United States Patent [19]

Elliott

1541 MASS SPECTROMETER ION SOURCE HAVING MEANS FOR RAPIDLY EXPELLING IONS FROM THE SOURCE AND METHOD OF OPERATION

- [75] Inventor: Richard M. Elliott, Sale, England
- [73] Assignee: Associated Electrical Industries Limited, London, England
- [22] Filed: Apr. 27, 1970
- [21] Appl. No.: 32,324

[30] Foreign Application Priority Data

Apr. 28, 1969 Great Britain......21,462/69

- [51] Int. Cl......H01j 37/08
- [58] Field of Search.....250/41.9 SB, 41.9 SE; 313/63

[56] **References Cited**

UNITED STATES PATENTS

3,247,373 4/1966 Herzog.....250/41.9 SB

[11] **3,731,089**

[45] May 1, 1973

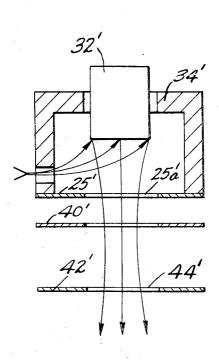
3,115,591	12/1963	Brunnee
3,356,843	12/1967	McElligott250/41.9 SB

Primary Examiner—James W. Lawrence Assistant Examiner—C. E. Church Attorney—Watts, Hoffmann, Fisher & Heinke

[57] ABSTRACT

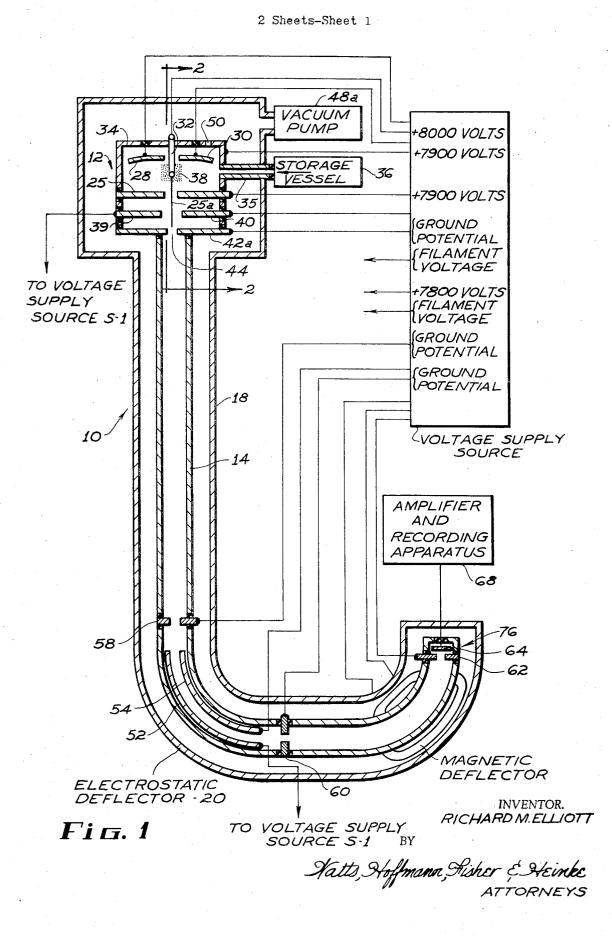
An ion source for mass spectrometers including an ionization chamber having an aperture for the passage of ions and an electrode disposed therein, electron generating means for directing a beam of electrons toward the electrode, means for introducing a sample into the chamber, and source means for developing an electrical signal having a value greater than the value of a signal applied to an electron source and less than the value of a signal necessary to cause substantial field ionization. Also included are circuit means for connecting the source means to the electrode to generate an electrical field about the electrode to rapidly expel ions, developed upon bombardment of the sample by the electrons, through the aperture.

4 Claims, 3 Drawing Figures



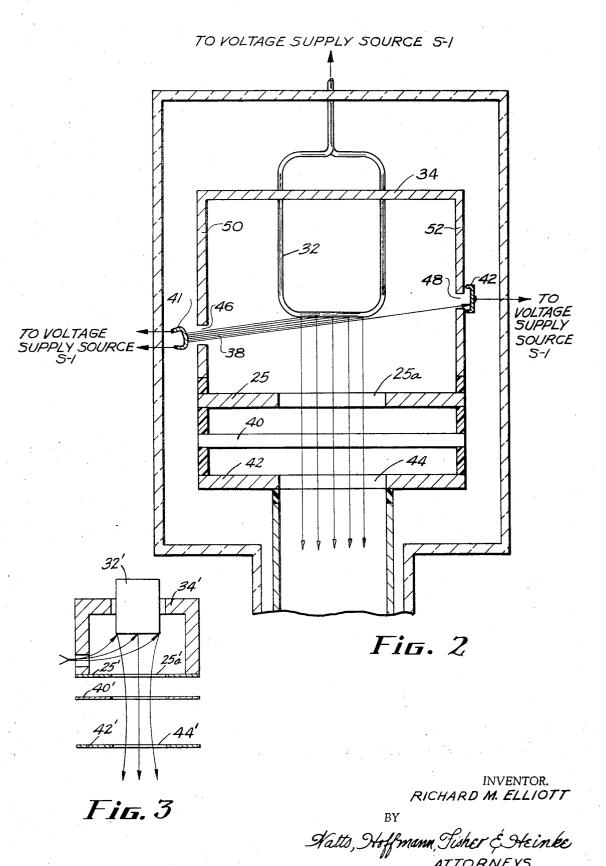
Patented May 1, 1973

3,731,089



3,731,089

ATTORNEYS



2 Sheets-Sheet 2

MASS SPECTROMETER ION SOURCE HAVING MEANS FOR RAPIDLY EXPELLING IONS FROM THE SOURCE AND METHOD OF OPERATION

BACKGROUND OF THE INVENTION

This invention pertains to the art of ion sources to be used in mass spectrometers, and, more particularly, to improved ion sources having means for rapidly expelling ions from the ion source.

Known ion sources have included an ionization chamber into which samples, such as a gas to be analyzed, are introduced in order to ionize the sample by electron bombardment. Generally, the molecules of the sample are ionized by an electron beam which passes through the ionization chamber. The ions produced by this ionization process are then focussed and accelerated by a series of electrodes. The ions are then projected through an ion exit slit, or aperture, in the ion source. When such an ion source is employed in a mass spectrometer system, the ions are directed from the exit slit and along an evacuated path to a suitable collecting and/or detecting device.

In a single focussing spectrometer, the ion path 25 traverses a magnetic analyzer in which the ion beam is subjected to a magnetic deflection by a traverse magnetic field. In a double focusing spectrometer, the ion path traverses an electrostatic analyzer which precedes the magnetic analyzer and subjects the ions to an elec- 30 trostatic deflection.

The analyzers deflect the ions to an extent dependent on their respective mass numbers. For any given accelerating voltage and magnetic field strength in the or mass number will pass into the detector. Ions of higher or lower mass numbers will be deflected more or less than the appropriate amount necessary to focus them on the detector.

In these mass spectrometer systems, ions frequently 40 dwell within the ion source for a period of time on the order of approximately 1 to 10 microseconds. Because of this dwell time within the ion source, ions are frequently lost or decomposed simultaneously and a relatively small number of the desired ions are available 45 for analysis by the spectrometer.

SUMMARY OF THE INVENTION

The present invention is directed toward an ion source which may be used in mass spectrometers in 50which ions, developed by electron bombardment, are rapidly expelled out of the ion source thereby overcoming the noted disadvantages, and others, of such previously known ion sources.

In accordance with one aspect of the present invention, the ion source includes an evacuable ionization chamber for ionizing a sample. The chamber has an aperture for the passage of ions. Passage means is provided for introducing a sample into the chamber. An electrode is disposed within the chamber. Source means is provided for developing an electrical signal having a value less than the value necessary to cause substantial field ionization. Circuit means couples the source means to the electrode to thereby develop an 65 electrical field about the electrode. Also included is an electron generating means which is coupled to the ionization chamber for emitting a beam of electrons

into the chamber. Means is provided for directing the beam of electrons in a direction toward the electrode so that the ions are rapidly expelled through the aperture by the electrical field surrounding the electrode.

In accordance with another aspect of the present invention, the electrode is constructed of a length of elongated conductive material formed in a generally Ushaped configuration.

In accordance with another aspect of the present in-10 vention, the electrode is constructed of a conductive wire and is formed in a generally U-shaped configuration.

In accordance with still another aspect of the present invention, the electrode is of a blade configuration hav-15 ing a relatively sharp edge and the directing means includes focusing means for directing the beam of electrons in a direction toward the edge of the electrode.

In accordance with still another aspect of the present 20 invention, the source means includes circuit means for developing a signal having a potential greater than a potential applied to an electron source and less than a potential which would cause substantial field ionization.

In accordance with still another aspect of the present invention, the source means includes circuit means for developing a signal having a potential less than a potential necessary to cause any field ionization.

In accordance with another aspect of the present invention, there is provided a method of rapidly expelling ions from an ionization chamber including an evacuatable chamber having an aperture for the passage of ions, means for introducing a sample into the chamber, and analyzer, only ions having a specific mass-charge ratio 35 an electrode positioned within the chamber, electrical signal generating means, and electron generating means. The method includes the step of: generating a beam of electrons, developing an electrical potential having a value greater than the value of a potential applied to the electron source and less than the potential necessary to cause substantial field ionization, applying the electrical potential to the electrode, developing an electrical field around the electrode, directing the beam of electrons in a precise direction toward the electrode, bombarding the sample with the beam of electrons to thereby form ions, and rapidly expelling the ions through the chamber aperture with the electrical field surrounding the electrode.

> The primary object of the present invention is to provide an ion source in which the dwell time of ions within the source is decreased substantially.

Another object of the present invention is to provide an ion source with a relatively high efficiency ion out-55 put.

Another object of the present invention is to provide an ion source in which the ions are rapidly expelled through an exit aperture of the ion source.

A further object of the present invention is to provide an ion source for use with mass spectrometers in which a relatively large number of molecular ions which are generated by the ion source are available for analysis by the mass spectrometer.

A still further object of the present invention is to provide a method of operating an ion source which enables ions to be expelled from the ion source more rapidly than with heretofore known ion sources.

5

5

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and advantages of the invention will become apparent from the following description of the preferred embodiments of the invention as read in conjunction with the accompanying drawings in which:

FIG. 1 is a sectional view and electrical block diagram of an ion source illustrating a preferred embodiment of the present invention in combination with a 10 mass spectrometer:

FIG. 2 is a sectional view of the mass spectrometer illustrated in FIG. 1, as seen from the plane indicated by the line 2-2 and employing a wire electrode within the ionization chamber; and,

FIG. 3 is a sectional view of a portion of a mass spectrometer employing a blade electrode within the ionization chamber.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, FIGS. 1 and 2 illustrate a mass spectrometer 10, which generally comprises an evacuatable chamber 12 coupled through passage 14 to a detecting mechanism 16. The evacuatable chamber 12, passage 14, and detecting mechanism 16, are positioned within an evacuatable housing 18. An electrostatic deflector 20 and a magnetic deflector 22 are positioned in relation to or as part of the passage 30 14 so that a beam of ions passing through the passage 14 may be deflected and analyzed. More particularly, the ionization chamber 12 includes an ion exit plate 25 having an aperture or ion exit slit 25a extending therethrough so that ions may be expelled out of the 35 chamber 12.

Disposed within ionization chamber 12 are a pair of generally arcuate shaped ion repeller electrodes 28, 30, which are positioned to direct ions, developed within chamber 12, through the aperture or ion exit slit 25a. Also disposed within ionization chamber 12 is an electrical wire 32 formed in a generally U-shaped configuration, as illustrated in FIG. 2. The legs of the U-shaped electrode 32 extend through a top wall 34 of chamber 45 12 and are electrically insulated from the chamber 12.

The ionization chamber 12 is coupled through a passage 35 to a gas storage vessel 36 which is electrically insulated from ionization chamber 12 so that a gas sample to be analyzed may be introduced into the 50 electron bombardment by the beam of electron 38. The ionization chamber 12. Also, an electron beam 38 is emitted into the ionization chamber 12 by the flow of electrons between a cathode 41 and an anode 42. These electrons pass through a pair of aperture 46, 48, which extend through the side walls 50, 52, respective- 55 ionize the sample material. ly, of the ionization chamber 12. The cathode 41 and the anode 42 are connected to a voltage supply source S-1 in a known manner for providing the flow of an electron current between these elements. Also, a potential is applied to the cathode 41 which is lower 60 than the potential applied to the electrode 32 or the anode 42 in order that the electrons are accelerated toward the latter electrodes.

A pair of beam centering plates 39, 40 are positioned 65 below the ion exit plate 25, and generally provide the function of focussing and centering the beam of ions which pass through ion exit slit 25a. In addition, a

chamber exit plate 42, having an aperture or chamber exit slit 44 extending therethrough, is positioned below the beam centering plates 39, 40.

The arcuate-shaped electrodes 28, 30 are connected to voltage supply source S-1. The generally U-shaped electrode 32 is connected to an 8,000 volt terminal of voltage supply source S-1. The ionization chamber 12 and the ion exit plate 25 are connected to a 7,900 volt terminal of supply source S-1. In addition, the beam centering plates 38, 40 are connected to suitable voltage terminals on the voltage supply source S-1. The chamber exit plate 42 is connected to a ground potential terminal of supply source S-1.

The mass spectrometer 10 also includes a vacuum 15 pump 48a for maintaining a relatively high vacuum within the chamber 18, and within ionization housing 12. The small passage 50 extending through the top wall 34 into chamber 12 facilitating vacuum evacuation 20 of the chamber 12. Thus, ions generated upon ionization of the gas sample in the ionization chamber 12 are emitted through ion exit slit 25a to form a single beam of ions. This beam of ions is focussed by the pair of beam centering electrodes 39, 40, and passes through 25 the chamber exit slit 44. The beam of ions is then projected into passage 14 of mass spectrometer 10.

The mass spectrometer 10 further includes a conventional electrostatic deflector 20, including deflector plates 54, 56, and a conventional magnetic deflector 22. An apertured electrode 58 is located at the beam entrance of electrostatic deflector 20 and an apertured electrode 60 is located between electrostatic deflector 20 and magnetic deflector 22 in a manner known in the art. These electrodes 58, 60 are directly coupled to a ground potential terminal of supply source S-1.

The collector assembly 16, positioned at the other end of passage 14, includes an apertured plate outlet 62 and a collector electrode 64. The apertured outlet plate 62 and collector electrode 64 are respectively con-40 nected to voltage supply source S-1 and an amplifier in a recording apparatus 68. Each of the electrodes 58, 60, 62, 64 are electrically insulated from the passage 14.

Thus, upon application of the appropriate voltages a beam of electrons 38 is focused in a direction close to the generally U-shaped electrode 32. A sample of material to be ionized is introduced into the ionization chamber 12, and it is then ionized through a process of cathode 41 is maintained at a potential on the order of 10-100 volts negative relative to the U-shaped electrode 32 so that emitted electrons travel toward the edge of electrode 32 in the vicinity of which they then

An intense electrical field is established in a region around U-shaped electrode 32 since the electrode is maintained at a very high potential, for example 8,000 volts. This electrical field accelerates ions out of the ionization chamber 12 in a very short period of time. Thereafter, the ions are deflected in a known manner by the beam centering plates 39, 40, and pass through the chamber exit slit 44 into the passage 14 of mass spectrometer 10.

With the relatively small surface area of the wire electrode 32, it is possible to establish a field for expelling ions out of chamber 12 with a voltage potential less than that necessary to cause substantial field ionization. The same result can also be had by using a plate electrode such as is shown at 32' in FIG. 3 in place of the wire loop electrode 32. The spectrometer shown in FIG. 3 is substantially the same as that shown 5 and described in conjunction with FIG. 2. Accordingly the reference numerals used in FIG. 3 are the same as those used in FIG. 2 with the addition of a "prime" to each.

It is believed that as the ions are being formed they 10 are in a very steep electrical gradient, and therefore are immediately accelerated out of the ion source. In known sources, the ions are formed in a region of relatively low electrical gradient; therefore, a substantial delay occurs before the ions enter the analyzer and 15 reach a position where they can be analyzed and deflected. Known field ionization sources produce rapid ion extraction from the source, but often fail to supply the desired number of ions for analysis. Thus, the present invention provides an ionization chamber 20 in which ions are rapidly accelerated out of the chamber without requiring substantial field ionization with the chamber.

Although the invention has been shown in connection with the preferred embodiment, it will be readily 25 apparent to those skilled in the art that various changes in form and arrangement of parts may be made to suit requirements without departing from the spirit and scope of this invention.

Having thus described my invention, I clam:

1. In a mass spectrometer, an ion source having an ionization chamber for ionizing a sample and comprising:

- a. an evacuatable chamber having an aperture for the passage of ions;
- b. means for introducing a sample into said chamber;
- c. an electrode constructed of a length of elongated conductive material having an edge lying in a direction generally at right angles to the required direction of the ion beam, and disposed within said 40 chamber for propelling said ions out of said chamber:
- d. source means for developing an electrical signal having a value less than the value necessary to cause substantial field ionization;
- e. circuit means coupling said source means to said electrode to thereby develop an electrical field about said electrode;
- f. said electrode being arranged such that said field is oriented so as to expell ions from said chamber 50 through said aperture;
- g. electron generating means for emitting a beam of electrons into said ionization chamber for developing said ions by electron bombardment of a said sample; and, 55
- h. means for directing said beam of electrons in a direction toward said electrode so that said resulting ions are rapidly expelled through said aperture by said electrical field.

2. In a mass spectrometer an ion source having an 60 ionization chamber for ionizing a sample and comprising:

a. an evacuatable chamber having an aperture for the

passage of ions;

b. means for introducing a sample into said chamber; c. an electrode constructed of a conductive wire formed in a generally U-shaped configuration hav-

б

- ing a portion lying in a direction generally at right angles to the required direction of the ion beam and disposed within said chamber for propelling said ions out of said chamber;
- d. source means for developing an electrical signal having a value less than the value necessary to cause substantial field ionization;
- e. circuit means coupling said source means to said electrode to thereby develop an electrical field about said electrode;
- f. said electrode being arranged such that said field is oriented so as to expell ions from said chamber through said aperture;
- g. electron generating means for emitting a beam of electrons into said ionization chamber for developing said ions by electron bombardment of said sample; and,
- h. means for directing said beam of electrons in a direction toward said electrode so that said resulting ions are rapidly expelled through said aperture by said electrical field.

3. In a mass spectrometer an ion source comprising an ionization chamber having an aperture for the passage of ions, ionization means other than field ionization means to ionize material within said 30 chamber, electrode means comprising a blade having an edge lying in a direction generally at right angles to the required direction of the ion beam and disposed within said chamber for generating an electrical field oriented so as to propel ions out of said chamber through said aperture, and means connected to said electrode means to develop an electrical field about said electrode means of a gradient and intensity to rapidly expel ions from said chamber, at least a portion of the region within said chamber wherein said material is ionized being coextensive with at least a portion of said electrical field.

4. A method of rapidly expelling ions from an ionization chamber having a blade electrode with an edge thereof lying in a direction generally at right angles to 45 the required direction of the ion beam, the blade electrode being positioned in the chamber and oriented to expell electrons through an aperture formed in the chamber, comprising the steps of:

- a. applying an electrical signal to the blade electrode so as to generate an electrical field about a relatively sharp edge of the blade electrode with the sharp edge oriented such that the field serves to expell ions from the chamber through the aperture, the field being of an intensity less than that which is required to cause substantial field ionization:
- b. ionizing a material to be ionized within the chamber by a method other than field ionization; and.
- c. subjecting the ions so formed to the electric field whereby they are expelled from the chamber through the aperture.

35