Feb. 5, 1957 C. F. ROBINSON ET AL 2,780,729

MASS SPECTROMETRY

Filed May 24, 1954 2 Sheets-Sheet 1

FIG. 1.

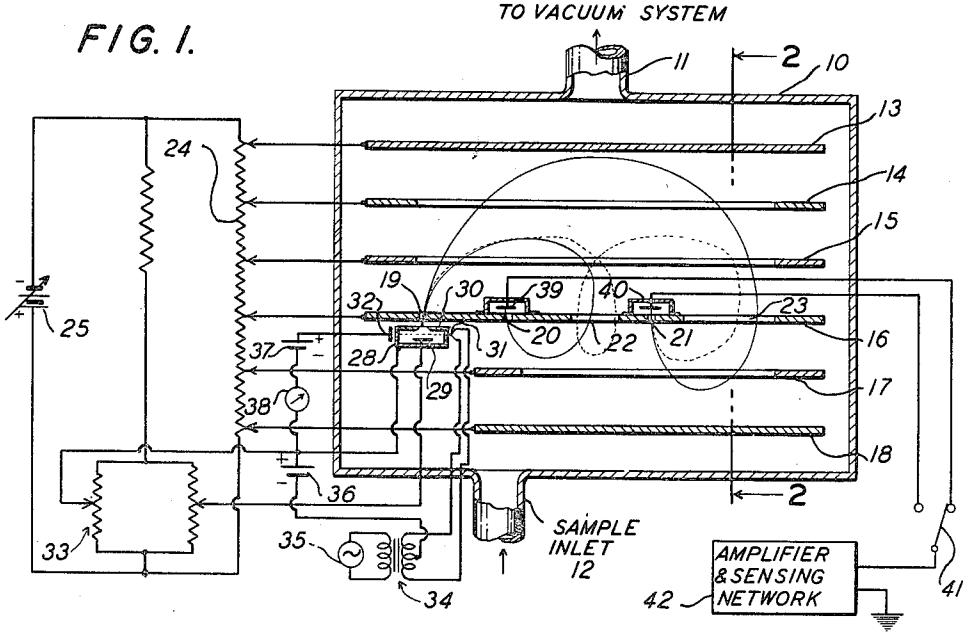
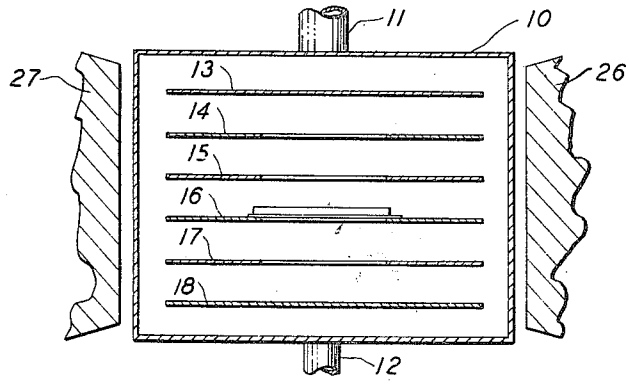


FIG. 2.



CHARLES F. ROBINSON
ROBERT V. LANGMUIR
WILSON M. BRUBAKER
GEORGE D. PERKINS
INVENTORS.

BY

James B. Christie

ATTORNEY

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FIG. 3.

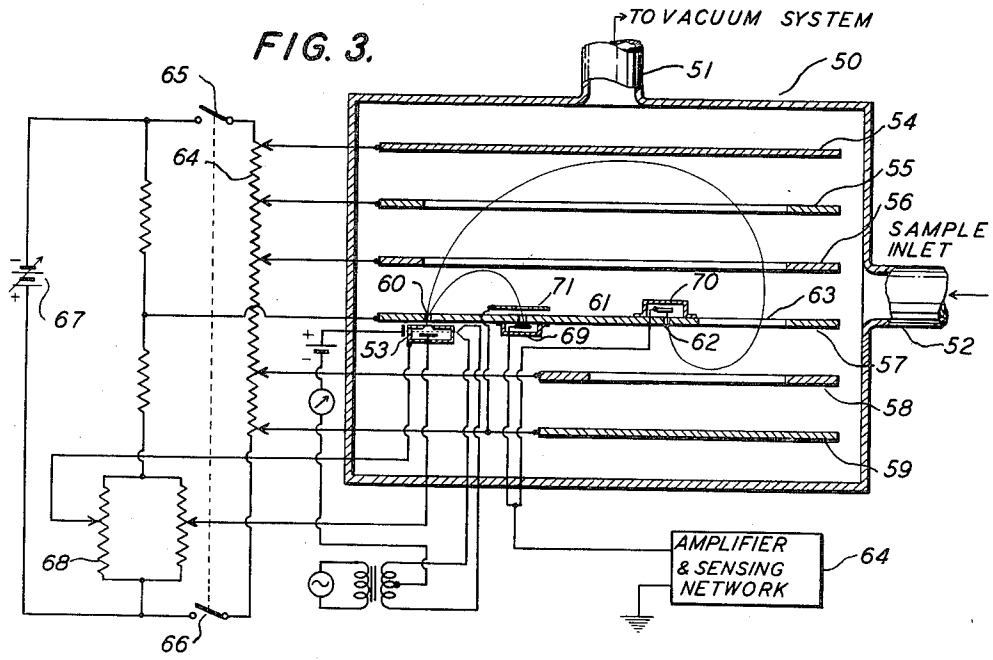
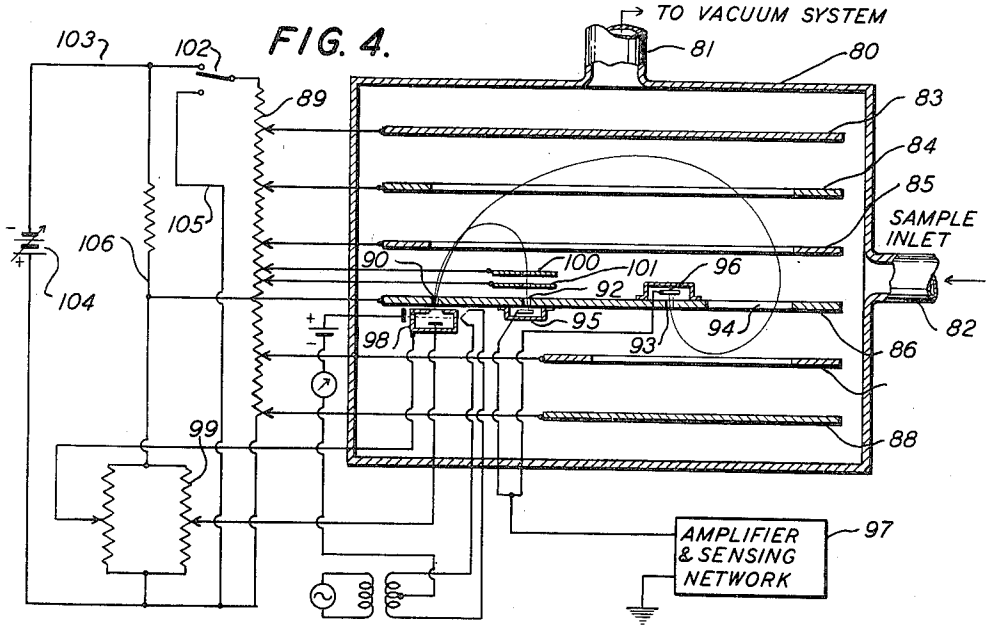


FIG. 4.



CHARLES F. ROBINSON
ROBERT V. LANGMUIR
WILSON M. BRUBAKER
GEORGE D. PERKINS
INVENTORS.

BY

James B. Christie

ATTORNEY

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2,780,729

MASS SPECTROMETRY

Charles F. Robinson, Pasadena, Robert V. Langmuir, Altadena, Wilson M. Brubaker, Arcadia, and George D. Perkins, Duarte, Calif., assignors, by mesne assignments, to Consolidated Electrodynamics Corporation, Pasadena, Calif., a corporation of California

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14 Claims. (Cl. 250—41.9)

This invention relates to mass spectrometry and particularly to improvements in cycloidal mass spectrometers.

Mass spectrometry is the art of analysis by ionization and selective detection of the relative abundance of ions of given mass to charge ratio or mass to charge ratios. In general, a mass spectrometer involves an ion source in which a sample to be analyzed is ionized by means of an electron beam, an analyzer chamber into which ions are propelled from the source and in which they are subjected to the influence of electrical or magnetic fields, or both. Under the influence of such fields, and depending upon their application and orientation, the ions are caused to pursue characteristic paths of travel in the analyzer chamber as a function of their mass to charge ratio. Means are normally provided for selectively collecting ions as a function of spatial, temporal or directional separation between ion masses in the analyzer chamber.

The cycloidal mass spectrometer to which this invention is directed, derives its name from the fact that ion motion within the analyzer chamber is normally in a cycloidal trajectory. This is accomplished by subjecting the ion to transverse magnetic and electrical fields, for which reason the instrument is frequently referred to also as a "crossed field" mass spectrometer.

If a charged particle is introduced into a magnetic field it will move in a circular path to return to its point of origin. This is true regardless of the mass of the particle, particles of increasing mass traveling in circles of increasing radius but in each instance returning to the point of origin. If a uniform electrical field is imposed across the space defined by the magnetic field and normal to the magnetic field, the ions pursue a path under the influence of the crossed field which may be considered as rigorously circular in a coordinate system moving with uniform velocity. The movement of the coordinate system is a function of the ratio of the electric and magnetic field strengths. If ions of a particular mass are introduced into such a system they will complete one turn of their trajectory in a time which depends directly on the mass of the particle, and if the electric field strength is uniform so that the coordinate systems corresponding to each particle move at the same velocity, the particles will converge to a series of rigorous point foci after any integral number of turns in the magnetic field regardless of their velocity or direction of travel at the moment of introduction into the field. Since the time required for ions to complete one turn of the trajectory depends directly on the mass, and since under the condition of uniform field strength specified the rate of motion of the coordinate system is invariant to the mass of the particle involved, the focal point of the heavy particles will be displaced farther from the point of origin than the focal point of the lighter particle. This is the basic concept of the cycloidal or crossed-field mass spectrometer.

In a typical instrument of this type the electrical field is established in an analyzer region by means of a plu-

rality of spaced-parallel electrodes, with one of the electrodes defining a so-called focal plane. Ions are introduced into the field influence through an inlet aperture located on the focal plane defining electrode and are focused through a resolving aperture in the electrode spaced from the inlet aperture. These slit positions are normally fixed with respect to each other. Under such circumstances the focal distance X_f in centimeters is given by the expression:

$$X_f=\frac{2\pi mEc^2}{qB^2} \quad (1)$$

where

B=the magnetic field strength in Gauss;
E=the electric field strength in statvolt/cm.;
q=the ion charge in e. s. u.; and
m=the ion mass in grams.

To maintain a constant trajectory shape during scanning, the ratio of the electric field strength and the energy V with which the ions are injected into the resolving system should be held constant. Consequently, optimum and, at the same time, the simplest operation is achieved when the voltages applied to the several field-forming electrodes and to the ion source are taken from a divider, and scanning is accomplished by varying the voltage V_o applied across the divider.

If scanning is carried out in this way, the product of ion mass and the voltage across the divider (V_o) is, for a constant magnetic field, a fixed constant of the instrument. As a consequence, the voltage required to bring an ion of mass 2 into focus is 50 times as great as that required to focus ions of mass 100 at the fixed resolving aperture. It is apparent therefore that if mass 100 is focused at reasonable operating voltages, the voltage required to similarly focus mass 2 is frequently excessive.

The present way of circumventing this difficulty is to change the magnetic field strength so that the instrument constant mV_o has two or more discrete values, this constant being high for high masses and low for low masses. When the mass spectrometer is to be used for process monitoring, however, it is frequently necessary that the instrument step quickly from one mass peak to another throughout the range mass 2 to mass 100 or greater. To vary the instrument constant mV_o through the expedient of changing the magnetic field under such circumstances requires cumbersome and expensive mechanism.

We have now developed a cycloidal mass spectrometer in which both low and high masses can be conveniently collected without requiring a change in the magnetic field strength and without requiring inconveniently high operating voltages. We have found that this objective can be accomplished in a cycloidal mass spectrometer by the use of two ion collectors disposed at different fixed distances from the inlet aperture so that ions of low and high masses may be separately collected. The two collectors are respectively referred to as the "short focus collector" and the "long focus collector," and preferably the resolving apertures associated with each collector are located at different points on a common radius from the inlet aperture.

The invention therefore contemplates in a mass spectrometer, the combination comprising an envelope, an ion source, means producing an electrical field across a space in the envelope, means producing a magnetic field across the space normal to the electrical field, means for propelling ions from the source into the space, first collector means disposed in the space at a fixed given distance from the ion source to collect ions which focus at the first given distance, second collector means disposed in the space at a second given distance from the ion source to collect ions which focus at the second given distance,

and means operable to selectively sense ion discharge at the two collectors.

The instrument is operated so that ions focused on the high mass collector are subjected to the cycloidal mode of separation, i. e. the conventional mode of the cycloid or crossed-field mass spectrometer. With respect to the so-called short focus collector the instrument may be operated either in a cycloidal mode or in the manner of a conventional 180° mass spectrometer.

To render an instrument of this type practical it is necessary that provision be made to selectively sense ion discharge at the two collectors. One means of accomplishing this selectivity is to interchangeably connect the two collectors to a common amplification and sensing network, under which circumstance simultaneous discharge of ions of differing mass at the two collectors is not detrimental.

In another embodiment ions of low mass may be prevented from focusing at the short focus collector during periods when it is desired to collect only heavy ions at the long focus collector by disposing a biasing grid immediately in front of the short focus resolving slit and maintaining this grid at a potential sufficiently positive that ions cannot enter the short focus resolving slit when it is desired that they not do so. Another means of excluding ions from the short focus collector is to arrange a series of baffles in such a manner that when heavy ions are moving in the normal cycloidal trajectory for collection at the long focus collector, light ions, which also move in cycloids under the same field influences, cannot traverse the baffle system for collection at the short focus collector. With this arrangement, light ions will reach the short focus collector only if they move in a trajectory of different shape than the one they normally have under the influence of the crossed-field applied for discrimination of heavier masses.

The invention will be more clearly understood with reference to the following detailed description taken in conjunction with the accompanying drawing in which:

Fig. 1 is a schematic sectional elevation of a cycloidal mass spectrometer in accordance with one embodiment of the invention;

Fig. 2 is a transverse schematic sectional elevation taken on the line 2—2 of Fig. 1 and showing the orientation of the magnet means for developing the transverse magnetic field;

Fig. 3 is a schematic sectional elevation of a cycloidal mass spectrometer in accordance with another embodiment of the invention; and

Fig. 4 is a schematic sectional elevation of a third embodiment of a cycloidal mass spectrometer in accordance with the invention.

The mass spectrometer shown in Figs. 1 and 2 comprises an envelope **10** having the usual connection **11** to a vacuum system (not shown) and sample inlet line **12**. A series of electrodes **13, 14, 15, 16, 17, 18** are supported in the envelope in parallel, uniformly spaced relation. Electrode **16** defines a so-called focal plane and is provided with an ion inlet aperture **19**, a first or short focus resolving aperture **20**, and a second or long focus resolving aperture **21**. Additionally, electrode **16** has relatively enlarged openings **22, 23** to permit ion travel in the cycloidal trajectories induced under the imposed electrical and magnetic fields.

Electrodes **13, 14, 15, 16, 17** and **18** are connected to a voltage divider **24** across which a voltage is applied from a variable source **25**. By means of the electrodes and the divider network illustrated schematically, a uniform electrical field is applied across the region defined by the electrodes. As shown in Fig. 2, the envelope is immersed in a magnetic field developed by magnet poles **26, 27**, the direction of the magnetic field being normal to the uniform electrical field.

An ion source **28** is disposed adjacent the ion entry slit aperture **19** in electrode **16**. The ion source is in conventional form, including a repeller electrode **29**, an accelerating electrode **30**, an electron gun **31** and an electron target **32**. By means of the electron gun and target an ionizing electron beam (shown in dotted lines) is directed across the ion source. The repeller electrode **29** and accelerating electrode **30** are connected to a voltage divider network **33** which is in turn connected across the voltage source **25**. Electron gun **31** is connected through a transformer **34** to an A. C. source **35** for filament heat and through a bias battery **36** to the accelerator **28**. The target **32** is connected through a bias battery **37** and an emission indicating meter **38** to the accelerator **28**. The illustrated ion source is conventional and, apart from its necessary function in the combination, forms no part of the present invention. A short focus collector electrode **39** is disposed adjacent the short focus resolving aperture **20** and a long focus collector electrode **40** is disposed adjacent the long focus resolving aperture **21** in the electrode **16**. The two collectors are connected through a switch **41** to an amplification and sensing network **42** which may be of conventional form.

The operation of the instrument of Fig. 1 is as follows: A sample to be analyzed is introduced through inlet **12** which, although not so illustrated, may be directly connected into the ion source **28**. Under influence of the ionizing electron beam the sample is ionized and ions are expelled into the region of the crossed electrical and magnetic fields under the influence of an accelerating potential existing between the repeller electrode **29**, accelerating electrode **30** and plate electrode **16**, ions passing from the source into the field region through the inlet aperture **19**.

If it is desired to collect ions of relatively low mass, as for example in the region of mass 2 to 12, the voltage applied across divider **24** is set to focus the desired mass on the short focus resolving aperture **20**. Under this circumstance, collector **39** is connected through switch **41** to the amplification and sensing network so that ion discharge at the short focus collector is amplified and sensed. During this sensing period any heavier ions which may focus and discharge on the collector **40** are not sensed since this long focus collector is disconnected from the amplifying and sensing network. If ions of heavier mass are of interest, the voltage applied across the divider **24** is controlled to focus the ion of desired heavier mass at the long focus aperture for collection at collector **40**. Switch **41** is actuated to interconnect the long focus collector to the amplifying and sensing network, at the same time disconnecting the short focus collector. By the illustrated means it is possible to selectively sense ion discharge at one or the other of the short focus or long focus collector.

The instrument shown in Fig. 1 consists essentially of two cycloidal mass spectrometers, one with a short focal distance and one with a long focal distance operating from a common ion source. Ion focus in either instance is controlled by varying the voltage applied to the field-forming electrodes, the total variation required for analysis of a wide mass range being smaller by a very major factor than in the conventional single focus cycloidal instrument. The arrangement shown in Fig. 1 has a limitation in that highly complex designing is involved to prevent the possible appearance of harmonics at the long focus collector when that collector is being sensed.

Another embodiment of the dual collector cycloidal mass spectrometer is shown schematically in sectional elevation in Fig. 3. This apparatus includes an envelope **50**, exhaust line **51**, sample inlet **52**, an ion source **53**, all substantially identical to the corresponding portions of the apparatus illustrated in Fig. 1. Electrodes **54, 55, 56, 57, 58, 59** comprise the field-forming electrodes with electrode **57** defining the focal plane and having an ion inlet aperture **60**, a short focus aperture **61** and a long focus resolving aperture **62**. This electrode differs from the corresponding electrode **16** of the device of Fig. 1 in

that it has only a single relatively enlarged opening 63. This is because the instrument is designed for short focus application in the 180° mode of operation rather than in the cycloidal mode of operation. The electrodes 54, 55, etc. are connected to a voltage divider 64 which is connected through tandem switches 65 and 66 across a variable voltage source 67.

The various components of the ion source are connected to a secondary voltage divider 68 as in the first described embodiment. A collector electrode 69 is disposed adjacent the short focus aperture 61, in this instance below the focal plane as contrasted with the arrangement of the short focus collector in the first described embodiment. A long focus collector 70 is disposed adjacent the long focus resolving aperture 62 and the two collectors are connected in parallel to an amplification and sensing system network 64.

The operation of this device for sensing high masses in the cycloidal mode is identical to the operation of the apparatus of Fig. 1. When it is desired to sense relatively low masses by collection at the short focus collector 69, the switches 65, 66 are opened to destroy the electrical field in the envelope. As a consequence, ions issuing from the ion source will travel in a rigorously circular pattern, as in the manner of the operation of the conventional 180° mass spectrometer. In effect, the short focus resolving slit effects a fixed focus resolution at a given magnetic field strength. In view of the fact that the electrical field in the instrument has been destroyed, any low mass scanning is accomplished by varying either the accelerating voltages applied to the ion source or the magnetic field strength, the former being the most acceptable scanning method for the 180° mode of operation. There is no problem of sensing any ion discharge at the long focus collector electrode during periods of 180° operation since ion motion in the magnetic field in the absence of the electrical field is strictly circular, and no ions can possibly traverse the aperture 62.

However, when the instrument is operated in the cycloidal mode for collection of heavier masses at the collector 70, it is possible for low masses to focus at the resolving slit 61 since the first 180° of cycloidal trajectory under these circumstances may resemble very closely the normal semi-circular trajectory. To exclude any ion discharge at collector 69 during operation of the instrument in a cycloidal mode, a bias grid 71 is disposed adjacent the short focus resolving aperture 61, the grid being biased to a potential preventing ion access to the collector 69. Conveniently the grid is controlled without any external connection by connecting it directly to the electrode 59 as shown. This connection provides a suitable bias potential on the grid during periods of cycloidal operation and automatically nullifies the effect of the grid during periods of 180° operation.

Another embodiment of the invention is shown in Fig. 4. The instrument comprises an envelope 80 with an exhaust line 81 and a sample inlet line 82. Field-forming electrodes 83, 84, 85, 86, 87, 88 are connected across a divider 89 as in the foregoing embodiments. Electrode 86 defines the focal plane of the instrument and includes an ion inlet aperture 90, a short focus aperture 92, a long focus aperture 93 and a single relatively enlarged opening 94 for providing access to the long focus aperture 93. A first collector electrode 95 is disposed adjacent the short focus aperture 92 and on the lower side of the focal plane, and a second collector electrode 96 is disposed adjacent the long focus aperture 93 on the upper side of the focal plane. The two collector electrodes are connected in parallel into an amplification and sensing network 97.

An ion source 98 of the type illustrated in detail in Fig. 1 is disposed adjacent the inlet aperture 90, and the various portions of the ion source are connected into a second voltage divider network 99. A pair of apertured baffles 100 and 101 are disposed in front of the short focus resolving slit 92 and are interconnected to the voltage

divider 89 in such a manner that no distortion of the uniform electrical field is produced by them.

As above described, the use of baffles to prevent access to the short focus collector requires that they be positioned so as to block low mass ions in their normal cycloidal trajectory. This may be accomplished by destroying the electrical field as in the embodiment of Fig. 2 so that ion travel will be semi-circular under the sole influence of the magnetic field. However, a cycloidal trajectory of comparatively small radius as pursued by low mass ions and a semi-circular trajectory will sometimes not differ appreciably so that it is difficult to provide a baffle system which will reject normal cycloids and pass semi-circles.

Provision is made in the instrument of Fig. 4 to alter the travel of the ions to an appreciable extent during periods of low mass measurement. This is accomplished by reversing the electrical field, or at least a critical portion of the electrical field, so as to invert the normal cycloidal path. With such a reversed field the focal point is displaced to the left of the entry slit as viewed in Fig. 4. Such cycloids show an approximate focus at a position to the right of the entry slit, and by properly placing the short focus resolving slit 92 a sufficient resolution of the low mass range can be obtained. Such reversal of a critical portion of the electrical field may be accomplished by means of the circuit shown schematically in which one end of divider 89 is connected through a switch 102 either through lead 103 to one side of a variable voltage source 104, or through lead 105 to the other side of the voltage source 104. With this connection the upper end of the divider 89 is either at a given positive potential or a given negative potential, dependent upon the setting of the switch 102. Field-forming electrode 86, which defines the focal plane of the instrument, is connected to a separate divider network 106 so that reverse connection of the divider 89 has no effect on the potential of this electrode.

The operation of the apparatus of Fig. 4 is essentially identical to that of the above described embodiments. During periods of high mass measurement when focus is at the collector 96, the baffles 100 and 101 prevent access of low mass ions traveling in a normal cycloidal trajectory to the low mass collector 95. When it is desired to collect low mass ions to the exclusion of high mass ions, reversal of the electrical field, at least as determined by the electrodes 83, 84 and 85, inverts the cycloidal trajectory of all of the ions so that the low mass ions can traverse the baffle system for collection at collector 95. Since the true focus under these circumstances is at the left of the entry slit, the high mass ions cannot gain access to the high mass collector 96 during periods of field inversion. Consequently, the amplifier and sensing network 97 senses only the low mass ions focused on collector 95 during this period.

To avoid the necessity for excessively high operating voltages as normally required for the analysis of a sample of wide mass range, I have designed a cycloidal mass spectrometer provided with two collector electrodes which, as illustrated, are preferably located adjacent a so-called focal plane in common to the inlet and resolving apertures. In the illustrated apparatus this focal plane is defined by one of the field-forming electrodes. Collection of low mass ions on the short focus electrode may be accomplished in the normal cycloidal mode, in a conventional 180° mode, or in a distorted cycloidal mode, such procedures being respectively illustrated in Figs. 1, 3 and 4. Preferably, means are provided to prevent the sensing of low mass ions during the period of analysis of high mass ions. Such means may take the form in any of the illustrated embodiments of the external collector switching means illustrated in Fig. 1. Alternatively, a biasing electrode may be used operable to prevent access of low mass ions to low mass collector during periods of high mass collection at the high mass collector. This is convenient in the particular embodiment shown in Fig. 2 wherein the electrical field is de-

stroyed during the periods of low mass collection and in which the ions are subjected to semi-circular travel under the influence only of the magnetic field. A similar bias grid may be used even if the low ion masses are subject to normal cycloidal trajectories, in which event a biasing voltage may be impressed on the grid independently of any of the field-forming electrodes. A third means of preventing the sensing of low mass ions during the desired period comprises a number of apertured baffles which, as described with relation to Fig. 4, are particularly adaptable where provision is made to alter the ion trajectory during periods of low mass collection. In this way, the baffles may be set to block low mass ions traveling in the normal cycloidal trajectory imposed in periods of high mass collection and to pass these ions in this particular instance when an inverse cycloidal trajectory is imposed by reversing the polarity of the electrical field.

We claim:

1. In a cycloidal mass spectrometer, the combination comprising an envelope, an ion source, means producing an electrical field across a space in the envelope exclusive of the ion source, means producing a magnetic field across said space normal to the electrical field, means for propelling ions from the source into the space, first collector means disposed in the space at a first given distance from the ion source, second collector means disposed in the space at a second given distance from the ion source, and means operable to selectively sense the output of the two collectors.

2. In a cycloidal mass spectrometer, the combination comprising an envelope, an ion source, means producing a D. C. electrical field across a space in the envelope exclusive of the ion source, means producing a magnetic field across said space normal to the electrical field, means for propelling ions from the source into the space, first collector means disposed in the space at a first given distance from the ion source, second collector means disposed in the space at a second given distance from the ion source, amplification and sensing means, and means operable to selectively connect the two collectors to the amplification and sensing means.

3. In a mass spectrometer, the combination comprising an envelope, an ion source, means producing a D. C. electrical field across a space in the envelope, means producing a magnetic field across the space normal to the electrical field, means for propelling ions from the source into the space, first collector means disposed in the space at a first given distance from the ion source, second collector means disposed in the space at a second given distance from the ion source, means operable to destroy the electrical field in at least the region traversed by ions between the source and the first collector means, and means operable to selectively sense the output of the two collectors.

4. In a mass spectrometer, the combination comprising an envelope, an ion source, means producing a D. C. electrical field across a space in the envelope, means producing a magnetic field across the space normal to the electrical field, means for propelling ions from the source into the space, first collector means disposed in the space at a first given distance from the ion source, second collector means disposed in the space at a second given distance from the ion source, an apertured electrode disposed in front of the first collector means, means operable to impress a D. C. potential on the apertured electrode to exclude ions from the first collector means, means operable to destroy the D. C. electrical field, means operable to destroy the potential on the apertured electrode, and means operable to selectively sense the output of the two collectors.

5. In a mass spectrometer, the combination comprising an envelope, an ion source, means producing a D. C. electrical field across a space in the envelope, means producing a magnetic field across the space normal to the

electrical field, means for propelling ions from the source into the space, first collector means disposed in the space at a first given distance from the ion source, second collector means disposed in the space at a second given distance from the ion source, a plurality of apertured baffles disposed in front of the first collector means to exclude ions moving under the influence of the electrical and magnetic fields imposed to focus ions on the second collector means, and means operable to selectively sense the output of the two collectors.

6. In a mass spectrometer, the combination comprising an envelope, an ion source, means producing a D. C. electrical field across a space in the envelope, means producing a magnetic field across the space normal to the electrical field, means for propelling ions from the source into the space, first collector means disposed in the space at a first given distance from the ion source, second collector means disposed in the space at a second given distance from the ion source, a plurality of apertured baffles disposed in front of the first collector means, means for distorting the electrical field to cause ions to traverse the baffle aperture for collection at the first collection means, and means operable to selectively sense the output of the two collectors.

7. Apparatus according to claim 6 wherein the means for distorting the electrical field comprises circuit means for reversing the polarity of at least a part of the field whereby ions are caused to travel in cycloidal paths of inverted shape.

8. In a mass spectrometer, the combination comprising an envelope, an ion source, a plurality of spaced parallel electrodes disposed in the envelope, means including said electrodes for producing a D. C. electrical field across a space in the envelope, means producing a magnetic field across the space normal to the electrical field, one of the plurality of electrodes having an inlet aperture and first and second spaced resolving apertures, means for propelling ions from the source through the inlet aperture into the space, first collector means disposed adjacent the first resolving aperture, second collector means disposed adjacent the second resolving aperture, and means operable to selectively sense the output of the two collectors.

9. In a mass spectrometer, the combination comprising an envelope, an ion source, a plurality of spaced parallel electrodes disposed in the envelope, means including said electrodes for producing a D. C. electrical field across a space in the envelope, means producing a magnetic field across the space normal to the electrical field, one of the plurality of electrodes having an inlet aperture and first and second resolving apertures spaced at different distances on the same side of the inlet aperture, means for propelling ions from the source through the inlet aperture into the space, first collector means disposed adjacent the first resolving aperture, second collector means disposed adjacent the second resolving aperture, and means operable to selectively sense the output of the two collectors.

10. In a mass spectrometer, the combination comprising an envelope, a plurality of spaced parallel electrodes disposed in the envelope, means including said electrodes for producing a D. C. electrical field across a space in the envelope, means producing a magnetic field across the space normal to the electrical field, one of the plurality of electrodes having an inlet aperture and first and second resolving apertures spaced at different distances on the same side of the inlet aperture, an ion source disposed adjacent the inlet aperture, means for propelling ions from the source through the inlet aperture into the space, first collector means disposed adjacent the first resolving aperture and on the same side of said one electrode as the ion source, second collector means disposed adjacent the second resolving aperture and on the opposite side of said one electrode, and means operable to selectively sense the output of the two collectors.

11. In a mass spectrometer, the combination comprising an envelope, a plurality of spaced paraliel electrodes disposed in the envelope, means including said electrodes for producing a D. C. electrical field across a space in the envelope, means producing a magnetic field across the space normal to the electrical field, one of the plurality of electrodes having an inlet aperture and first and second resolving apertures spaced at different distances on the same side of the inlet aperture, an ion source disposed adjacent the inlet aperture, means for propelling ions from the source through the inlet aperture into the space, first collector means disposed adjacent the first resolving aperture and on the same side of said one electrode as the ion source, second collector means disposed adjacent the second resolving aperture and on the opposite side of said one electrode, means operable to destroy the D. C. electrical field without altering the voltage impressed on said one electrode, and means operable to selectively sense the output of the two collectors.

12. In a mass spectrometer, the combination comprising an envelope, an ion source, a plurality of spaced parallel electrodes disposed in the envelope, means including said electrodes for producing a D. C. electrical field across a space in the envelope, means producing a magnetic field across the space normal to the electrical field, one of the plurality of electrodes having an inlet aperture and first and second resolving apertures spaced at different distances on the same side of the inlet aperture, means for propelling ions from the source through the inlet aperture into the space, first collector means disposed adjacent the first resolving aperture, second collector means disposed adjacent the second resolving aperture, the first and second collectors being on the same side of said one electrode, and means operable to selectively sense the output of the two collectors.

13. In a mass spectrometer, the combination comprising an envelope, a plurality of spaced parallel electrodes disposed in the envelope, means including said electrodes for producing a D. C. electrical field across a space in the envelope, means producing a magnetic field across the space normal to the electrical field, one of the plurality of electrodes having an inlet aperture and first and second spaced resolving apertures spaced at different distances and on the same side of the inlet aperture, an ion source disposed adjacent the inlet aperture, means for propelling ions from the source through the inlet aperture into the space, first collector means disposed adjacent the first resolving aperture and on the same side of said one electrode as the ion source, second collector means disposed adjacent the second resolving aperture and on the opposite side of said one electrode, and means operable to selectively sense the output of the two collectors.

14. In a mass spectrometer, the combination comprising an envelope, a plurality of spaced parallel electrodes disposed in the envelope, means including said electrodes for producing a D. C. electrical field across a space in the envelope, means producing a magnetic field across the space normal to the electrical field, one of the plurality of electrodes having an inlet aperture and first and second resolving apertures spaced at different distances on the same side of the inlet aperture, an ion source disposed adjacent the inlet aperture, means for propelling ions from the source through the inlet aperture into the space, first collector means disposed adjacent the first resolving aperture and on the opposite side of said one electrode as the ion source, second collector means disposed adjacent the second resolving aperture and on the opposite side of said one electrode, and means operable to selectively sense the output of the two collectors.

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