Aug. 31, 1954 C. F. ROBINSON 2,688,087

MASS SPECTROMETRY

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FIG. 1A.

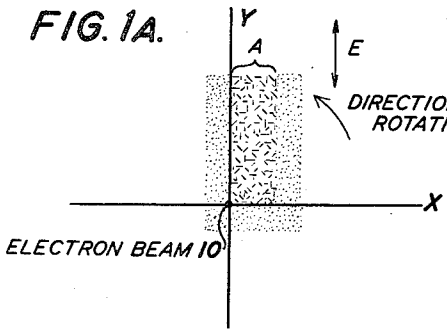


FIG. 1B.

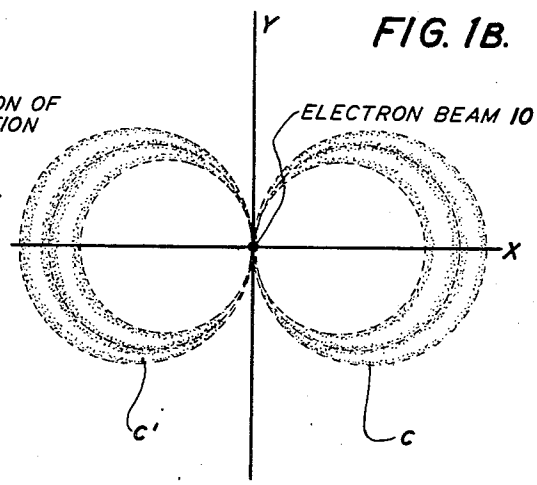
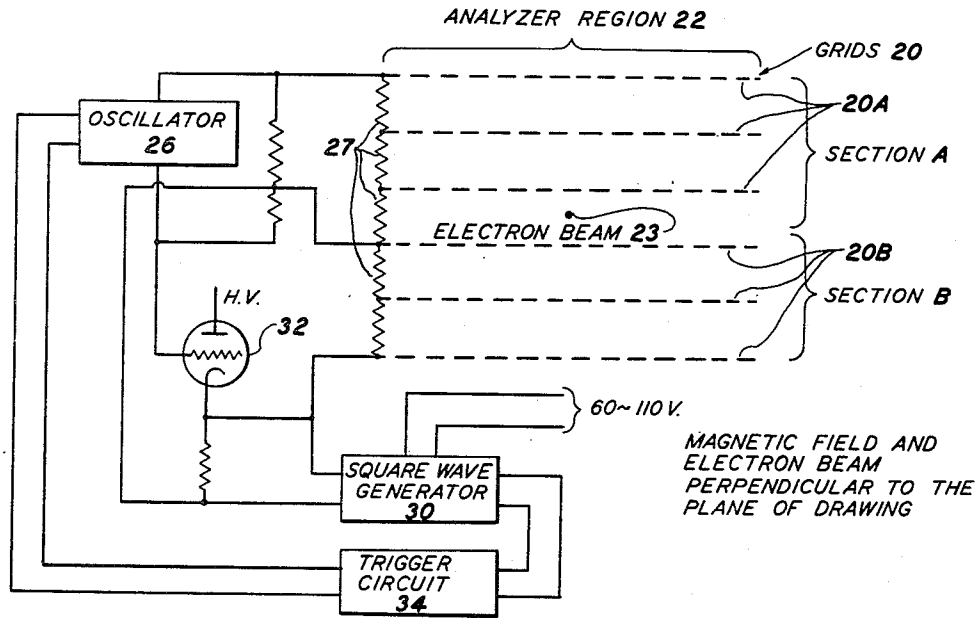


FIG. 2.



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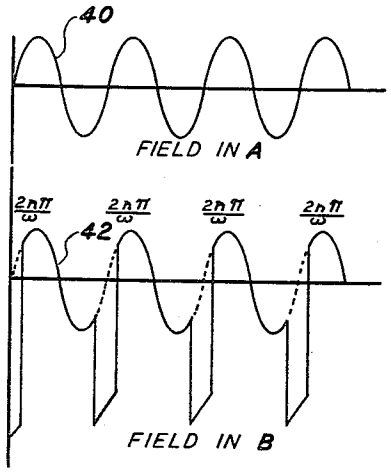


FIG. 3.

DRIFT FIELD PARALLEL TO A.C. FIELD

FIG. 6.

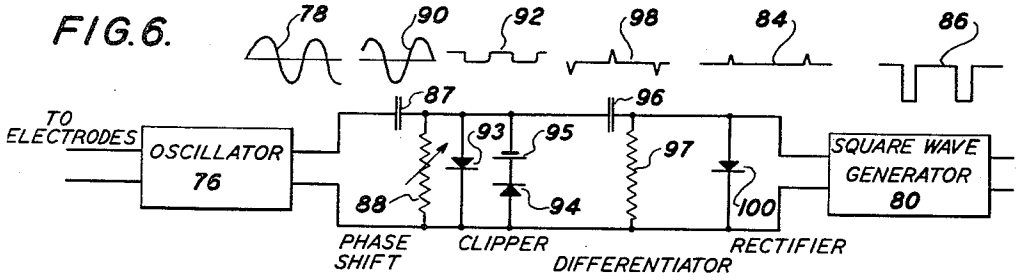
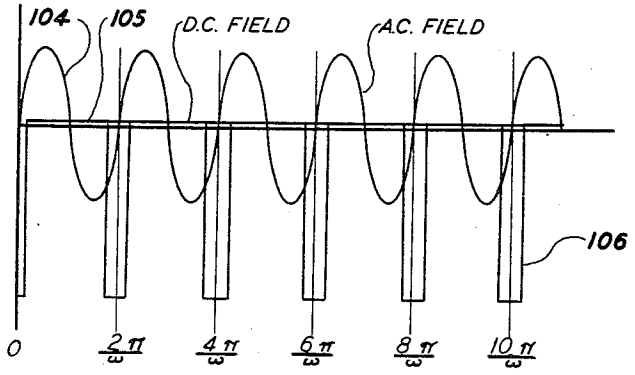


FIG. 7.



DRIFT FIELD TRANSVERSE TO A.C. FIELD

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FIG. 4.

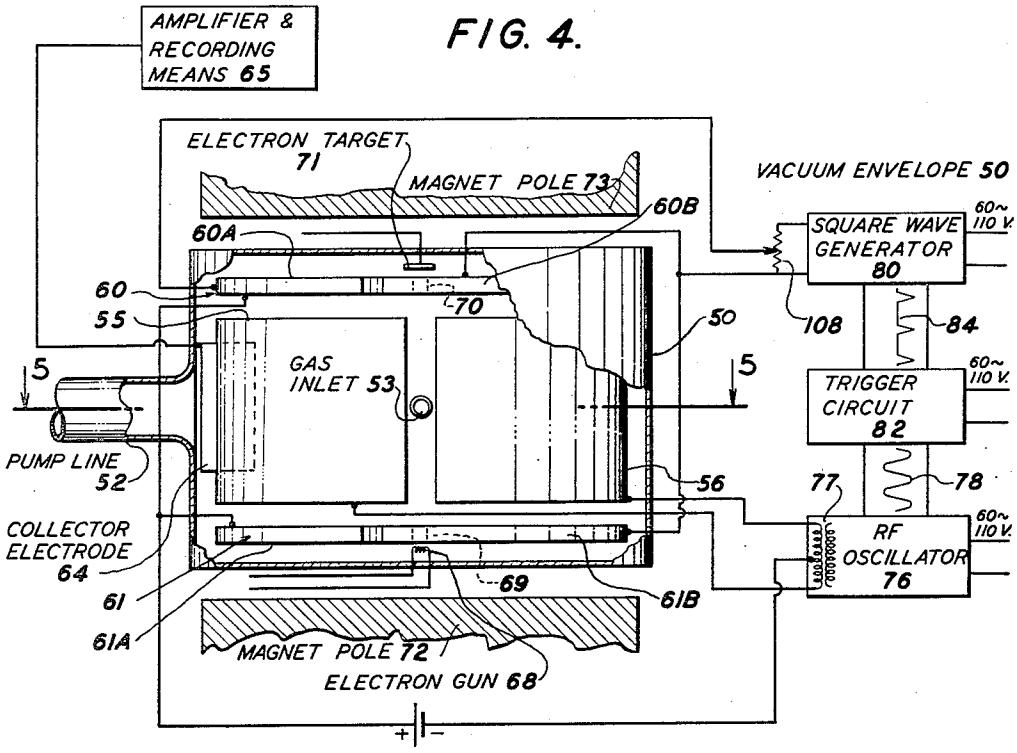
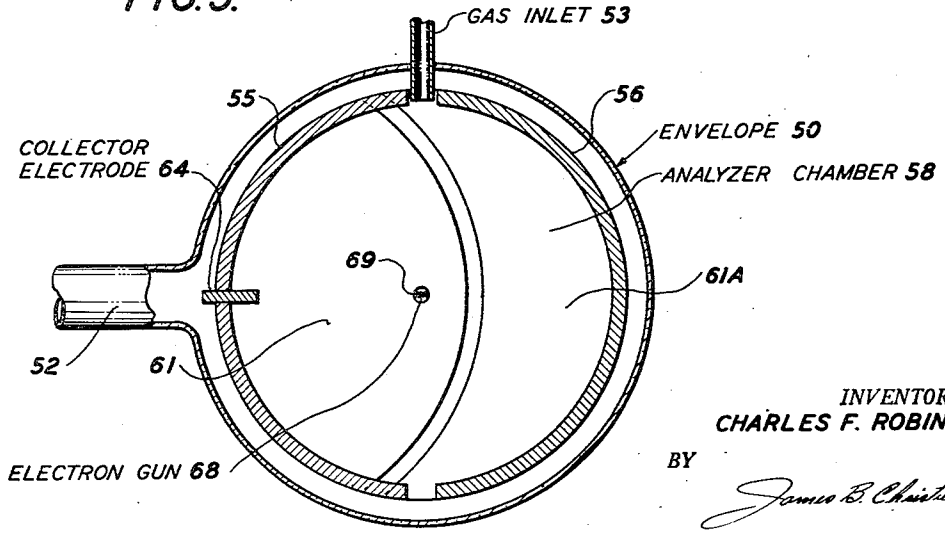


FIG. 5.



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UNITED STATES PATENT OFFICE

2,688,087

MASS SPECTROMETRY

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Application August 3, 1950, Serial No. 177,481

12 Claims. (Cl. 250—41.9)

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This invention relates to mass spectrometry and particularly to mass spectrometry wherein charged particles of differing mass-to-charge ratio are segregated according to their periodicity of motion in a magnetic field.

Mass spectrometry in general involves ionization of a sample to be analyzed, as by bombardment with an electron beam, segregation of the resultant ions in accordance with their mass-to-charge ratio, and selective discharge of ions of a given mass-to-charge ratio. The magnitude of the current developed by discharge of the ions of given mass-to-charge ratio provides a basis for calculating the partial pressure of those molecules in the sample from which these particular ions were derived. Where a sample is to be analyzed for more than one component, the practice is to scan the mass spectrum by successively discharging ions of differing mass-to-charge ratio. The spectrum is scanned by varying one or more of the operation variables which determine the paths of travel of the ions.

One means of segregating or sorting the ions comprises introducing them into or forming them in a space traversed by a magnetic field and a high frequency alternating electrical field normal to the magnetic field. It has been found that ions will assume characteristic paths of motion in the space traversed by these fields, the orbits of which depend primarily upon whether or not the ions are in resonance with the alternating field. At any given magnetic field strength and at any given frequency of the alternating field, only ions of a given mass-to-charge ratio will be in resonance with the alternating field.

Under these circumstances, the so-called resonant ions will pursue a path from their origin in the form of an ever expanding spiral or uniformly increasing radius, the radius being normal to the magnetic field. The non-resonant ions, on the other hand, will be driven in a spiral path starting at their point of origin and increasing in decreasing increments to a maximum radius whereupon they collapse back to the origin. The origin may be considered as an axis parallel to the magnetic field and on which ion flow into the space occurs or as the axis of an electron beam projected through the space parallel to the magnetic field and along which ions are formed in the space. As might be expected, the non-resonant ions of mass most closely adjacent the mass of the resonant ions will have the largest orbital radii and for this reason ultimate segregation depends upon discharging the resonant ions, as for example at a collector electrode, beyond the radius of travel of the most closely adjacent non-resonant ions. To scan the mass spectrum it is only necessary to vary the frequency of the alternating field so

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that ions of a different mass-to-charge ratio will become in resonance therewith.

By reason of the nature of the paths of the non-resonant ions, these ions are retained in the space and accumulate indefinitely unless special provision is made for their removal. Prolonged accumulation of these ions may give rise to a space charge intense enough to affect adversely the operation of the instrument. Consequently, it is important to remove non-resonant ions from the analyzer region. The present invention is directed to that end.

Before describing the invention, it is necessary to consider in greater detail the nature of ion movement in the crossed magnetic and alternating electrical fields. It can be shown (see copending application Serial No. 177,502, filed August 3, 1950, now Patent No. 2,632,112 by Clifford E. Berry and Harold W. Washburn) that all ions of resonant mass starting at arbitrary times at the origin, and with no initial energy, lie in a roughly radial band where the electrical field E is given by the expression

$$E=E_0 \sin(\omega t+\theta) \quad (1)$$

E_0=the amplitude, or maximum absolute value of the electric field;
ω=the angular frequency of alternation;
t=time, and
θ=arbitrary phase angle.

The resonant ions orient themselves into a radial spoke with the axis of rotation coinciding with the axis of origin and such that ions contained in the spoke will absorb a maximum of energy from the field. Phase differences with respect to the time of formation are substantially eliminated within the first few revolutions of the spiral path. In practice where the origin may be anywhere along the ionizing electron beam, the ions may move parallel to the beam without altering their characteristic spiral paths and at any given instant all of the ions of resonant mass will lie in or near a radial plane intersecting the beam, the beam being the axis of origin as well as the axis of rotation.

Non-resonant ions; that is, ions whose charge to mass ratio does not satisfy the condition

$$q/m=\omega/B \quad (2)$$

where:

q=the charge of the ion;
m=the mass of the ion;
ω=the angular frequency of the alternating field, and
B=the transverse magnetic field.

will also move in bands. However, the non-resonant bands are curved and do not lie on a radius of the axis of origin as does the band of resonant ions.

The effect of initial energies in either the ions of resonant mass or non-resonant mass is to obscure or spread the boundaries of the respective band leaving its angular orientation unaffected. If a small D. C. field is maintained parallel to the electron beam to retain the ions in the space, ions formed at different points along the beam will have differences in initial energy. Only those ions formed at the midpoint of the beam will be at the zero point of the D. C. retaining field and these ions alone will have zero initial energy contributed by the fields. However, since a difference in initial energy has no effect on the angular orientation of the ions, they do not interfere with the practice of the present invention.

I have now discovered a method and apparatus for preventing excessive accumulation of non-resonant ions in the analyzing region based on the characteristic motion of the resonant and non-resonant ions and without adversely affecting the sensitivity of the instrument. In accordance with the invention, non-resonant ions are selectively removed from the analyzing region by dividing the region into two portions such that only one portion contains the resonant ions at the instant $\omega t=2n\pi$, where n is an integer representing the number of cycles of revolution, and periodically applying to the other portion of the analyzer region an electrical drift field to impel the ions lying in this portion out of the analyzer region. This drift field is applied only for a brief interval before and after $t=2n\pi/\omega$ during which time none of the resonant ions will come under the influence of the drift field. An important feature of the invention is that the drift field may be either parallel to or transverse to the A. C. field provided that it is established across only a portion of the analyzer chamber and only during a period in which no resonant ions are in that portion of the chamber. There results a selective and periodic removal of non-resonant ions without appreciable diminution of the number of resonant ions.

The invention also contemplates, in addition to the method described above for selectively removing non-resonant ions from the analyzer region, a mass spectrometer comprising an analyzer chamber having means for admitting a gas to be analyzed to the chamber and means for ionizing the gas in the chamber along an axis of the chamber. Means are provided for establishing a magnetic field across the chamber parallel to the axis of ionization and a high frequency alternating field across the chamber transverse to the magnetic field. A collector electrode is mounted adjacent a wall of the chamber in the path of the resonant ions, which, as explained above, travel in a spiral about the axis of origin and means are provided for periodically establishing a drift field in a portion of said chamber which does not include the axis of ion origin.

The invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings wherein:

Figs. 1A and 1B show graphically the orientation of resonant and non-resonant ions respectively at the condition $t=2n\pi/\omega$;

Fig. 2 is a diagram of one type of instrument together with associated electrical circuit for carrying out the method of the invention;

Fig. 3 is a graph of the electrical fields established in the analyzer region of the apparatus of Fig. 2;

Fig. 4 is an elevation of another form of apparatus for carrying out the invention;

Fig. 5 is a horizontal section taken on the line 5—5 of Fig. 4;

Fig. 6 is a more detailed illustration of a portion of the electrical circuit associated with the apparatus of Fig. 4; and

Fig. 7 is a graph of the electrical fields established in the analyzer region of the apparatus of Fig. 4.

In Figs. 1A and 1B, a section is taken on a plane transverse to the axis of the ionizing electron beam showing the orientation of the resonant and non-resonant ions at an instant $t=2n\pi/\omega$. At this instant the resonant ions having no initial energy will lie in a radial path A extending from electron beam 10. The radial band A rotates counter-clockwise about the beam 10. As shown in Fig. 1B, the non-resonant ions of zero initial energy at the same instant will be in curved bands C, C^1 the origin of the bands being at the electron beam as is the origin of the band A of resonant ions (Fig. 1A). These bands of non-resonant ions are in the form of circles which have diameters depending on the specific mass of the particles and which have the origin on their peripheries as shown.

The radial band of ions of resonant mass and the circular bands of non-resonant ions rotate above the axis, which is in this instance the electron beam, while maintaining the same relative relationship. Any given resonant ion in the band A will move out radially with respect to the axis during each cycle of rotation but will remain in the same radial plane. Non-resonant ions gradually proceed around the circular paths of Fig. 1B. Each of the bands A, C and C^1 is shown having a shaded border of appreciable thickness, the border representing resonant and non-resonant ions respectively having small initial energies. As stated above, these ions of small initial energies smear the boundaries of the paths but do not affect the configuration or orientation thereof.

Figs. 1A and 1B illustrate two important considerations in this type of mass spectrometry. Thus it is apparent from an examination of these figures that a collector electrode spaced from the electron beam a distance greater than the maximum radial extension of the band C of non-resonant ions will collect only the resonant ions in the radial band shown in Fig. 1A as these ions progress outwardly from the electron beam. It is also evident that at time $t=2n\pi/\omega$ a major portion of the non-resonant ions will be removed from the axis on which the resonant ions lie. It is this latter phenomenon which makes possible the practice of the present invention by periodically applying in one portion of the analyzer region a drift field to sweep ions out of this region during periods when resonant ions are not present in this region.

Because of the existence of resonant ions having small initial energies, the resonant band is not at any time entirely oriented on one side or the other of either the X or Y axes. As shown in Fig. 1A, although the resonant ions of zero initial energy are all above the X axis, some of the resonant ions of small initial energies are not. For this reason the portion of the analyzer chamber in which the aforementioned drift field is periodically applied preferably does not include the axis of origin and in preferred practice is spaced sufficiently far from the axis of origin so that substantially none of the resonant ions,

even those of small initial energies, come under the influence of the field.

Referring again to Fig. 1B, it will be seen that a small part of the non-resonant ions will always lie in the same portion of the analyzer region as do the resonant ions. Hence, a drift field applied in one portion of the analyzer region will not at any one time remove all of the non-resonant ions where that drift field is established so as to avoid the resonant ions. However, since the major portion of the non-resonant ions lie in a quadrant free of resonant ions, a majority of the non-resonant ions can be removed during each period of application of the drift field.

One form of apparatus is shown schematically in Fig. 2 for carrying out the invention. In this apparatus a plurality of grids 20 are spaced in parallel relationship in an analyzer region 22 more or less symmetrically about an electron beam 23. The electron beam is formed by an electron gun (not shown). The analyzer region 22 is arbitrarily divided into sections A and B located on opposite sides of the electron beam and each including three of the grids 20 identified respectively as grids 20A and 20B. An oscillator 26 is connected across the several grids 20, the grids being connected together through resistors 27 so that a uniform field is established between the outer-most grids. A square wave generator 30 is connected across the grids 20B in section B of the analyzer region through a vacuum tube isolation circuit 32. This circuit drives grids 20B in section B and prevents any surge from the square wave generator from feeding back through the oscillator 26 to the grids 20A in section A of the analyzer region. The oscillator 26 is connected through a trigger circuit 34 to trigger the square wave generator so that the pulse delivered thereby will be synchronized with the frequency of the A. C. field established across the region. To complete the apparatus, a magnetic field is established across the analyzer region parallel to the electron beam 23, i. e. perpendicular to the plane of the drawing by conventional means (not shown).

In Fig. 3, the nature of the electrical fields in sections A and B of the analyzer region are shown graphically. In section A, which does not receive any signal from the square wave generator, the field is in the nature of a simple alternating current sign wave illustrated by the trace 40. In section B the same alternating field is applied, and during the periods in which no pulse is delivered from the square wave generator the field is the same as in section A, as illustrated by the trace 42. However, when a square wave is delivered from the generator 30, the field in section B is driven strongly negative so that any ions present in this section are driven to and discharged at the envelope of the region (not shown).

It is, of course, essential to synchronize the output of the square wave generator with the oscillator so that a negative pulse will be delivered to the grids in section B only during intervals when no resonant ions are present in this section. This synchronization is accomplished by the trigger circuit 34 which may take any conventional form. One type of trigger circuit is described in greater detail with relation to Fig. 6. As is apparent from the foregoing description, the resonant ions will all be in section A of the analyzer region at an instant given by the expression $t=2n\pi/\omega$. At this instant the square wave generator is triggered and the negative pulses appearing in the trace 42 are impressed on the grids of section B and the non-resonant ions present in this section are impelled out of the region. Actually, the pulse is of a duration which overlaps the time $t=2n\pi/\omega$, the total elapsed time of the pulse, however, being less than the time which the band of resonant ions spends outside the limits of section B of Fig. 2. Attention is called to the fact that the drift field represented by the negative pulses in trace 42 of Fig. 3 is, in this embodiment, parallel to the alternating field and is in fact established by means of the same electrodes or grids as those on which the alternating field is impressed.

The invention is not limited to this condition and in fact a more practical form of apparatus is illustrated in Fig. 4 in which the drift field is parallel to the magnetic rather than the alternating field and is established by electrodes independent of the alternating field electrodes.

Referring to Figs. 4 and 5, the latter being a section taken on the line 5—5 of Fig. 4, the apparatus there shown includes an envelope 50 having an exhaust line 52 opening thereinto for evacuation of the system. A gas inlet 53 opens through a wall of the envelope 50 providing means for introducing a sample to be analyzed. A pair of semi-cylindrical electrodes 55, 56 are mounted adjacent each other in the envelope to define a cylindrical analyzer chamber 58. A sectioned electrode 60 is mounted at one end of the electrodes 55, 56 sections 60A, 60B thereof being insulated from each other and together defining one end of the analyzer chamber. A second sectioned electrode 61 is mounted at the opposite end of electrodes 55, 56 sections 61A, 61B thereof likewise being insulated from each other and together defining the opposite end of the analyzer chamber. The two electrodes 60, 61 are insulated from electrodes 55, 56 as by a small gap as shown. The sections of each electrode are shaped so that together they form a substantially circular electrode with the sections of each electrode being insulated from each other along a curvilinear line spaced from the central axis of the analyzer chamber. The corresponding sections of each electrode 60, 61 are similarly shaped and oriented so that the analyzer chamber is in effect divided into two longitudinal sections, i. e. longitudinal with respect to the axis of electrodes 55, 56 across which different types of fields may be impressed by the respective sections of each electrode.

A collector electrode 64 is mounted through a wall of semi-cylindrical electrode 55 and is insulated therefrom, the collector being connected to suitable amplification and recording means 65.

The electrodes 60, 61 are perforated on the vertical axis of the analyzer chamber as viewed in Fig. 4, and electron gun 68 is mounted outside the chamber adjacent one of these perforations 69 and an electron target 71 is mounted outside the chamber adjacent the opposite perforation 70 in electrode 60. The electron gun 68 is connected to a suitable source of power to develop an electron beam which is directed through the analyzer chamber and on the axis thereof to strike the electron target 71. Magnetic pole pieces 72, 73 are mounted adjacent opposite ends of the envelope 50 to develop a magnetic field across the analyzer chamber parallel to the electron beam. Although shown as separate elements, the magnetic pole pieces may actually form a part of the enclosing envelope.

An oscillator 76 is connected through a trans-

former 77 across electrodes 55, 56 whereby an alternating field having a wave form illustrated by the trace 78 is established across the analyzer chamber transverse to the magnetic field. A square wave generator 80 is connected across electrodes 60, 61 to develop on the electrode sections 60A and 61A a strong negative pulse at times and for intervals determined by a trigger circuit 82 connected between the oscillator 76 and the square wave generator 80. The trigger circuit 82 is designed to deliver triggering pips (see trace 84, Fig. 6) at uniform intervals synchronized with the wave pattern developed by the oscillator.

One possible type triggering circuit is illustrated diagrammatically in Fig. 6 which shows the oscillator 76 delivering an alternating current of wave form 78 and the square wave generator 80 delivering a wave 86. A signal from the oscillator is applied across a phase-shift network comprising a capacitor 87 and a variable resistor 88 whereby the phase of the signal 78 is altered as shown at 90. The phase of the signal may be controlled by variation in the value of resistor 88. The out of phase signal leads the output signal of the oscillator and is applied across a clipper in the nature of a biased rectifier which develops a signal 92. The clipper comprises rectifier elements 93, 94 and a bias battery 95 biasing the rectifier element 94. The signal 92 is differentiated in a differentiating circuit comprising a capacitor 96 and a resistor 97 to convert it into a series of pips as illustrated at 98. The signal represented by the trace 98 is applied across a rectifier element 100 which erases the negative pips of the trace 98 resulting in the signal 84. The signal 84 is fed to the square wave generator 80 triggering the generator to develop a wave form as shown by the trace 86.

The nature of the fields developed in the analyzer chamber by the several electrodes is shown graphically in Fig. 7. The high frequency alternating potential applied across the semi-cylindrical electrodes 55, 56 produces a field of the form shown by the sine wave 104 in the figure. The bias battery connected to bias the plate electrodes 60, 61 develops a small positive field shown by the trace 105, the field across the electrode sections 60A and 61A being uniform. The field developed between electrode sections 60B and 61B is affected by pulses applied across these electrodes from the square wave generator, this field being in substantially the form represented by the trace 106 of Fig. 7. Electrode sections 60B, 61B are conveniently connected to the square wave generator 80 through a divider 108 (Fig. 4) so that the magnitude of the pulses impressed on these sections can be varied at will.

The operation of the apparatus shown in Figs. 4 and 5 is as follows. With the envelope 50 evacuated, a sample to be analyzed is introduced through the inlet line 53 finding its way into the analyzer chamber by diffusion. As molecules of the sample intersect the electron beam traversing the analyzer chamber from the electron gun 63 to the electron target 70, the molecules are ionized. At the moment of ionization the ions become subject to the crossed magnetic and alternating fields and commence to move in a path about the axis of the electron beam. The shape of the path of the ion travel is, as described above, a function of the mass-to-charge ratio of these ions with those ions of resonant mass-to-charge ratio travelling in an ever-expanding spiral until they strike the collector electrode 64.

The small positive potential impressed on the electrodes 60, 61 repels ions from these electrodes so that ions formed anywhere along the electron beam other than at the center thereof will oscillate under the influence of the propelling potential back and forth across the transverse axis of the electron beam. However, this oscillation does not in any way affect their orbital paths around the electron beam nor the angular orientation at any given moment with respect to the beam. As explained in detail above, at a time $t=2n\pi/\omega$ all of the resonant ions will be in a radial band extending from the electron beam in the general direction parallel to the immediately previous direction of the electric field. At the same time the non-resonant ions will lie in a path, the major portion of which extends from the electron beam in a direction opposite that of the resonant ions. At this moment the square wave generator delivers a pulse to segments 60B, 61B of the plate electrodes so that these electrode segments strongly attract ions in the region bounded by these electrodes without having any effect on the resonant ions.

It is not essential that a drift field be established at each cycle of the alternating field, as is illustrated in Fig. 7. It is only necessary that each time a drift field is set up, it be at approximately the same relative time with respect to A. C. field. Referring again to Fig. 5 the drift field is established in the region between electrode section 61B and the corresponding electrode section 60B (see Fig. 4), which does not include the electron beam. This is for the reason that the band of resonant ions traverses the axis, as shown in Fig. 1, because of the presence of ions with small initial energies.

Although the apparatus of Figs. 4 and 5 is designed so that the drift field is applied in a region of the analyzer chamber generally opposite the collector electrode and excluding the axis of the electron beam, such need not be the case. Thus the configuration of the sections of each of electrodes 60, 61 may be altered so that the respective electrode of each pair which lies adjacent the collector electrode does not intersect the axis of the electron beam and the drift field may be applied across these electrodes at a time roughly approximating $t=(2n+1)/\pi/\omega$ at which time the band of resonant ions is on the side of the axis of rotation opposite the collector electrode, and the band of non-resonant ions is, for the most part, on the side of the axis of rotation nearest the collector electrode.

The important limitation of the invention is that the drift field be so synchronized with the A. C. field that as the frequency of the latter is changed, the periodicity of the negative pulse which develops the drift field is correspondingly changed so that it is applied across a region of the analyzer chamber only for an interval in which none of the resonant ions are in this region. As mentioned above, it does not matter where the drift field is applied, providing that it does not include the axis of rotation of the ions in the chamber since some of the resonant ions will overlap this axis. Moreover, the cross-section of the drift field is not important. It may have a substantially crescent shaped cross-section, as defined by electrode sections 60B, 61B (see Fig. 5) or it may constitute a true segment of a circle. Additionally, the shape of the A. C. electrodes 55 and 56 is not critical. These may be semi-cylindrical as shown so as to define a

substantially cylindrical analyzer region, or they may be channeled or flat.

It becomes obvious that many modifications may be made in the illustrated structure and in the described method materially affecting the practice of the invention, so long as the limitations set forth above are adhered to. For example, conventional means for adjusting the length and amplitude of the voltage pip delivered by square wave generator **80** of Fig. 4 may be incorporated without affecting the scope of the invention. One means of adjusting the amplitude of the applied pulse comprises the illustrated divider **108**.

I claim:

1. A mass spectrometer comprising an analyzer chamber, means for admitting gas to the chamber, means for ionizing the gas, means for establishing a magnetic field across said chamber, means for establishing a high frequency alternating electrical field across the chamber transverse to the magnetic field, a collector electrode mounted adjacent a wall of said chamber in the path of ions following orbital paths around an axis parallel to the magnetic field, and means for periodically establishing a drift field in a portion of said chamber to sweep ions from said portion.

2. A mass spectrometer comprising an analyzer chamber, means for admitting gas to the chamber, means for ionizing the gas in the chamber and along one axis of the chamber, means for establishing a magnetic field across the chamber parallel to said axis, means for establishing a high frequency alternating electrical field across the chamber transverse to the magnetic field, a collector electrode mounted adjacent a wall of said chamber in the path of ions following orbital paths around said axis, and means for periodically establishing a drift field in a portion of said chamber to sweep ions from said portion.

3. A mass spectrometer comprising an analyzer chamber, means for admitting gas to the chamber, means for directing an ionizing electron beam axially across the chamber to ionize the gas along an axis of the chamber, means for establishing a magnetic field across the chamber parallel to said axis, means for establishing a high frequency alternating electrical field across the chamber transverse to the magnetic field, a collector electrode mounted in the chamber in the path of ions following orbital paths around said axis, and means for periodically establishing a drift field in a portion of said chamber to sweep ions from said portion.

4. A mass spectrometer comprising an analyzer chamber, means for admitting gas to the chamber, means for directing an ionizing electron beam axially across the chamber to ionize the gas along an axis of the chamber, means for establishing a magnetic field across the chamber parallel to said axis, means for establishing a high frequency alternating electrical field across the chamber transverse to the magnetic field, a collector electrode mounted in the chamber and spaced from said axis in the path of ions following orbital paths around said axis, and means for periodically establishing a drift field in a portion of said chamber excluding said axis to sweep ions from said portion.

5. A mass spectrometer comprising an analyzer chamber, means for admitting gas to the chamber, means for ionizing the gas in the chamber and along one axis of the chamber, means for establishing a magnetic field across the chamber parallel to said one axis, means for establishing a high frequency alternating electrical field across the chamber transverse to the magnetic field, a collector electrode mounted in the chamber in the path of ions following orbital paths around said axis, a separate plate electrode mounted at each end of the chamber at opposite ends of said axis, each of said separate plate electrodes comprising a pair of sections insulated from each other, with the sections of one electrode conforming in shape and position about the axis to the sections of the other electrode, and means for periodically impressing a D. C. drift field between one section of one of said plate electrodes and the corresponding section of the other of said plate electrodes to sweep ions from the portion of said chamber defined by these sections of said plate electrodes.

6. Apparatus according to claim 5 wherein one section of each of said plate electrodes intersects said one axis of the chamber, and said means for periodically impressing a D. C. drift field between corresponding sections of each of said plate electrodes is connected across the other section of each of said plate electrodes.

7. Apparatus according to claim 6 wherein said other section of each of said plate electrodes is crescent shaped and partially encompasses said one axis of the chamber.

8. A mass spectrometer comprising an analyzer chamber, means for admitting gas to the chamber, means for ionizing the gas in the chamber and along one axis of the chamber, means for establishing a magnetic field across the chamber parallel to said one axis, means for establishing a high frequency alternating electrical field across the chamber transverse to the magnetic field, a collector electrode mounted in the chamber in the path of ions following orbital paths around said axis, a separate plate electrode mounted at each end of said axis, each of said plate electrodes comprising two sections insulated from each other, with the sections of one plate electrode corresponding in shape and orientation about said axis with the sections of the other plate electrode, and means for impressing a D. C. potential on the plate electrodes so that one corresponding section of each electrode is maintained at a positive potential and the other corresponding section is periodically at a negative potential of greater magnitude than the positive potential whereby ions are swept from that portion of the chamber defined by said other corresponding sections of the plate electrodes when these electrodes are at the negative potential.

9. A mass spectrometer comprising an analyzer chamber, means for admitting gas to the chamber, means for ionizing the gas in the chamber and along one axis of the chamber, means for establishing a magnetic field across the chamber parallel to said one axis, means for establishing a high frequency alternating electrical field across the chamber transverse to the magnetic field, a collector electrode mounted in the chamber in the path of ions following orbital paths around said axis, and a separate plate electrode mounted at each end of said axis, each of said plate electrodes comprising two sections insulated from each other, with the sections of one plate electrode corresponding in shape and orientation about said axis with the sections of the other plate electrode, and means for impressing a D. C. potential on the plate electrodes so that one corresponding section of each electrode is maintained at a positive potential and

the other corresponding section is periodically at a negative potential of greater magnitude than the positive potential whereby ions are swept from that portion of the chamber defined by said other corresponding sections of the plate electrodes when these electrodes are at the negative potential, and means for synchronizing the means for impressing a D. C. potential on the plate electrodes with the alternating field so that said other of said corresponding sections of the plate electrodes are at a negative potential only when no ions of a mass-to-charge ratio in resonance with the alternating field are present in that portion of the chamber defined by said other corresponding sections of the plate electrodes.

10. Apparatus according to claim 8 including means for varying the amplitude of the D. C. potential impressed on said plate electrodes.

11. A mass spectrometer comprising an analyzer chamber, means for admitting gas to the chamber, means for ionizing the gas, means for establishing a magnetic field across the chamber, means for establishing a high frequency alternating electrical field across the chamber transverse to the magnetic field, a collector electrode mounted in the chamber in the path of ions following orbital paths around an axis parallel to the magnetic field, and means independent of the collector electrode for periodically removing ions from a portion of the chamber.

12. A mass spectrometer comprising an analyzer chamber, means for admitting gas to the chamber, means for ionizing the gas, means for establishing a magnetic field across the chamber, means for establishing a high frequency alternating electrical field across the chamber transverse to the magnetic field, whereby under the influence of such fields the ions are caused to travel in spiral paths about the axis of symmetry of the alternating field, influence means electrically energizable to remove substantially all the ions from a portion of the chamber, and electrical means operable to energize the influence means at predetermined intervals.

No references cited.