Jan. 24, 1956 I. H. McLAREN ET AL 2,732,500

ION SOURCE

Filed April 18, 1951 2 Sheets-Sheet 1

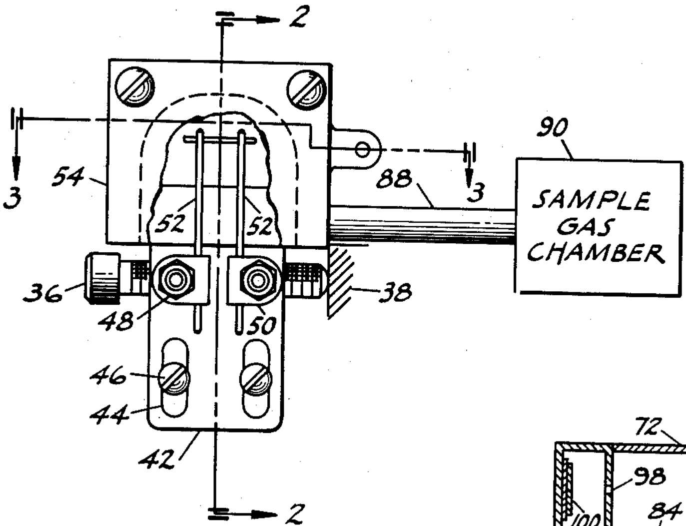

FIG. 1

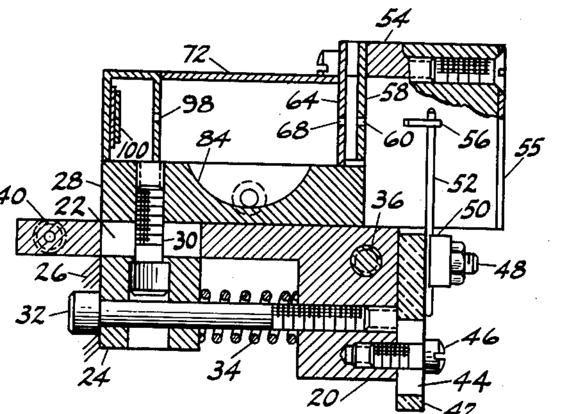

FIG. 2

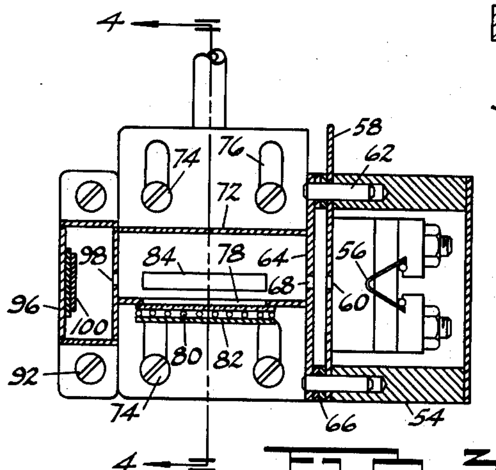

FIG. 3

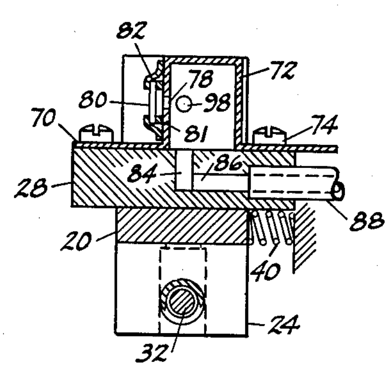

FIG. 4

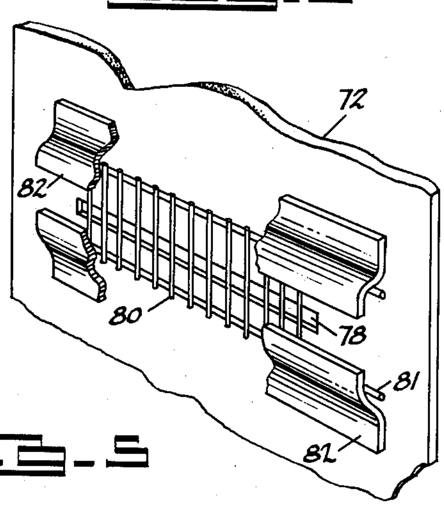

FIG. 5

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ION SOURCE

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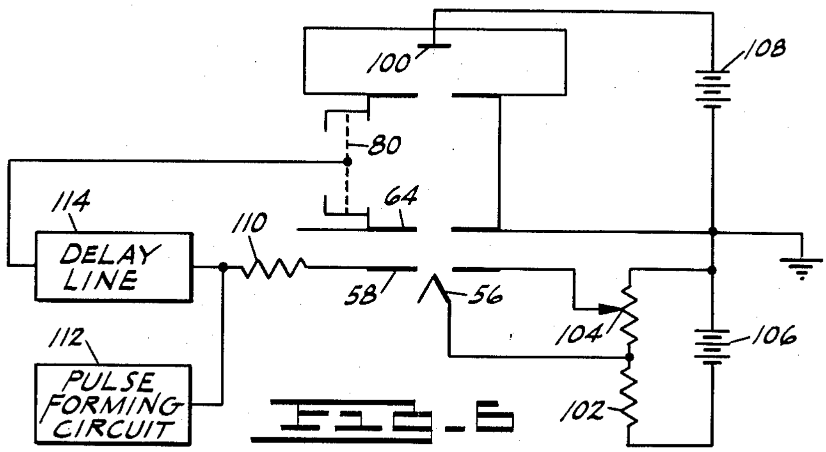

FIG. 6

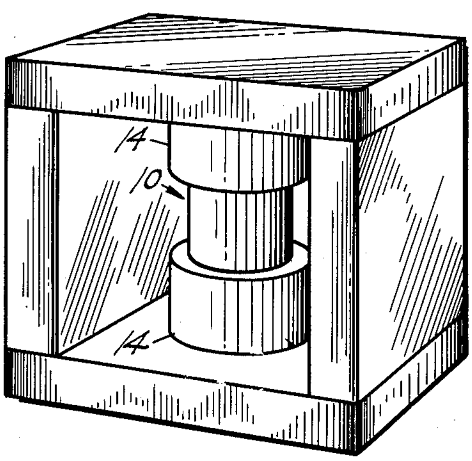

FIG. 8

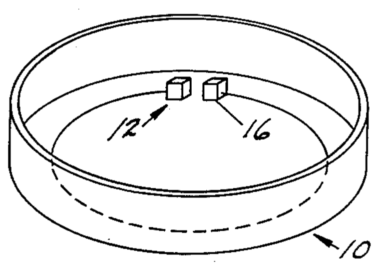

FIG. 7

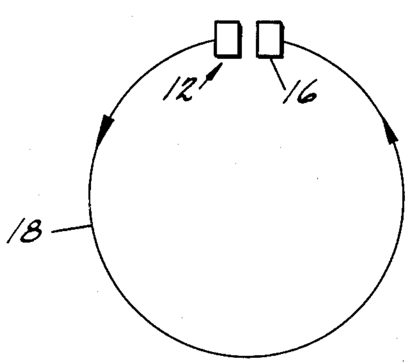

FIG. 9

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2,732,500

Patented Jan. 24, 1956

2,732,500

ION SOURCE

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Application April 18, 1951, Serial No. 221,554

21 Claims. (Cl. 250—41.9)

This invention relates to apparatus for, and methods of, producing a beam of ions and more particularly to apparatus for, and methods of, producing a beam of ions in pulse form. The invention is especially adapted for use in conjunction with a mass spectrometer to produce pulses of ions from the gases in an unknown mixture.

A mass spectrometer is known which has a magnetic field of constant strength to rotate ions of different mass through circular paths of one or more complete revolutions. As they rotate, the ions of relatively small mass travel faster than the ions of larger mass. Thus, the ions arrive at a collector assembly at times directly dependent upon their mass. By measuring the times of flight of the different ions, the mass of the ions can be easily determined.

Since the masses of different ions are measured on the basis of their time of flight, a continuous supply of ions to the mass spectrometer would prevent a physical separation between the ions of different mass. Because of this, pulses of ions must be produced in order for the spectrometer to operate properly. The ion sources now being used to produce pulses of ions for introduction to the mass spectrometer do not operate entirely satisfactorily. For example, the pulses produced by the ion sources now in use are not sharply delineated and are relatively weak. As a result, they hinder clear-cut and precise measurements of mass from being made by the spectrometer.

This invention provides an ion source which produces pulses of ions having strengths far in excess of the pulse strengths produced by the sources now in use. In addition to producing pulses having relatively large numbers of ions, the source also concentrates the ions in each pulse into a clearly defined space so that each pulse of ions is sharply delineated with respect to all other pulses. Concentrating the ions in each pulse into a small space also increases the accuracy in the operation of the spectrometer into which the ions may be introduced.

An object of this invention is to provide an ion source for producing sharply delineated pulses of ions.

Another object of the invention is to provide an ion source of the above character for producing ion pulses having a maximum strength.

A further object is to provide an ion source of the above character for concentrating a maximum number of ions into a minimum space to produce a sharp and strong pulse.

Still another object is to provide a method of producing strong and sharply defined pulses of ions.

Other objects and advantages will be apparent from a detailed description of the invention and from the appended drawings and claims.

In the drawings:

Figure 1 is a side elevational view, as seen from the right side, of an ion source constituting one embodiment of the invention and of a sample chamber for introducing gases to the ion source for the production of ions;

Figures 2 and 3 are sectional views substantially on

the lines 2—2 and 3—3, respectively, of Figure 1, illustrating the ion source in further detail;

Figure 4 is a sectional view substantially on the line 4—4 of Figure 3;

Figure 5 is a perspective view illustrating the grid for withdrawing the ions in pulses from the ion source;

Figure 6 is a simplified diagram of the electrical circuit used to apply the proper voltages to the various grids in the ion source shown in the previous figures;

Figure 7 is a perspective view illustrating a mass spectrometer with which the ion source shown in the previous figures may be used and further illustrating the relative position of the ion source in the spectrometer;

Figure 8 is a perspective view showing particular features of the spectrometer illustrated in Figure 7 in further detail; and

Figure 9 is a schematic diagram illustrating a representative travel path followed in the spectrometer by the ions which are produced by the ion sources.

A mass spectrometer, generally illustrated at **10** in Figures 7 and 8, is adapted to receive pulses of ions from an ion source, generally indicated at **12** and illustrated in detail in Figures 1 to 5, inclusive. The mass spectrometer **10** is in general cylindrically shaped and is disposed between opposite poles of a magnet **14** (Figure 8) which is adapted to provide a magnetic field of uniform strength axially along the length of the cylinder. The ion source **12** and a collector assembly **16** (Figures 7 and 9) are both disposed within the spectrometer in relatively close angular relationship to each other and in closely aligned axial relationship to each other, for reasons which will be explained in detail hereinafter.

The source **12** operates upon the different gases constituting an unknown mixture to produce ions from the gases. Each ion has a mass which is proportionate to the mass of the gas from which it is produced. The ions are given an initial velocity by the source **12** and are then emitted from the source in a direction perpendicular to the magnetic field created by the magnet **14**. This causes the magnetic field to exert a force upon the ions in a direction perpendicular to the direction of ion travel and the ions to describe a circular path, as illustrated at **18** in Figure 9.

Since the emitting force exerted by the ion source **12** is substantially constant, this force has a greater effect upon the ions of relatively light mass than upon the ions of relatively heavy mass. Thus, each ion is given an initial acceleration which is substantially inversely proportional to its mass. Or

$$a=\frac{K}{M}$$

where

a=the acceleration at which an ion leaves the source **10**;
M=the mass of the ion; and
K=a constant.

Because of their greater initial acceleration, the ions of relatively low mass rotate through a complete revolution faster than the ions of relatively heavy mass and reach the collector plate **16** before the ions of heavy mass. By measuring the time required for the ions to describe one or more substantially complete revolutions, the masses of the different ions can be determined. The abundance ratio of the different constituents in the unknown mixture can also be determined by measuring the relative amplitudes of the signals produced at the collector plate **16** by the ions formed from each constituent in the mixture.

In order to measure the times of flight required for ions of different mass, pulses of ions must be provided by the ion source 12, which includes a base 20 (Figure 2) having a relatively thin portion slotted as at 22. A block 24 suitably secured to a wall as at 26 is positioned below the thin portion of the base 20 and a pedestal 28 is supported on top of the base. The block 24 and pedestal 28 have vertical bores which are aligned with the slot 22, and a bolt 30 extends through the bores and the slot to secure the pedestal and block to the base. Because of the slot 22, the base 20 may be moved relative to the block 24 and the pedestal 28. For example, the base 20 may be moved to the left or right in Figure 2 and also, the base may be pivoted about the bolt 30 which is fixedly held by the block 24.

Horizontally aligned bores are also provided in the block 24 and in the thick portion of the base 20 so that a bolt 32 may extend through the bores. The bolt 32 supports a spring 34 in compression between the block 24 and the base 20. A second bolt 36 (Figures 1 and 2) extends through a threaded bore in the thick portion of the base 20 and presses against a wall 38. A compressed spring 40 (Figures 2 and 4) helps to press the bolt 36 against the wall 38 since the base 20 pivots about the bolt 30.

An insulating plate 42 (Figures 1 and 2) slotted as at 44 is secured to the base 20 as by screws 46. Screws 48 extend into the plate 42 and press against the plate a clamp 50 holding filament leads 52. The leads 52 extend upwardly into a housing 54 suitably closed at one end by a plate 55. The leads are connected within the housing 54 to a wedge-shaped strip 56 of tungsten, which serves as a filament for the emission of electrons.

A control grid 58 (Figures 2 and 3), made from a sheet of suitable conductive material such as brass and having a centrally disposed hole 60, is secured as by glass studs 62 to the housing 54 at the opposite end of the chassis from the plate 55. The studs 62 also support an electron accelerator grid 64 which is also made from brass and which is spaced from the control grid 58 as by mica washers 66. A hole 68 is centrally provided in the electron accelerator grid 64 in alignment with the hole 60 in the control grid 58.

The control grid 58 and acceleration grid 64 are disposed above the pedestal 28. Flanges 70 (Figures 3 and 4) on a substantially U-shaped casing 72 are supported as by studs 74 in the pedestal 28 and are provided with elongated holes 76 for slidable positioning relative to the pedestal 28. A slot 78 is provided in one side of the cover 72 and an ion accelerator grid 80 (Figures 4 and 5) is provided in juxtaposition to the slot 78. The grid 80 includes a plurality of equally spaced copper wires vertically supported between two rods 81, the rods in turn being pinned against the casing 72 by brackets 82 and being suitably insulated from the casing.

A semi-cylindrical groove 84 (Figures 2, 3 and 4) is provided in the top of the pedestal 28 in longitudinal alignment with the holes 60 and 68 in the grids 58 and 64, respectively. The groove 84 communicates with a hole 86 (Figure 4) which extends through the pedestal 28 in a transverse direction relative to the groove and which in turn communicates with a pipe 88 push fit into the base. The pipe 88 and the hole 86 provide a continuous circuit for the flow of fluid between the groove 84 and a sample chamber 90 (Figure 1) containing the different gases in an unknown mixture.

Studs 92 (Figure 3) also fit into the pedestal 28 and support flanges extending from a casing 96. One side of the casing 96 has a hole 98 aligned with the holes 60 and 68 in the grids 58 and 64, respectively. The opposite side of the casing has a collector plate 100 secured to it in insulated relationship.

The circuit shown in Figure 6 applies the proper voltages to the filament 56, the grids 58, 64 and 80 and the collector plate 100. The circuit includes a resistance 102 and a potentiometer 104 in series with a suitable power supply, such as a battery 106, the positive terminal of which is grounded. The filament 56 is connected to the common terminal between the resistance 102 and potentiometer 104, the control grid 58 to the movable contact of the potentiometer 104, and the accelerator grid 64 to the grounded positive terminal of the battery 106. In practice, approximately −90 volts may be applied to the filament 56 and approximately −70 volts to the control grid 58. The collector plate 100 is connected to the positive terminal of a suitable power supply, such as a battery 108, supplying approximately +30 volts. The negative terminal of the battery 108 is grounded.

In addition to being connected to the movable contact of the potentiometer 104, the control grid 58 is also connected through a resistance 110 to the output terminal of a pulse forming circuit 112 so as to receive at predetermined times a pulse of approximately −100 volts and approximately 1 microsecond or less in length. The output pulse from the circuit 112 is also introduced through a suitable delay line 114 to the ion accelerator grid 80, which receives a pulse of approximately −200 volts, preferably at approximately the same time as the introduction of a pulse to the control grid 58 as will be disclosed in detail hereinafter.

Before the emission of any ions from the source 12, the filament 56 is adjusted in position relative to the control grid 58 and the electron accelerator grid 64. The distance of the filament from the grids 58 and 64 is controlled by the bolt 32. For example, when the bolt 32 is turned in a clockwise direction, it moves the base 20 to the left in Figure 2 and brings the filament 56 closer to the control grid 58. In like manner, the lateral position of the filament 56 relative to the holes 60 and 68 in the grids 58 and 64, respectively, can be varied by rotating the bolt 36. For example, the filament moves towards the right in Figure 1 when the bolt 36 is turned in a clockwise direction, since the thick portion of the base 20 will move away from the wall 38 and the insulating plate 42 will move with the base and carry the filament 56 with it. The actual movement of the filament 56 will be along an arc since the base 20 pivots on the bolt 30. Because of the slight adjustments required in the lateral positioning of the filament 56, its movements along the arc are small and are substantially straight-line movements. The vertical position of the filament relative to the holes 60 and 68 can be adjusted by loosening the screws 46 and moving the insulating plate 42 upwardly or downwardly before the screws are tightened.

After the filament 56 has been properly positioned relative to the grids 58 and 64, it is heated by current flowing through it and the leads 52 to a temperature which produces an emission of electrons. The electrons are attracted towards the control grid 58 by the voltage on the grid and are concentrated into a narrow beam by the hole 60 in the grid. After passing through the hole 60 in the grid 58, the electrons are accelerated towards the collector plate 100 by the voltages on the accelerator grid 64 and on the collector plate and are further concentrated into a narrow beam by the hole 68 in the accelerator grid and the hole 98 in the casing 96. Since the voltages on the control grid 58, the accelerator grid 64 and the collector plate 100 become progressively positive, the electrons increase in speed as they travel from the filament to the collector plate. A magnetic field may be applied in the same direction as the electron flow to assist in forming and maintaining a thin stream of electrons.

As the electrons travel through the space above the groove 84, they collide with gas molecules flowing from the sample chamber 90 through the pipe 88 and upwardly into the groove. Because of their relatively high speed, the electrons strike some of the gas molecules with sufficient force to produce ionization of these molecules. Since most of these ions have a positive charge and the electrons have a negative charge, the ions are retained in the potential well created by the electron stream. This potential well initially has a large negative potential because of the relatively large number of electrons flowing towards the collector plate **100** and thus is able to retain a relatively large number of ions before its potential is neutralized.

As the number of ions in the potential well approaches saturation, the electron stream is cut off, preferably by applying a negative pulse of approximately −100 volts on the control grid **58** from the pulse forming circuit **112** (Figure 6). Since only the ions remain in the space above the groove **84** after the cut-off of the electron stream, a strong electric field of positive potential is created. Upon the application of a negative pulse of approximately −200 volts on the ion accelerator grid, a potential difference is produced between the ion field and the grid **80** to provide a strong attraction of the ions towards the grid. This causes the ions to travel in a pulse or bunch towards the ion accelerator grid and beyond the grid into the magnetic field of the mass spectrometer shown in Figures 7 and 8. As previously disclosed, the ions of different mass in each pulse become separated as they describe a circular path in the spectrometer and reach the collector assembly **16** (Figure 7) at different times, the times of flight providing an indication of the mass of the ions.

The negative pulse of approximately −200 volts is preferably applied on the ion accelerator grid **80** at approximately the same time as the electron stream from the filament **56** is cut off. It may also be applied shortly after the cut-off of the electron stream, and it may sometimes even be applied shortly before the introduction of a pulse to the control grid **58**. As previously disclosed, a negative pulse is preferably applied to the control grid **58** to return the electrons to the filament **56**, but a positive pulse may also be applied to the grid **58** to collect the electrons at the grid. The filament **56** may also be normally maintained at approximately ground potential to prevent the flow of any electrons and may be pulsed to a negative potential at such times as pulses of electrons are desired. The polarity of the pulse applied to the control grid **58** and the relative timing between the pulses on the control grid and on the ion accelerator grid **80** are somewhat dependent on the use which is made of the pulses of ions. In other words, the pulse polarities and time relationships are dependent somewhat upon whether the ion pulses are used in a mass spectrometer or in some other application.

The ion source disclosed above has several important advantages. By retaining the ions which are produced within the potential well created by the electron stream, the number of ions held within a relatively small space is greatly increased over the capacity of equipment now in use. Suddenly cutting off the pulse stream makes this vast reservoir of ions available in pulse form to apparatus such as a mass spectrometer. For example, we have found that the number of ions retained within the potential well created by the electrons is approximately 1,000 to 1,000,000 times greater than the number of ions which would normally be in the same space if no potential well existed. This increase in the number of ions facilitates the measurement of the ion masses in a spectrometer and materially alleviates any difficulty in the design of amplifiers and other equipment associated with the spectrometer.

The potential well created by the electron stream may be made as narrow as desired by varying the cross-sectional areas of the holes **60** and **68** in the control grid **58** and the ion accelerator grid **64**, respectively. Producing a narrow potential well is desirable since it in turn causes an ion pulse of relatively short length to be produced. When introduced to a mass spectrometer, an ion pulse of short length facilitates a sharp differentiation between the pulses of different mass.

As previously disclosed, the control grid **58** and ion accelerator grid **80** are usually pulsed when the number of

ions in the potential well approaches saturation. The grids may be pulsed at a constant frequency, such as 100 times per second, or may be pulsed for only a few times. A multiple number of pulses, rather than one pulse, is preferably produced when the ion source is used in conjunction with a mass spectrometer to facilitate visual inspection of the pulses on an oscilloscope and to average out statistical fluctuations in pulse amplitudes if present.

Although this invention has been disclosed and illustrated with reference to particular applications, the principles involved are susceptible of numerous other applications which will be apparent to persons skilled in the art. The invention is, therefore, to be limited only as indicated by the scope of the appended claims.

What is claimed is:

1. An ion source, including, means for forming an electron stream, means for introducing a plurality of molecules into the electron stream for ionization by the electrons and for retention in the potential well created by the electron stream, means for cutting off the electron stream, and means for imposing a pulsed force upon the ions at a predetermined time relative to the cutting off of the electron stream to remove the ions in a pulse from the potential well.

2. An ion source, including, means for forming an electron stream, means for introducing a plurality of molecules into the electron stream for ionization by the electrons and for retention in the electric field created by the electron stream, means for periodically cutting off the electron stream, and means for applying a pulsed field upon the ions at a predetermined time relative to each cutting off of the electron stream to remove the ions in a pulse from the area defined by the electron stream.

3. An ion source, including, means for producing a plurality of electrons, means for channeling the electron flow, means for introducing a plurality of molecules into the electron channel for ionization by the electrons and for retention in the electron channel, means for cutting off the flow of electrons when the number of ions in the electron channel approaches saturation, and means for applying an electric field of brief duration upon the ions at a predetermined time relative to the cutting off of the electron flow to remove the ions in a bunch from the electron channel.

4. An ion source, including, means for producing an electron stream, means for introducing molecules of the different gases in an unknown mixture into the stream for ionization by the electrons in the stream and for retention in the potential well created by the electron stream, means for considerably reducing the strength of the electron stream, and means for subjecting the ions to a pulsed electric field to withdraw the ions in a bunch from the potential well at a predetermined time relative to the reduction in the strength of the electron stream.

5. An ion source, including, means for producing a plurality of electrons, means for channeling the electron flow, means for introducing into the electron channel molecules of the different gases in an unknown mixture for ionization by the electrons in the channel and for retention in the electron channel, means for cutting off the flow of electrons at predetermined times, and means for subjecting the ions to a pulsed field at approximately each cut-off of the electron flow for withdrawing the ions in a bunch from the channel.

6. An ion source, including, a filament adapted to emit a plurality of electrons, a control grid spaced from the filament and having a voltage to attract the electrons from the filament, there being a hole in the control grid to pass the electrons in a directed stream, a collector plate for receiving the stream of electrons, means for directing into the electron stream a plurality of molecules of the different molecules in an unknown mixture for ionization by, and retention in, the electron stream, means for applying a voltage pulse between the control grid and the filament to cut off the electron stream, an ion accelerator grid

transversely disposed relative to the control grid, and means for applying a voltage pulse on the ion accelerator grid at a predetermined time relative to the pulse on the control grid to withdraw the ions in a bunch.

7. An ion source, including, a filament adapted to emit a plurality of electrons, a control grid spaced from the filament, an electron accelerator grid spaced from the control grid, there being holes in the control and accelerator grids in alignment with the filament to create a beam of electrons, a collector plate spaced from the electron accelerator grid in alignment with the grid, means for applying voltages on the filament, the control and accelerator grids and the collector plate to produce an accelerated travel of the electrons towards the collector plate, means for introducing a plurality of molecules into the potential well created by the electron beam for ionization by the beam and for retention within the space occupied by the beam, an ion accelerator grid disposed in transverse relationship to the electron accelerator grid, means for applying a voltage pulse between the control grid and the filament to cut off the flow of electrons to the collector plate, and means for applying a voltage pulse to the ion accelerator grid at a predetermined time relative to the application of the voltage pulse on the control grid to attract the ions in a bunch from the potential well towards the ion accelerator grid.

8. An ion source, including, means for forming a plurality of electrons, a collector, means for directing the electrons in a stream towards the collector, means for producing a plurality of ions and for storing the ions in the electron stream, means for reducing the strength of the electron stream, and means for subjecting the ions to a pulsed field to withdraw the ions in a pulse in a direction transverse to that of the electron stream.

9. An ion source, including, a filament for emitting a plurality of electrons, a collector for receiving the electrons emitted from the filament, a backing plate, a grid disposed relative to the backing plate to hold the electron stream between it and the plate, means for introducing a plurality of molecules into the region between the plate and the grid for ionization by the electron stream and for retention of the ions within the stream, means for reducing the strength of the electron stream, and means for applying a pulsed field between the backing plate and the grid upon the reduction in the strength of the electron stream to impose an accelerating force upon the ions for the withdrawal of the ions in a pulse from their place of retention.

10. An ion source, including, a filament for emitting a plurality of electrons, a collector for receiving the electrons emitted from the filament, a backing plate, a grid disposed in substantial alignment with the backing plate and on the opposite side of the electron stream relative to the backing plate, means for introducing a plurality of molecules into the region between the plate and the grid for ionization by the electron stream and for retention of the ions within the stream, means for reducing the strength of the electron stream, and means for applying a voltage pulse to the grid upon the reduction in the strength of the electron stream to impose an electric field between the plate and the grid for the withdrawal of the ions in a pulse from their place of retention.

11. An ion source, including, means for forming a plurality of electrons, means for channeling the electron flow, means for introducing into the electron channel molecules of the different gases in an unknown mixture for ionization by the electrons in the channel and for retention in the channel, means for reducing the strength of the electron channel, and means operative upon the reduction in the strength of the electron channel to impose a pulsed electric field upon the ions for the withdrawal of the ions in a pulse from their place of retention.

12. An ion source, including, means for forming a plurality of electrons, means for channeling the electrons into a stream, means for introducing a plurality of molecules into the electron stream for ionization by, and retention within, the stream, means for reducing the strength of the stream, and means for imposing an accelerating force on the ions for a short period of time, upon the reduction in the strength of the stream, to withdraw the ions in a pulse from their place of retention.

13. An ion source, including, a filament for emitting a plurality of electrons, a collector for receiving the electrons emitted from the filament, a first grid for accelerating the electrons towards the collector and for confining them in a narrow stream, a backing plate, a second grid disposed on the far side of the electron stream from the backing plate, means for introducing a plurality of molecules into the electron stream for ionization by the electrons and for retention of the ions within the stream, means for reducing the strength of the electron stream, and means operative upon the reduction in the strength of the electron stream to impose pulses of voltage on the backing plate and the second grid to withdraw the ions in a pulse from their place of retention.

14. An ion source, including, means for producing a plurality of electrons, means for channeling the electron flow, means for introducing into the electron channel molecules of the different gases in an unknown mixture for ionization by the electrons in the channel and for retention of the ions in the channel, means for considerably reducing the flow of electrons periodically, and means for subjecting the ions to a pulsed electric field at approximately each reduction in the flow of electrons to withdraw the ions in a bunch from their place of storage and in a direction transverse to that of the electron channel.

15. An ion source, including, a filament for emitting a plurality of electrons, a collector for receiving the electrons emitted from the filament, a first grid for channeling the flow of electrons into a beam, means for introducing a plurality of gas molecules into the electron beam for ionization by the beam and for retention in the beam, a backing plate disposed in substantially parallel relationship to the beam, a second grid disposed in substantially parallel relationship to the backing plate on the other side of the beam with respect to the backing plate, means for cutting off the electron beam, and means for applying voltage pulses to the second grid upon the cut-off of the electron beam to withdraw the ions in a pulse from their place of retention and in a direction substantially perpendicular to the beam.

16. An ion source, including, means for forming a plurality of electrons, means for channeling the electron flow, means for introducing a plurality of molecules into the channel for ionization by the electrons in the channel and for retention in the channel, and electrical circuits for reducing the strength of the electron channel and for imposing a pulsed electric field upon the ions for the withdrawal of the ions in a pulse from their place of retention.

17. An ion source, including, a filament for emitting a plurality of electrons, a first grid for accelerating the electrons and for confining them in a narrow stream, a backing plate disposed on one side of the electron stream, a second grid disposed on the other side of the electron stream, means for introducing a plurality of molecules into the electron stream for ionization by the electrons and for retention of the ions within the stream, and electrical circuits for reducing the strength of the electron stream and for imposing pulses of voltage on the backing plate relative to the voltage on the second grid to withdraw the ions in a pulse from their place of retention.

18. An ion source, including, a filament for emitting a plurality of electrons, a collector for receiving the electrons, a first grid for accelerating the electrons towards the collector and for confining them in a narrow stream, a backing plate disposed on one side of the electron stream, a second grid disposed on the other side of the electron stream, means for introducing a plurality of

molecules into the electron stream for ionization by the electrons and for retention of the ions within the stream, and electrical circuits for reducing the strength of the electron stream and for producing a pulsed electric field between the backing plate and the second grid to withdraw the ions in a pulse from their place of retention.

19. An ion source, including, a filament for emitting a plurality of electrons, a first grid for channeling the flow of electrons into a beam, means for introducing a plurality of molecules into the electron beam for ionization by the beam and for retention of the ions in the beam, a backing plate disposed on one side of the electron beam and in substantially aligned relationship to the beam, a second grid disposed on the other side of the electron beam and in substantially aligned relationship with the beam, and electrical circuits for cutting off the electron beam and for imposing a pulse of voltage on the second grid relative to the backing plate to withdraw the ions in a pulse from their place of retention after the interruption of the beam and in a direction substantially perpendicular to the beam.

20. An ion source, including, means for forming an electron stream in a substantially field free region, means for introducing a plurality of molecules into the electron stream for ionization by the electrons and for retention of the ions in the potential well created by the electron stream, means for cutting off the electron stream upon the

retention of a particular amount of ions in the potential well created by the electron stream, and means for subjecting the ions to a pulsed field at a particular time relative to the cutting off of the electron stream to produce a movement of the ions in a pulse from their place of retention.

21. An ion source, including, means for forming an electron stream in a substantially field free region, means for introducing a plurality of molecules into the electron stream for ionization by the electrons and for retention of the ions in the potential well created in the field free region by the electron stream, means for considerably reducing the strength of the electron stream, and means for applying to the ions a pulsed electric field at a particular time after the reduction in the strength of the electron stream to produce a movement of the ions in a pulse from their place of retention.

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