate of the gas a flow or pressure regulator was also require onto both tank and chromatograph gas inlet. This applies different gas type will use different type of regulator. The carrier gas is preheated and filtered with a molecular sieve to remove impurities and water prior to being introduced to the vaporization chamber. A carrier gas is typically required in GC system to flow through the injector and push the gaseous components of the sample onto the GC column, which leads to the detector (see more detail in detector section

Autosamplers

Autosamplers are instruments that automatically take a sample and insert it into the GC for analysis, which is both more time effective and more reliable than doing it by hand. GC autosamplers can be used anywhere GC is used, including forensic, environmental, and medical labs, in the pharmaceutical and food and beverage industries, to analyze a sample for quality control, purity, or to look for a particular analyte. There are three main types of GC autosamplers; liquid, which work with liquid samples, headspace, which work with volatile organic samples, and SPME which uses a fiber to extract the components of your sample. There are GC autosamplers that can do all three types of autosampling.

The types of samples you will be analyzing will dictate which type of autosampler you will need. Keep in mind the sample size you wish to use, how many analyses need to be run in a given time, and if there are different types of samples that would require a multipurpose autosampler.

Inlets

The column inlet (or injector) gives the way to bring a sample into a continuous stream of carrier gas. The inlet is a piece of equipment appended to the column head the common inlet sorts are: S/SL (split/split less) injector, on-column inlet, PTV injector, and Gas source inlet or gas switching valve, P/T (Purge-and-Trap) system.

The decision of carrier gas (portable stage) is very important. The carrier gas must be chemically inert. Generally utilized gasses include nitrogen, helium, argon, and carbon dioxide. The decision of carrier gas is regularly depended upon the sort of indicator which is utilized.

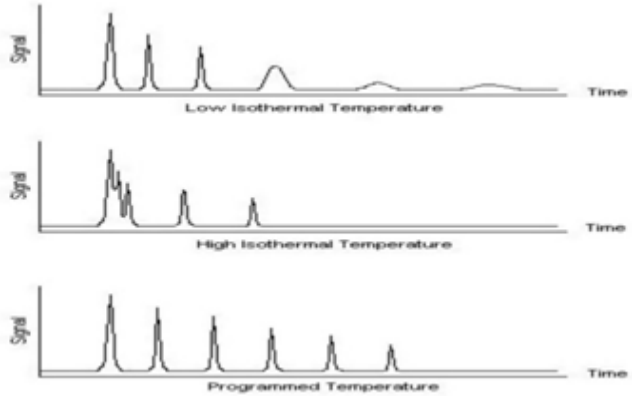
The carrier gas framework likewise contains a molecular sieve to expel water and different other impurities. So, helium might be more efficient and give the best separation if flow rates are optimized.

Helium is non-combustible and works with a more prominent number of detectors. Thus, helium is the most well-known carrier gas utilized. In any case, the cost of helium has gone up significantly over recent years, causing an expanding number of chromatographers to change to hydrogen gas.

Column Oven

The thermostated oven serves to control the temperature of the column within a few tenths of a degree to conduct precise work. The oven can be operated in two manners: isothermal programming or temperature programming. In isothermal programming, the temperature of the column is held constant throughout the entire separation. The optimum column temperature for isothermal operation is about the middle point of the boiling range of the sample. However, isothermal programming works best only if the boiling point range of the sample is narrow. If a low isothermal column temperature is used with a wide boiling point range, the low boiling fractions are well resolved but the high boiling fractions are slow to elute with extensive band broadening. If the temperature is increased closer to the boiling points of the higher boiling components, the higher boiling components elute as sharp peaks but the lower boiling components elute so quickly there is no separation.

In the temperature programming method, the column temperature is either increased continuously or in steps as the separation progresses. This method is well suited to separating a mixture with a broad boiling point range. The analysis begins at a low temperature to resolve the low boiling components and increases during the separation to resolve the less volatile, high boiling components of the sample. Rates of 5-7 °C/minute are typical for temperature programming separations.



Column:

Two types of columns are used in gas chromatography:
1. Packed columns
2. Open tubular columns

Open tubular columns, which are also known as capillary columns, come in two basic forms. The first is a wall-coated open tubular (WCOT) column and the second type is a support-coated open tubular (SCOT) column. WCOT columns are capillary tubes that have a thin later of the stationary phase coated along the column walls. In SCOT columns, the column walls are first coated with a thin layer (about 30 micrometers thick) of adsorbant solid, such as diatomaceous earth, a material which consists of single-celled, sea-plant skeletons. The adsorbant solid is then treated with the liquid stationary phase. While SCOT columns are capable of holding a greater volume of stationary phase than a WCOT column due to its greater sample capacity, WCOT columns still have greater column efficiencies.

Most modern WCOT columns are made of glass, but T316 stainless steel, aluminum, copper and plastics have also been used. Each material has its own relative merits depending upon the application. Glass WCOT columns have the distinct advantage of chemical etching, which is usually achieved by gaseous or concentrated hydrochloric acid treatment. The etching process gives the glass a rough surface and allows the bonded stationary phase to adhere more tightly to the column surface.

One of the most popular types of capillary columns is a special WCOT column called the fused-silica wall-coated (FSWC) open tubular column. The walls of the fused-silica columns are drawn from purified silica containing minimal metal oxides. These columns are much thinner than glass columns, with diameters as small as 0.1 mm and lengths as long as 100 m. To protect the column, a polyimide coating is applied to the outside of the tubing and bent into coils to fit inside the thermostated oven of the gas chromatography unit. The FSWC columns are commercially available and currently replacing older columns due to increased chemical inertness, greater column efficiency and smaller sampling size requirements. It is possible to achieve up to 400, 000 theoretical plates with a 100 m WCOT column, yet the world record for the largest number of theoretical plates is over 2 million plates for 1.3 km section of column.

Packed columns are made of a glass or a metal tubing which is densely packed with a solid support like diatomaceous earth. Due to the difficulty of packing the tubing uniformly, these types of columns have a larger diameter than open tubular columns and have a limited range of length. As a result, packed columns can only achieve about 50% of the efficiency of a comparable WCOT column. Furthermore, the diatomaceous earth packing is deactivated over time due to the semi-permanent adsorption of impurities within the column. In contrast, FSWC open tubular columns are manufactured to be virtually free of these adsorption problems.

Different types of columns can be applied for different fields. Depending on the type of sample, some GC columns are better than the others. For example, the FSWC column shown in Figure 5 is designed specially for blood alcohol analysis. It produces fast run times with baseline resolution of key components in under 3 minutes. Moreover, it displays enhanced resolutions of ethanol and acetone peaks, which helps with determining the BAC levels.

This particular column is known as Zebron-BAC and it made with polyimide coating on the outside and the inner layer is made of fused silica and the inner diameter ranges from.18 mm to.25 mm. There are also many other Zebron brand columns designed for other purposes.

Another example of a Zebron GC column is known as the Zebron-inferno. Its outer layer is coated with a special type of polyimide that is designed to withstand high temperatures. As shown in figure 6, it contains an extra layer inside. It can withstand up to 430 °C to be exact and it is designed to provide true boiling point separation of hydrocarbons distillation methods. Moreover, it is also used for acidic and basic samples.

	Type of Column			
	FSWC	WCOT	SCOT	Packed
Length	10 to 1000 m	10 to 1000 m	10 to 100 m	1 to 6 m
Inner Diameter	0.1 to 0.3 mm	0.25 to 0.75 mm	0.5 mm	2 to 4 mm
Efficiency (plates/m)	2000 to 4000	1000 to 4000	600 to 1200	500 to 1000
Sample Size	10 to 75 ng	10 to 1000 ng	10 to 1000 ng	10 to 10^6 ng
Pressure	Low	Low	Low	High
Speed	Fast	Fast	Fast	Slow
Inertness	Best	Good	Fair	Poor

Figure: The effect of Column temperature on the shape of the peaks

Detectors

There are numerous detectors which can be utilized as a part of gas chromatography. Distinctive detectors will give different sorts of selectivity. A non-selective detector reacts to all mixes aside from the carrier gas, a particular indicator reacts to a range of compounds with a typical physical or chemical property and a particular detector reacts to a one chemical compound.

Detectors can likewise be gathered into concentration dependant detectors and mass flow dependant detectors. The sign from a concentration dependant detector is identified with the grouping of solute in the detector, and does not generally crush the sample Dilution of with make-up gas will bring down the detector's reaction. Mass flow dependant detectors ordinarily decimate the sample, and the sign is identified with the rate at which solute particles enter the detector. The reaction of a mass flow dependant detector is unaffected by make-up gas.

Types of detectors used in GC are:

- Mass Spectrometer (GC/MS)
- Flame Ionization Detector (FID)
- Thermal Conductivity Detector (TCD)
- Electron Capture Detector (ECD)
- Nitrogen-phosphorus
- Flame photometric (FPD)
- Photo-ionization (PID)
- Chemiluminescence Detectors

Mass spectrometer (GC/MS)-

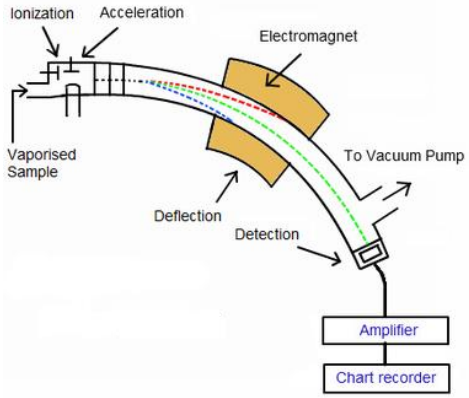
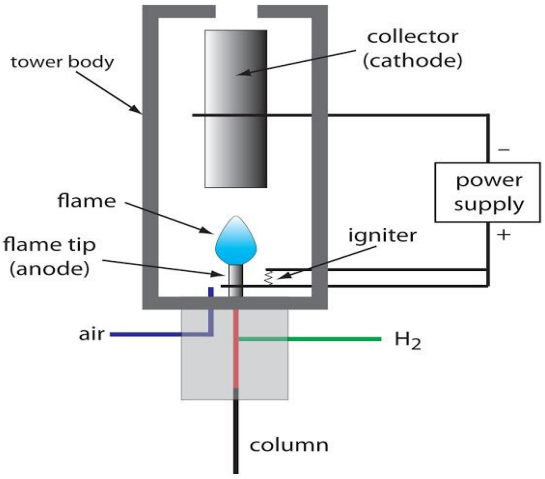


Figure: mass spectrometer detector

Numerous GC instruments are combined with a mass spectrometer, which is a very good blend. The GC isolates the compounds from each other, while the mass spectrometer distinguishes them in view of their fragmentation pattern. A mass spectrometer can measure the mass of a molecule only after it converts the molecule to a gas-phase ion. To do so, it imparts an electrical charge to molecules and converts the resultant flux of electrically charged ions into a proportional electrical current that a data system then reads.

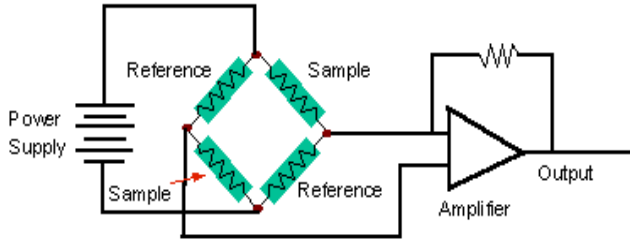
Flame ionization detector (FID)-



Flame ionization detectors (FID) are the most generally applicable and most widely used detectors. In a FID, the sample is directed at an air-hydrogen flame after exiting the column. At the high temperature of the air-hydrogen flame, the sample undergoes pyrolysis, or chemical decomposition through intense heating. Pyrolized hydrocarbons release ions and electrons that carry current. A high-impedance picoammeter measures this current to monitor the sample's elution.

It is advantageous to use FID because the detector is unaffected by flow rate, non-combustible gases and water. These properties allow FID high sensitivity and low noise. The unit is both reliable and relatively easy to use. However, this technique does require flammable gas and also destroys the sample.

Thermal conductivity detector-

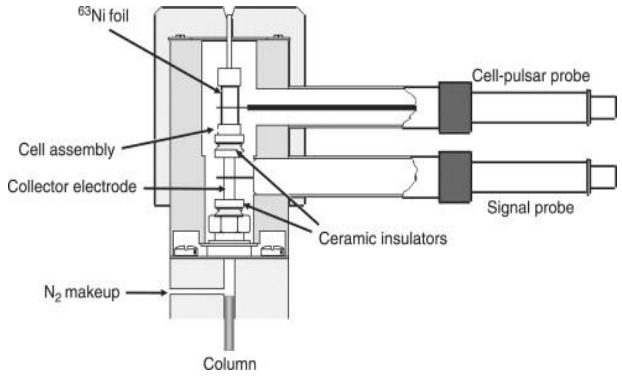


Thermal conductivity detectors (TCD) were one the earliest detectors developed for use with gas chromatography. The TCD works by measuring the change in carrier gas thermal conductivity caused by the presence of the sample, which has a different thermal conductivity from that of the carrier gas. Their design is relatively simple, and consists of an electrically heated source that is maintained at constant power. The temperature of the source depends upon the thermal conductivities of the surrounding gases. The source is usually a thin wire made of platinum, gold or. The resistance within the wire depends upon temperature, which is dependent upon the thermal conductivity of the gas.

TCDs usually employ two detectors, one of which is used as the reference for the carrier gas and the other which monitors the thermal conductivity of the carrier gas and sample mixture. Carrier gases such as helium and hydrogen has very high thermal conductivities so the addition of even a small amount of sample is readily detected.

The advantages of TCDs are the ease and simplicity of use, the devices' broad application to inorganic and organic compounds, and the ability of the analyte to be collected after separation and detection. The greatest drawback of the TCD is the low sensitivity of the instrument in relation to other detection methods, in addition to flow rate and concentration dependency.

Electron capture detector (ECD)-



This detector comprises of a depression that contains two terminals and a radiation source that transmits-radiation (i. e., 63Ni, 3H). The impact amongst electrons and the carrier gas (methane in addition to an inert gas) creates a plasma-containing electrons and positive ions. On the off chance that a compound is available that contains electronegative molecules, those electrons will be "caught" to frame negative particles and the rate of electron accumulation will diminish [86]. The identifier is to a great degree particular for mixes with particles of high electron liking (10-14 g/s), yet has a generally little straight range (~102-103). This indicator is every now and again utilized as a part of the investigation of chlorinated mixes i. e., pesticides (herbicides, insecticides), polychlorinated biphenyls, and so forth for which it shows a high sensitivity.

Nitrogen-phosphorus-

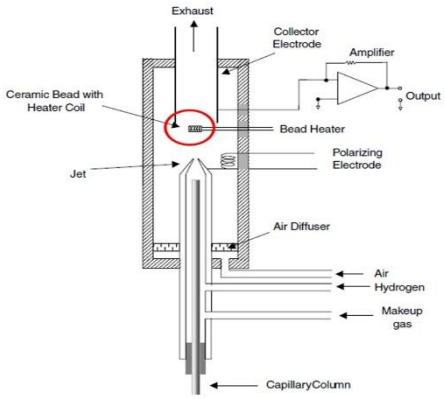
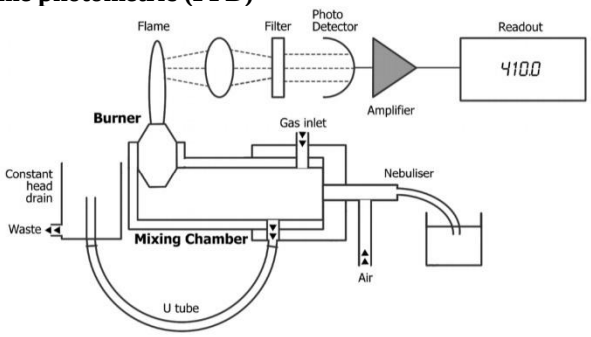


Fig: Nitrogen phosphorus detector

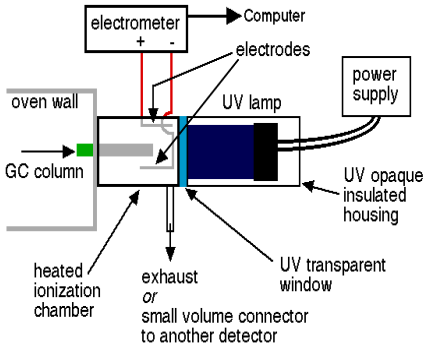
A type of thermionic detector where nitrogen and phosphorus change the work capacity on an uncommonly coated bead and a subsequent current is measured. Alkali Flame Detector, AFD or Alkali Flame Ionization Detector, AFID. AFD has high affectability to nitrogen and phosphorus, like NPD. Nonetheless, the alkaline metal particles are supplied with the hydrogen gas, instead of a bead over the fire. Consequently, AFD does not endure the "fatigue" of the NPD, but rather gives a steady sensitivity over drawn out stretch of time. What's more, when alkaline ions are not added to the fire, AFD works like a standard FID.

Flame photometric (FPD)-



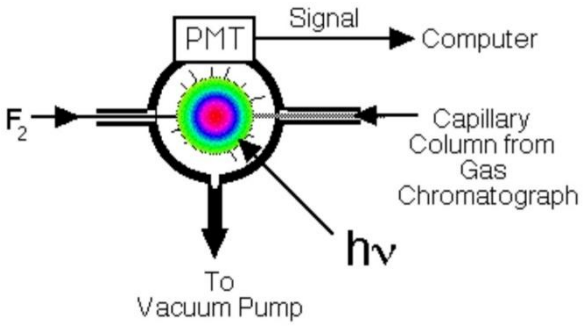
Flame photometric (FPD) which utilizes a photomultiplier tube to identify spectral lines of the mixes as they are burned in a fire. Compounds eluting off the column are conveyed into a hydrogen energized fire which excites particular components in the molecule, and the excited components (P, S, Halogens, Some Metals) radiate light ofparticular characteristic wavelengths. The emitted light is separated and detected by a photomultiplier tube. Specifically, phosphorus emission is around 510-536 nm and sulphur discharge at 394 nm.

Photo-ionization detector (PID)-



Another different kind of detector for GC is the photoionization detector which utilizes the properties of chemiluminescence spectroscopy. Photoionization detector (PID) is a portable vapor and gas detector that has selective determination of aromatic hydrocarbons, organo-heteroatom, inorganic species and other organic compounds. PID comprise of an ultraviolet lamp to emit photons that are absorbed by the compounds in an ionization chamber exiting from a GC column. Small fraction of the analyte molecules are actually ionized, non-destructive, allowing confirmation analytical results through other detectors. In addition, PIDs are available in portable hand-held models and in a number of lamp configurations. Results are almost immediate. PID is used commonly to detect VOCs in soil, sediment, air and water, which is often used to detect contaminants in ambient air and soil. The disadvantage of PID is unable to detect certain hydrocarbon that has low molecular weight, such as methane and ethane.

Chemiluminescence Detectors-



Chemiluminescence spectroscopy (CS) is a process in which both qualitative and quantitative properties can be determined using the optical emission from excited chemical species. It is very similar to AES, but the difference is that it utilizes the light emitted from the energized molecules rather than just excited molecules. Moreover, chemiluminescence can occur in either the solution or gas phase whereas AES is designed for gaseous phases. The light source for chemiluminescence comes from the reactions of the chemicals such that it produces light energy as a product. This light band is used instead of a separate source of light such as a light beam.

Like other methods, CS also has its limitations and the major limitation to the detection limits of CS concerns with the use of a photomultiplier tube (PMT). A PMT requires a dark current in it to detect the light emitted from the analyte.

Recorder

Recorders are used to record the response obtained from the detectors after amplification in gas chromatography generally potentiometric detector is used. In this type of recorder the input response is continuously balanced by feedback response.

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