

Electronics And Instrumentation

8th Semester

Subject: Analytical Instrumentation

Subject code: BT 808

Unit-4

Mass Spectrometers

6.2 Multiple-Sector Instruments

In cases where high-resolution MS/MS experiments are required, multiple-sector field instruments are the only choice. They have the advantages of potentially high resolution in both stages, a wide mass range, and high sensitivity. However, there is a considerable trade off due to complexity, space requirements, and high cost. This is true particularly for the four-sector field mass spectrometers. As an example, the schematic of a four sector field instrument is there . Such mass spectrometers are highly flexible since the possible combinations of sectors and the number of field-free regions allow many different experiments to be performed. The limitation is that the fragmentation process becomes less probable with increasing mass and the upper limit seems to be around 2500amu. To increase the dissociation efficiency not only collision cells, but also photo-dissociation and surface- collision-induced dissociation have been investigated as well as simultaneous recording with a zoom lens integrated into the second MS .

6.3 Hybrids (Sector - Quadrupoles)

The apparently logical combination of the high resolution capabilities of sector instruments with the simplicity of quadrupoles in hybrid instruments is complicated in practice. Since the quadrupole only accepts ions of low kinetic energy, it must be floated at the potential of the sector instrument or, if high-energy collisions are to be possible, a zoom lens allowing the deceleration of the ions must be incorporated between the mass spectrometers. The latter has been realized in only one commercial version, whereas the simpler first combination has been made by several manufacturers. Mostly the sequence is sector - quadrupole, but it is possible to arrange the spectrometers the other way around. Combinations of double focusing spectrometers with time-of-flight instruments

or with ion traps have been built and both are hybrids with great analytical potential. However, in general the sector instruments made these combinations too complicated and too expensive.

6.4 Ion-Storage Devices (FTMS, Ion Traps)

Two types of ion-storage device (ion traps) are in use today as mass spectrometers, as discussed already, with built in MS/MS capabilities: the magnetic trap as ion cyclotron resonance spectrometer, which is, in its modern version, the Fourier transform mass spectrometer and the electric field version, called ion trap. Both types of instrument allow all but the one selected ion to be ejected, which then undergoes ion-molecule reactions, collisions, or photodissociation to yield fragments. This process may be repeated, allowing not only MS/MS but also MS/MS/MS and even MSⁿ, which allows the detailed study of fragmentation reactions. However, currently only daughter-ion scans are possible.

6.5 Quadrupole Time-of-Flight Tandem Mass Spectrometers

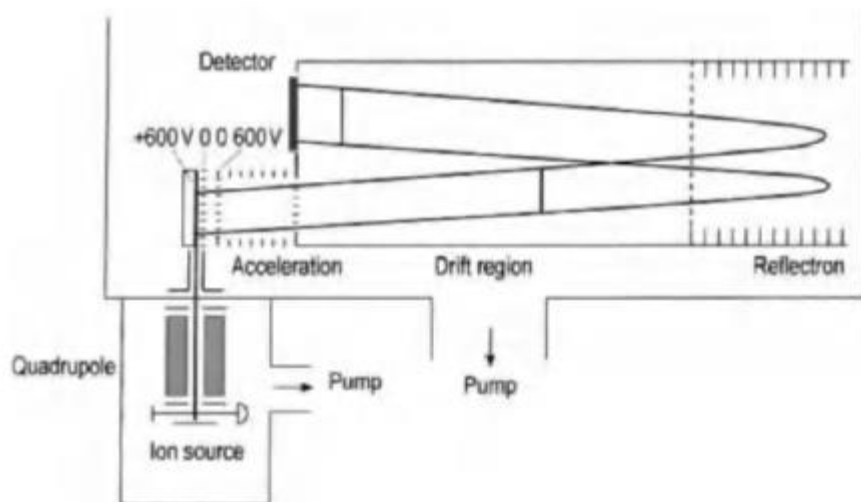


Figure . Q-TOF tandem mass spectrometer, schematic

The development of combination sector field TOF led almost instantaneously to the combination of quadrupoles with TOF spectrometers, since at the same time the TOF spectrometers were converted into high-resolution high-precision instruments (Fig.). A new aspect of this is that the ion injection into the TOF

spectrometer is orthogonal, yielding an MS/MS combination with extremely high sensitivity for the fragments, without compromising scanning speed, resolution, mass range or the mass accuracy [1%]. Thus this spectrometer has become one of the most successful new developments in the history of mass spectrometry (produced by two vendors) and today the instrument is one of the key tools in protein, peptide, and DNA research all over the world

7. Computer and Data Systems

The first applications of computers in mass spectrometry were merely the recording of signals from the multipliers, conversion to spectra, and some data handling. Today, powerful computers are integrated in the spectrometer. They control the scan, define the scan function, set the required voltages, tune the source, and supervise the experiments. The data are stored and interpreted with advanced tools, although at that stage the fully automated procedures are at an end.

7.1 Instrument Control. Automation

Modern mass spectrometers are completely dependent on computers and data systems. All the instrumental parameters of the inlet systems such as direct probe, GC, or LC (temperatures, gradients, times) are supervised by the computer. The ion source is tuned by automated procedures, the instrumental parameters (voltages, frequencies, resolution, etc.) are set by software procedures, and even the design of experiments (EI, CI, positive/negative ions, linked scans, MS/MS, etc.) can be started automatically, if specified conditions are met (e.g., signal height, retention times). Under such circumstances, the spectrometers can run a large number of samples unattended, since the analytical methods can be specified first, stored and activated upon request of the software. One advantage of this development is that a single man-machine interface is sufficient to work with such an MS. Further, most of the information necessary to describe an experiment from an instrumental point of view is stored automatically and is therefore available for reports and documentation.

7.2 Signal Processing

Most mass spectrometers produce analog signals at the detector. Thus it is necessary to convert the analog current or voltage signal into digital signals by means of analog-to-digital converters. This step has been a problem in the past, because the dynamic range and the speed of such devices was not always sufficient to maintain the integrity of resolution and dynamic range delivered by SEMs. In cases where ion counting is possible, different problems must be solved: the maximum counting speed is the limiting factor for the dynamic range. Since the design of the multiplier defines the pulse width and blind period, the dynamic range is a function of the performance of the multiplier and the pulse counting device. When pulses overlap, errors may occur, although correction is possible if the frequency is not too high.

7.3 Analog-to-Digital Conversion and Mass Calibration.

As mentioned above, the analog signal is digitized by fast and accurate A/D converters (typically above 200 kHz) with sufficient dynamic range (216 bit). The limiting factor for the dynamic range is often the noise of the baseline. The digitized information about the ion current is fed into the computer, where the signals are analyzed and converted from "raw data" into peaks or noise, the intensities are calculated and placed on a mass scale. The conversion can be performed on the basis of time, magnetic field, or frequency, depending on the type of spectrometer. The mass scale must be calibrated to achieve the required precision. The most reliable way to calibrate the mass scale for all mass spectrometers is by means of reference compounds, whose mass spectrum in terms of accurate masses and approximate intensities should be known to the software. In addition, they should have signals evenly spaced over a large mass range.

7.4 Data Handling

When the mass spectral data have been stored in the computer, the interpretation of the data is the next step. In most cases the data are spectra with peak intensities on a $d z$ scale. However, chromatograms from selected ion recordings and data from multichannel analyzers must also be handled. Sophisticated software has been written to develop increasingly automated procedures for quantitative analyses, mathematical treatment of data, display of spectra and structures, and to transport the data into laboratory data systems for integration into reports. While this aspect of data handling can be considered

rather satisfactory today, the extraction of information contained in the spectra is under development. The deduction of possible structures of unknown compounds from mass spectra is demanding and often fails, and the calculation of spectra based on the structure is in its infancy. It is still uncertain whether this is at all possible, because the competitive reactions of the gas-phase ions are controlled by minute differences in energy between intermediate structures, and the kinetic behavior is difficult to model for complex molecules. Initial attempts have been published for both the modeling of reactions in the mass spectrometer and the prediction of mass spectra from structures. In both cases the results are far from application for analytical purposes.

8. Applications

Typical areas for the application of mass spectrometry are:

- 1) Analysis of trace elements and compounds in environmental samples
- 2) Problem solving in biomedical research (protein identification, DNA), particularly the structure elucidation of natural compounds and determination of molecular mass
- 3) Control of synthetic procedures by rapid analysis of intermediates and products
- 4) Analysis of bulk materials and surfaces

One of the major driving forces for the rapid development of mass spectrometry during the last years is trace analysis in environmental chemistry and biochemistry. The search for sensitive, reliable methods that allow the determination of compounds at very low levels together with the option for mass spectra of highly polar and labile compounds motivated the development of new interfaces, ion sources, analyzers, and detectors. The second impetus is the search for techniques for the determination of very high molecular masses with better precision than is attainable by other known methods.