

Mass Spectrometer Containing Multiple Fixed Collectors

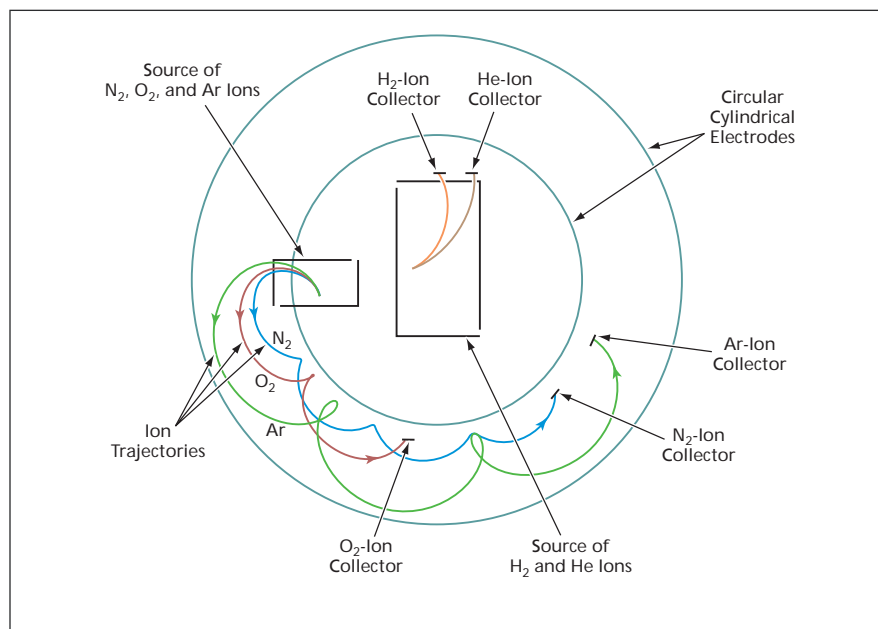
Two mass analyzers in a compact package detect five ion species simultaneously.

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A miniature mass spectrometer that incorporates features not typically found in prior mass spectrometers is undergoing development. This mass spectrometer is designed to simultaneously measure the relative concentrations of five gases (H₂, He, N₂, O₂, and Ar) in air, over the relative-concentration range from 10⁻⁶ to 1, during a sampling time as short as 1 second. It is intended to serve as a prototype of a product line of easy-to-use, portable, lightweight, high-speed, relatively inexpensive instruments for measuring concentrations of multiple chemical species in such diverse applications as detecting explosive or toxic chemicals in air, monitoring and controlling industrial processes, measuring concentrations of deliberately introduced isotopes in medical and biological investigations, and general environmental monitoring.

The heart of this mass spectrometer is an integral combination of a circular cycloidal mass analyzer, multiple fixed ion collectors, and two mass-selective ion sources. By "circular cycloidal mass analyzer" is meant an analyzer that includes (1) two concentric circular cylindrical electrodes for applying a radial electric field and (2) a magnet arranged to impose a magnetic flux aligned predominantly along the cylindrical axis, so that ions, once accelerated into the annulus between the electrodes, move along circular cycloidal trajectories. As in other mass analyzers, trajectory of each ion is determined by its mass-to-charge ratio, and so ions of different species can be collected simultaneously by collectors (Faraday cups) at different locations intersected by the corresponding trajectories (see figure). Unlike in other mass analyzers, the installation of additional collectors to detect additional species does not necessitate increasing the overall size of the analyzer assembly.

Each of the two mass-selective ion sources consists mainly of a filament and electrodes. One of the electrodes is an anode that contains one or more hole(s) through which ions leave the source. The filament, electrodes, and hole(s) are arranged such that under the influence of the combination of electric and magnetic fields, only ions in a desired mass/charge range can leave the source. One of the sources has a single hole



In the Circular Cycloidal Mass Analyzer, ions of O₂, N₂, and Ar follow different trajectories and, hence, can be collected simultaneously at different locations. Another ion-source/analyzer assembly located inside the inner cylindrical electrode generates and detects ions of H₂ and He only.

through which ions in the mass/charge range that includes O₂, N₂, and Ar ions can be released into the annulus between the inner and outer electrodes of the circular cycloidal mass analyzer, wherein collectors for the O₂, N₂, and Ar ions are located.

The other source has two holes — one for H₂ and one for He ions. In the presence of the magnetic field, this source is sufficiently mass-selective that the circular cycloidal mass analyzer is not needed for detecting H₂ and He ions. Therefore, this source is placed, along with collectors facing its two exit holes, within the inner cylindrical electrode, where there is no applied electric field but the applied magnetic field is present. Hence, the combination of this source and its two collectors is characterized as a mass analyzer within a mass analyzer.

The vacuum inside the mass spectrometer is provided by a combination of an ion pump and a non-evaporable-getter pump. This pump combination is designed to operate in conjunction with a gas-inlet system that includes a gas-permeable fluorinated ethylene-propylene membrane and miniature valves. Along with the operation of the rest of the instrument, operation of the valves and pumps is coordinated by a computer to

ensure that a high vacuum is retained when the instrument is switched off and the ion pump can be restarted safely after a long rest.

Current-to-voltage converters needed for processing the collector outputs are placed within the vacuum, close to the collectors, in order to minimize stray capacitance. Each such converter includes a number of feedback resistors for different sensitivity ranges. Special miniature, highly insulated, leaf-spring switches actuated by current pulses in the presence of the applied magnetic field have been developed to satisfy the unique combination of requirements for switching among the different feedback resistors.

This work was done by Robert Moskala, Alan Celo, Guenter Voss, and Tom Shaffer of Monitor Instruments Co., LLC for Kennedy Space Center.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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