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Mass Spectrometry: An Analytical Method

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Review Article

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ABSTRACT

Mass spectrometry is a central analytical technique for protein research and for the study of biomolecules in general. Driven by the need to identify, characterize, and quantify proteins at ever increasing sensitivity and in ever more complex samples, a wide range of new mass spectrometry–based analytical platforms and experimental strategies have emerged.

INTRODUCTION

Mass spectrometry (MS) is an analytical technique that ionizes chemical species and sorts the ions based on their mass to charge ratio. In simpler terms, a mass spectrum measures the masses within a sample. Mass spectrometry is used in many different fields and is applied to pure samples as well as complex mixtures [1-5].

HISTORY

In 1886, Eugen Goldstein observed rays in gas discharges under low pressure that traveled away from the anode and through channels in a perforated cathode, opposite to the direction of negatively charged cathode rays (which travel from cathode to anode) [6,7]. Goldstein called these positively charged anode rays "Kanalstrahlen"; the standard translation of this term into English is "canal rays". Wilhelm Wien found that strong electric or magnetic fields deflected the canal rays and, in 1899, constructed a device with parallel electric and magnetic fields that separated the positive rays per their charge-to-mass ratio (Q/m). Wien found that the charge-to-mass ratio depended on the nature of the gas in the discharge tube. English scientist J.J. Thomson later improved on the work of Wien by reducing the pressure to create the mass spectrograph [8-13].

PRINCIPLE

A mass spectrometer generates multiple ions from the sample under investigation; it then separates them per their specific mass-to-charge ratio (m/z), and then records the relative abundance of each ion type.

INSTRUMENTATION – MASS SPECTROMETER

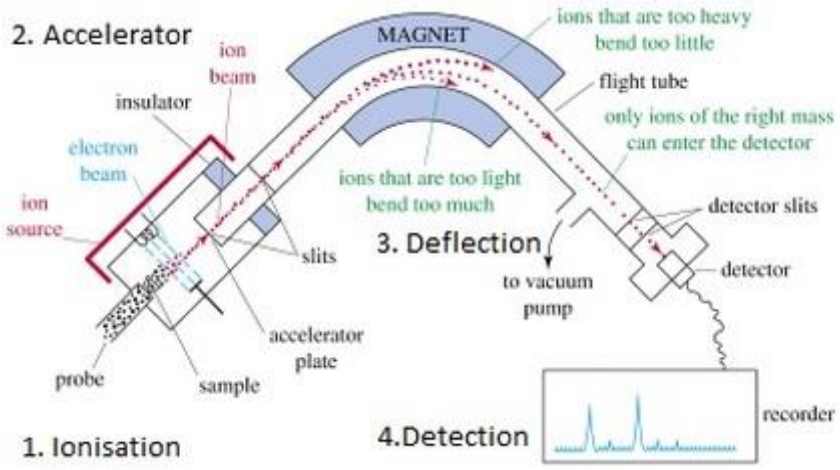
Inlet System

Samples can be introduced to the mass spectrometer directly by chromatographic methods [14,15].

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Ionization Methods

There are many types of ionization methods are used in mass spectrometry methods. The classic methods that most chemists are familiar with are electron impact (EI) and Fast Atom Bombardment (FAB). These techniques are not used much with modern mass spectrometry except EI for environmental work using GC-MS [16,17]. More modern techniques of atmospheric pressure chemical Ionization (APCI), electrospray ionization (ESI), matrix assisted laser desorption ionization (MALDI) and other derivative methods have taken their place in the mass spectrometry laboratory [18-28].



Analysers

The sector mass spectrometer was one of the most common types of mass analyser and probably the most familiar to the everyday scientist. In the 1950's, the first commercial mass spectrometers were sector instruments. They consist of some combination of a large electromagnetic, and electrostatic focusing device [2,6,29-34]. Different manufactures use differing geometries. The BE configuration is also called reverse geometry sector mass spectrometer - that is, a dual sector instrument consisting of a magnetic sector followed by an electrostatic sector.

Ions enter the instrument from the source (bottom left) where they are initially focused. They enter the magnetic sector through the source slit where they are deflected per the left-hand rule. Higher-mass ions are deflected less than lower-mass ions. Scanning the magnet enables ions of different masses to be focussed on the monitor slit [3,18,30,35]. At this stage, the ions have been separated only by their masses. To obtain a spectrum of good resolution where all ions with the same m/z appear coincident as one peak in the spectrum, ions have to be filtered by their kinetic energies. After another stage of focussing the ions enter the electrostatic sector where ions of the same m/z have their energy distributions corrected for and are focussed at the double focussing point on the detector slit.

Types of analysers

Magnetic analyser, Quadrupole analyser, Time of flight analyser, Magnetic analyser and Ion trapped analyser [36-41].

Detectors

Ion beams after passing through mass analyzer, strikes on detector. The ions can be electrically detected by detectors which have been separated per their mass/charge ratio in the system [42,43]. The choice of detector is based on the required detection senstivity and the speed and it is also determined by other application-soecific requirements, such as the thermal and chemical stability, required stability, and the amount of space available.

Desirable detector properties

The desirable detector properties include high amplification, fast time response, low noise, high collection efficiency, low cost, narrow distribution of responses, same response for all masses, large dynamic range, long term stability, long life, mounted outside of the vacuum if possible, etc [44-49].

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Types of detectors

Electron multipliers, faraday cups, photographic plates, channel electron multipliers, high mass detection detector, helium leak detector, and other detectors [50-71].

Vacuum Systems in Mass Spectrometry

A high level of vacuum within the instrument prevents deviation of the analyte ions from the required path and assists the processes of ion movement and separation in the following ways:

- By providing an adequate mean free path for the analyte ions.
- By providing collision free ion trajectories.
- By reducing ion-molecular reactions.
- By reducing background interference.

Recorder

The recording device is usually an oscilloscope, a chart recorder or a computer. The oscilloscope is useful for giving a preliminary scan of the whole sample spectrum. It allows both fine-tuning of instrument parameters and the determination of the ion signal strength before an accurate mass san is made [26,31,72-89].

A common method of taking a permanent record of the spectrum is to use a chart recorder. This device usually employs photosensitive paper, with the image of the spectrum being developed by allowing a light beam to traverse the paper [90,91].

APPLICATIONS

Mass spectrometry has both qualitative and quantitative uses [3,5,73,92]. These include identifying unknown compounds, determining the isotopic composition of elements in a molecule, and determining the structure of a compound by observing its fragmentation. Other uses include quantifying the amount of a compound in a sample or studying the fundamentals of gas phase ion chemistry (the chemistry of ions and neutrals in a vacuum). MS is now in very common use in analytical laboratories that study physical, chemical, or biological properties of a great variety of compounds [91-99].

As an analytical technique it possesses distinct advantages such as: Increased sensitivity over most other analytical techniques because the analyzer, as a mass-charge filter, reduces background interference, Excellent specificity from characteristic fragmentation patterns to identify unknowns or confirm the presence of suspected compounds, Information about molecular weight, Information about the isotopic abundance of elements, Temporally resolved chemical data.

A few of the disadvantages of the method is that often fails to distinguish between optical and geometrical isomers and the positions of substituent in o-, m- and p- positions in an aromatic ring. Also, its scope is limited in identifying hydrocarbons that produce similar fragmented ions [39,81,100].

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