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MASS SPECTROMETER

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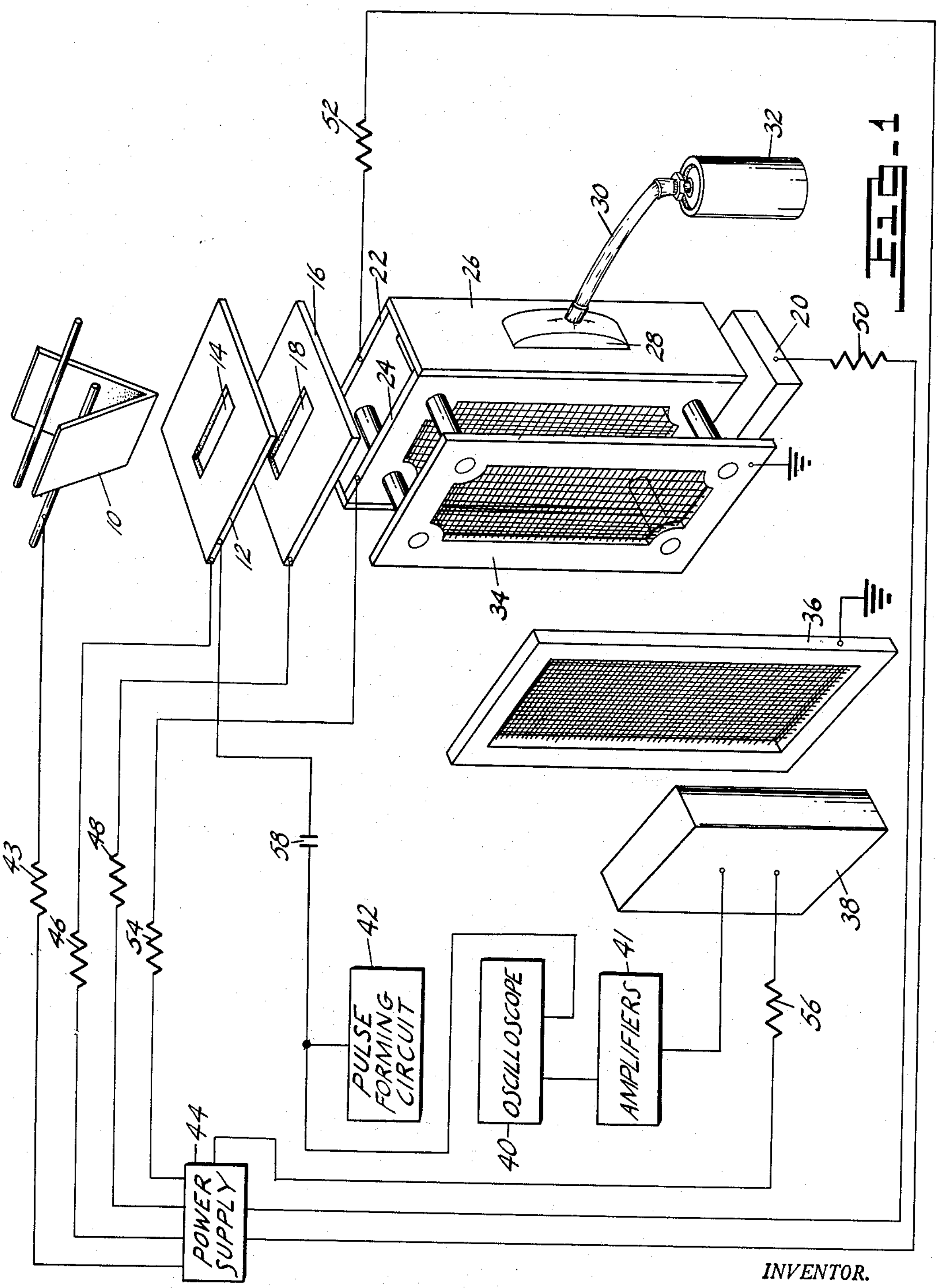

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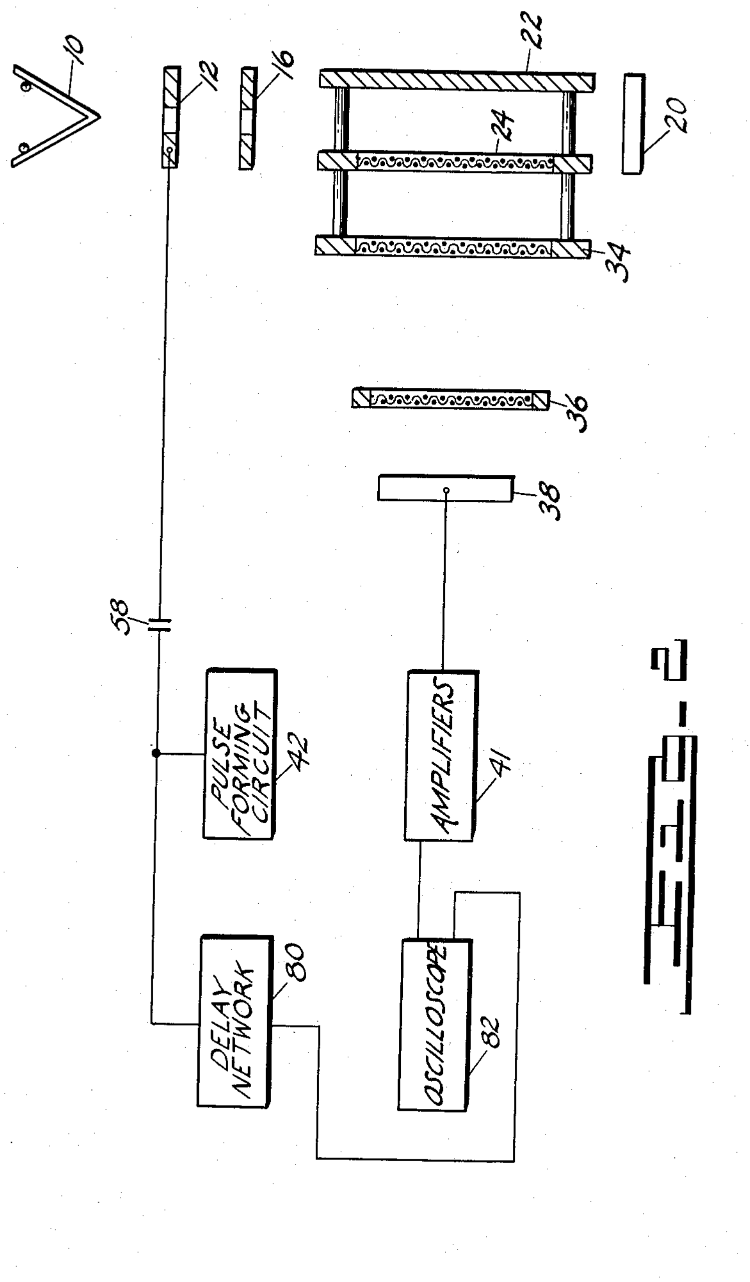

FIG. 2

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MASS SPECTROMETER

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13 Claims. (Cl. 250—41.9)

This invention relates to mass spectrometers and, more particularly, to mass spectrometers for operating in a simple manner to determine the masses of different ions by measuring the time required for the ions to travel through a predetermined distance. The invention also relates to methods of determining the masses of different ions.

In some types of mass spectrometers, pulses of ions are utilized to determine the masses of the different gases or vapors in an unknown mixture and the relative abundance of the gases and vapors in the mixture. The pulses of ions are accelerated by a force for movement through a predetermined distance. Because of this force, the ions of relatively light mass attain a greater velocity than the ions of heavy mass and travel through the predetermined distance before the ions of heavy mass. By indicating the relative times at which the ions of different mass travel through the predetermined distance, the masses of the ions can be determined.

Until now, pulses of ions have been formed by the application of pulses of voltage on electrodes which control the movements of the ions. Because of the application of voltage pulses on the ion-accelerating electrodes, a certain amount of instability has been inherent in the operation of the time-of-flight mass spectrometers. Such instability occurs because it is difficult to produce successive voltage pulses having the same amplitude and shape and, therefore, the acceleration provided by each pulse is different. This instability has prevented the full capabilities of the time-of-flight mass spectrometers from being realized to distinguish between the masses of different ions over a wide range of masses.

This invention provides a mass spectrometer for producing pulses of ions by ionizing molecules of gas at periodic intervals. The mass spectrometer includes ion-accelerating electrodes which have direct voltages imposed on them to accelerate the ions a moderate amount in a first region and a considerable amount in a second region to produce a separation of the ions on the basis of their mass and a collection of the ions at a focal distance from the regions. By imposing direct voltages on the electrodes controlling the movements of the ions, a relatively stable operation is provided in the mass spectrometer such that a relatively sharp delineation between ions of different mass is obtained. Since direct voltages are imposed on the ion-accelerating electrodes, the electrical system forming a part of the mass spectrometer is also considerably simplified.

An object of this invention is to provide a mass spectrometer for determining the masses of the different gases and vapors in an unknown mixture by measuring the times required for ions formed from the gases to travel through a predetermined distance.

Another object is to provide a mass spectrometer of the above character for producing pulses of ions and for imposing constant forces on the ions to produce a separation of the ions on the basis of the masses of the ions during the movement of the ions through a predetermined distance.

A further object is to provide a mass spectrometer of the above character which is more stable in operation than the time-of-flight mass spectrometers now in use.

Still another object is to provide a mass spectrometer of the above character requiring the use of relatively simple electrical components to provide a relatively sharp delineation between ions of different mass.

A still further object is to provide a method of producing pulses of ions and of separating the different ions in each pulse on the basis of their mass so as to determine the masses of the 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 somewhat schematic view, partly in block form and partly in perspective, illustrating the mechanical and electrical features which together constitute one embodiment of the invention; and

Figure 2 is a somewhat schematic view, partly in block form and partly in vertical section, illustrating a modification of the invention for detecting ions of a particular mass.

In the embodiment of the invention shown in Figure 1, a filament **10** made from a suitable material such as tungsten is provided. The filament has the shape of a wedge in a substantially vertical plane as seen in Figure 1 and has a relatively great width, such as 2.5 centimeters. A control electrode **12** is disposed at a relatively close distance to the filament **10** and is provided with a horizontal slot **14** aligned with the tip of the filament **10** along the complete width of the filament.

An accelerating electrode **16** having a slot **18** corresponding substantially in shape and position to the slot **14** is positioned in substantially parallel relationship with the electrode **12**. The electrode **16** is separated from the electrode **12** by a relatively small distance, such as 2 millimeters. A collector **20** is disposed at a moderate distance, such as 1 or 2 centimeters, from the electrode **16** and in substantially parallel relationship to the electrode.

A backing plate **22** having a relatively restricted length such as 1 centimeter is provided at an intermediate position between the electrode **16** and the collector **20**. The backing plate **22** is substantially perpendicular to the electrode **16** and the collector **20** and is slightly to the rear of an imaginary line extending from the tip of the filament **10** through the slots **14** and **18** to the collector **20**.

A control electrode **24** made from a suitable wire mesh is disposed in substantially parallel relationship to the backing plate **22** and at a relatively close distance, such as 2 millimeters, from the backing plate. The electrode **24** is slightly in front of the imaginary line disclosed above. Slats **26** extend laterally from the backing plate **22** to the electrode **24** to form a compartment with the electrode **16** and the collector **20**.

A vertical slot **28** is provided in one of the slats **26** at a position substantially aligned with the imaginary line disclosed above. The slot **28** communicates with a conduit **30** which extends from a receptacle **32** adapted to hold molecules of the different gases or vapors constituting an unknown mixture.

An electrode **34** made from a suitable wire mesh is separated from the electrode **24** by a relatively short distance, such as 2 millimeters, and is disposed in substantially parallel relationship to the electrode **24**. An electrode **36** is in turn positioned at a relatively great distance, such as 40 centimeters, from the electrode **34**. The electrode **36** is also made from a suitable wire mesh and is positioned in substantially parallel relationship to the electrode 34.

A detector is positioned at a moderate distance, such as 3 centimeters, from the electrode. For example, the detector may constitute a collector 38 or an electron multiplier similar to that disclosed on page 831 of "Radio Engineering" (third edition, 1947) by Professor Frederick E. Terman. A time indicator, such as an oscilloscope 40, is connected to the collector 38 through amplifiers 41 to indicate the relative times at which signals are produced by the collector. A connection is also made from the output terminal of a pulse forming circuit 42 to an input terminal of the oscilloscope 40 so that the sweep of the beam in the oscilloscope will be initiated every time that a pulse is produced by the circuit 42.

A relatively high positive voltage, such as 275 volts, is applied to the filament 10 through a resistance 43 from a suitable power supply 44. Positive voltages in the order of 250 volts and 375 volts are respectively applied to the electrodes 12 and 16 through suitable resistances 46 and 48 from the power supply 44. A voltage of 375 volts is also applied to the collector 20 through a resistance 50.

Positive voltages of 400 and 350 volts are applied to the backing plate 22 and the electrode 24 through suitable resistances 52 and 54, respectively, from the power supply 42. A positive voltage of approximately 50 volts is applied to the collector 38 through a suitable resistance 56 so that electrons secondarily emitted from the collector by the impingement of ions will be attracted back to the collector. The electrodes 34 and 36 are directly grounded.

Since the voltage on the control electrode 12 is lower than the voltage on the filament 10, electrons emitted by the filament are prevented from moving past the electrode 12 into the region between the backing plate 22 and the electrode 24. Because of the force imposed on the electrons to prevent them from travelling into the region between the backing plate 22 and the electrode 24, molecules of gas or vapor introduced into the region from the receptacle 32 cannot be ionized.

At predetermined times, voltage pulses having a relatively short durations such as 0.01 microsecond and having a magnitude in the order of +50 volts are applied to the electrode 12. The voltage pulses are applied to the electrode 12 through a coupling capacitance 58 from the pulse forming circuit 42. The pulse forming circuit 42 may be similar to that disclosed and claimed in co-pending application Serial No. 230,905 filed June 11, 1951 by William C. Wiley.

Upon the application of each voltage pulse to the electrode 12, the voltage on the electrode becomes greater than the voltage on the filament 10. This causes the electrons emitted by the filament to be accelerated towards the electrode 12. The electrons moving past the electrode 12 upon the imposition of a voltage pulse on the electrode are further accelerated in the region between the electrodes 12 and 16. The electrons are accelerated in this region since the electrode 16 is at a higher potential than the electrode 12 even during the time that the voltage pulse is applied to the electrode 12.

Because of the accelerations imparted to the electrons in the region between the filament 10 and the electrode 12 and in the region between the electrodes 12 and 16, the electrons have a considerable energy as they travel through the region between the backing plate 22 and the electrode 24. After travelling through this region, the electrons impinge on the collector 20.

As the electrons move through the region between the backing plate 22 and the electrode 24, some of them strike molecules of gas introduced into the region from the receptacle 32. Since the electrons have had considerable accelerations imparted to them between the filament 10 and the electrode 16, they strike the gas molecules with a sufficient force to produce an ionization of the molecules into electrons and positive ions. Most of the ions have a single positive charge but a few of the ions have more than one charge because of a loss of two or more electrons from the gas molecules.

Since the backing plate 22 is at a positive potential with respect to the voltage on the electrode 24, a repelling force is applied on the ions to move them towards the electrode 24. This repelling force is of only moderate magnitude because of the difference of 50 volts between the potentials applied to the backing plate 22 and the electrode 24. This repelling force imparts a greater acceleration to the ions of relatively light mass than to the ions of heavy mass. In this way, the light ions attain a greater speed than the heavy ions.

After the ions have traveled past the electrode 24, they are subjected to a force which is considerably greater than that imposed on them in the region between the backing plate 22 and the electrode 24. Such a considerable force is imposed on the ions in the region between the electrodes 24 and 34 because of the difference of approximately 350 volts between the potentials imposed on the electrodes.

Since the electrodes 34 and 36 are both at substantially ground potentials, no force is exerted upon the ions in this region. This causes the ions to travel through the region with substantially the same velocity as that attained by them as they move past the electrode 34. After moving past the electrode 36, the ions impinge on the collector 38 and produce signals having strengths dependent (in part) upon the relative abundance of the different gases or vapors in the unknown mixture. The signals produced by the collector 38 are amplified by the amplifiers 41 and are visually displayed on the oscilloscope 40. By determining the relative times at which the signals appear on the oscilloscope, the masses of the different ions can be determined. The relative abundance of the ions can also be determined from the amplitudes of the different signals.

The mass spectrometer disclosed above has several important advantages. Since the filament 10 has a considerable width, a relatively large number of electrons are accelerated into the region between the backing plate 22 and the electrode 24 during the short period of time that the pulse of voltage is applied to the electrode 12. As a result, a relatively large number of ions are instantaneously produced by the impingement of the electrons on molecules of gas introduced into the region between the backing plate 22 and the electrode 24.

Since the backing plate 22 and the electrode 24 have restricted lengths, they are not able to produce any material deflection of the electrons passing between them. The action of the plate 22 and the electrode 24 in deflecting the electrons from a straight path is further limited because of the moderate voltage difference between the plate and the electrode. The deflection of the electrons from a straight path is also limited because of the intermediate voltage on the electrode 16 and the collector 20 relative to the voltages on the plate 22 and the electrode 24.

Since the backing plate 22 and the electrodes 24 and 34 are maintained at substantially constant potentials, they impart a relatively stable operation to the spectrometer during the acceleration of the ions in the region between the backing plate 22 and the electrode 24 and in the region between the electrodes 24 and 34. Because of the stable operation of the mass spectrometer during these periods of ion acceleration, the ions become separated more sharply on the basis of their mass than in time-of-flight mass spectrometers operating with voltage pulses which do not maintain a constant amplitude and shape. This relatively sharp delineation between ions of different mass causes ions of adjacent masses to be distinguished from one another over a wide range of values.

The imposition of the particular voltages on the backing plate 22 and the electrodes 24 and 34 provides a compensation for differences in the positioning and random motion of the ions at the instant that the ions are formed. The differences in the positioning of the ions are produced because of the finite width of the electron beam. The finite width of the electron beam is produced because of the collimating action which is provided on the electrons by the slots **14** and **18**. Differences in the random motion of individual ions are caused by the thermal and other energy in the ions. Because of the differences in the random motion of the ions, some of the ions may be travelling towards the plate **22** at the instant that they are formed from gas molecules and other ions may be travelling towards the electrode **24**.

The compensation for the differences in the positioning and random motion of individual ions is provided because of the moderate acceleration imposed on the ions in the region between the backing plate **22** and the electrode **24** and the considerable acceleration imposed on the ions in the region between the electrodes **24** and **34**. The compensatory action provided on the ions in these regions is fully disclosed in co-pending application Serial No. 249,318 filed October 2, 1951 by William C. Wiley. Such compensatory action is provided even though constant voltages are imposed on the backing plate **22** and the electrodes **24** and **34** instead of the pulses of voltage disclosed in the co-pending application.

The relatively short time of 0.01 microsecond for the flow of electrons through the slots **14 and 18** also facilitates the production of relatively sharp output signals. Sharp output signals are produced since the period of 0.01 microsecond is considerably less than the time required for the ions of each mass in a pulse to be collected. It has been found that the period of time required for the ions of each mass in a pulse to be collected approximates 0.05 microsecond. The ions of each mass in a pulse are collected at a different time from the ions of all other masses in the pulse because of the separation of the ions on the basis of their mass during their travel towards the collector **38**.

In the mass spectrometer constituting this invention, a pulse of voltage is applied only to the electrode **12**. In this respect, the mass spectrometer disclosed above differs from other time-of-flight mass spectrometers now in use. These spectrometers require the initial imposition of voltage pulses on electrodes controlling the movement of the electrons and the subsequent imposition of voltage pulses on electrodes controlling the movement of the ions. Since a voltage pulse is imposed only on the electrode **12** in the mass spectrometer constituting this invention, the pulse forming circuit **58** shown in block form in Figure 1 can be relatively simple.

Since a pulse is applied by the pulse forming circuit **42** only to the electrode **12**, the period of time required for electrons to travel into the region between the backing plate **22** and the electrode **24** can be arithmetically approximated. The period of time required for the ions of each mass to travel to the collector **38** can also be arithmetically approximated. By adding together the two periods of time, an approximation can be made of the relative time between the formation of a voltage pulse by the circuit **42** and the appearance on the oscilloscope **40** of a signal produced by ions of a particular mass.

In Figure 2, a system is shown for distinguishing between ions of a particular mass and all other ions. The system includes a delay network **80** having an input terminal connected to the output terminal of the purse forming circuit **42** and having an output terminal connected to an input terminal of an oscilloscope **82**. The network **80** operates to delay the pulse produced by the circuit **42** for a period of time corresponding to that required for the ions of the particular mass to reach the collector **38**. The network then introduces the pulse to the oscilloscope **82**, which operates to provide an indication only during the time that a pulse is introduced to it from the network. In this way, the oscilloscope **82** provides an indication only as to the presence or absence of ions of a particular mass in each ion pulse. Such an indication is important when the mass spectrometer is utilized with other components to form a leak detector since an indication by the oscilloscope **82** of a particular gas, such as helium, indicates the presence of a leak in the equipment being tested.

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. A mass spectrometer, including, means for providing a plurality of electrons, means for providing a first region with the electron means, means for imposing on the electrons in the first region a force of relatively long duration to prevent the movement of the electrons from the electron providing means, means for imposing on the electrons a pulsating force of relatively short duration to accelerate the electrons through the region, means for providing a second region disposed relative to the first region to form a channel for the passage of electrons, means for introducing a plurality of molecules of gas into the second region for ionization by the electrons passing through the region, means for imposing on the ions in the second region a force of substantially constant magnitude to accelerate the ions through the region and to produce a separation of the ions on the basis of their mass, means for detecting the ions after their travel through a relatively great distance past the second region, and means for indicating the relative times at which the ions of different mass are detected.

2. A mass spectrometer, including, means for providing a plurality of electrons, means for providing a first region with the electron means, means for imposing on the electrons in the first region an electrical field to restrain the movement of the electrons from the emitting means, means for imposing on the electrons in the first region an electrical field of relatively short duration to accelerate the electrons through the region, means for providing a second region in a direction disposed to provide a channel for the passage of electrons through the region, means for introducing a plurality of molecules of gas into the second region for ionization by the electrons passing through the region, means for imposing an electrical field of substantially constant magnitude on the ions in the second region to produce an acceleration of the ions through the region and a separation of the ions on the basis of their mass, means for detecting the ions after their travel through a relatively great distance past the second region, and means for indicating the relative times at which the ions of different mass are detected.

3. A mass spectrometer, including, a filament for emitting a plurality of electrons, a control electrode separated from the filament by a relatively short distance, means for applying direct voltages on the filament and the electrode of such magnitude as to produce an electric field between them for preventing the flow of electrons towards the electrode, means for applying pulses of voltage between the filament and the electrode to produce a flow of electrons past the electrode during the pulses, a collector for receiving the electrons flowing past the electrode, a backing plate disposed between the control electrode and the collector and in substantially the same direction as the electron flow, an ion electrode separated from the backing plate by a relatively short distance and defining with the plate a region through which the electrons flow, means for introducing into the region between the backing plate and the ion electrode a plurality of gas molecules for ionization by the electrons, means for applying direct voltages on the backing plate and the ion electrode of such magnitude as to produce an electric field for directing towards the electrode the ions

produced from the gas molecules, a detector separated from the ion electrode by a relatively great distance to receive the ions, and a time indicator for determining the relative times at which ions of different mass are detected.

4. A mass spectrometer, including, a filament for emitting a plurality of electrons, a first electrode separated from the filament by a relatively small distance and having a direct voltage applied to it of less magnitude than that applied to the filament, a second electrode separated from the first electrode by a relatively small distance and having a direct voltage applied to it of greater magnitude than that applied to the filament, means for applying a pulse of voltage to the first electrode to bring the voltage on the electrode to an intermediate magnitude relative to the voltages on the filament and second electrode, a collector for receiving the electrons flowing to it upon the application of the voltage pulse on the first electrode, a backing plate disposed between the second electrode and the collector and having a direct voltage applied to it, an ion electrode separated from the backing plate by a relatively small distance to define with the plate a region through which the electrons flow, means for introducing molecules of gas into the region between the backing plate and the ion electrode for ionization by the electrons, the ion electrode having a direct voltage applied to it of such magnitude relative to the voltage on the backing plate as to produce a movement of the ions towards it, a detector separated from the ion electrode by a relatively great distance to receive the ions, and a time indicator for determining the relative times at which the ions of different mass are detected.

5. A mass spectrometer, including, a filament for emitting a plurality of electrons, a first electrode disposed at a relatively short distance from the filament, means for applying voltages of substantially constant magnitude on the filament and the electrode to restrain the electrons from movement towards the electrode, means for applying pulses of voltage on the electrode relative to the voltage on the filament to accelerate the electrons towards the electrode, a backing plate disposed in substantially parallel relationship to the direction of electron flow at a position past the electrode, a second electrode disposed in substantially parallel relationship to the backing plate at a relatively short distance from the plate and on the opposite side of the electron flow from the backing plate, means for introducing a plurality of gas molecules into the region between the backing plate and the second electrode for ionization by the electrons, means for applying voltages of substantially constant magnitude on the backing plate and the second electrode to accelerate the ions towards the electrode and to produce a separation of the ions on the basis of their mass, a detector disposed to produce signals in accordance with the time required for the ions of different mass to travel through a relatively great distance past the second electrode, and an indicator for showing the relative times at which the different signals are produced by the detector.

6. A mass spectrometer, including, a filament for emitting a plurality of electrons, a first electrode disposed at a relatively short distance from the filament, means for applying voltages of relatively long duration on the filament and the electrode to prevent the movement of the electrons towards the electrode, means for applying pulses of voltage of relatively short duration on the electrode relative to the voltage on the filament to accelerate the electrons towards the electrode, a backing plate, a second electrode disposed at a relatively short distance from the backing plate and in substantially parallel relationship to the backing plate to form a region through which the electrons flow, means for introducing a plurality of molecules of gas, into the region between the backing plate and the second electrode for ionization of the molecules by the electrons, means for applying voltages of substantially constant magnitude on the backing plate and the

second electrode to accelerate the ions towards the electrode and to produce a separation of the ions on the basis of their mass, means for detecting the ions after their travel through a relatively great distance past the second electrode, and means for indicating the relative times at which the ions of different mass are detected.

7. A mass spectrometer, including, a filament for providing a plurality of electrons, a collector, means for providing an electric field adjacent to the filament for normally restraining the movement of electrons towards the collector, means for varying the electric field in pulses to produce a movement of the electrons towards the collector, a backing plate, an electrode separated from the plate by a relatively short distance, the backing plate and the electrode being disposed relative to the electron flow to provide for the passage of the electrons between the plate and the electrode, means for introducing a plurality of molecules of different gas into the region between the backing plate and the electrode for ionization by the electrons, a power supply for applying direct voltages to the backing plate and the electrode of such magnitude as to produce an acceleration of the ions towards the electrode and a separation of the ions on the basis of their mass, a detector located at a relatively great distance past the electrode in the direction of ion travel to produce signals dependent upon the times at which the ions of different mass travel through the distance, and an indicator for showing the relative times at which the different signals are produced by the detector.

8. A mass spectrometer, including, a filament shaped to emit a beam of electrons having a relatively large dimension in a transverse direction, a first electrode disposed at a relatively close distance to the filament and in substantially parallel relationship to the filament in the transverse direction of the electron beam, means for applying direct voltages on the filament and the electrode of such magnitude as to restrain the flow of electrons towards the electrode, a pulse forming circuit for applying pulses of voltage on the electrode relative to the voltage on the filament to accelerate the electrons towards the electrode, a backing plate disposed in substantially parallel relationship to the direction of electron travel, a second electrode disposed in substantially parallel relationship to the backing plate at a relatively close distance to the plate and on the far side of the electron flow from the backing plate, means for introducing a plurality of molecules of gas into the region between the backing plate and the second electrode to obtain an ionization of the molecules by the electrons flowing through the region, means for applying direct voltages on the backing plate and the second electrode of such magnitude as to produce a movement of the ions towards the electrode and a separation of the ions on the basis of their mass, a detector for producing signals at times corresponding to those required for the ions of different mass to travel through a predetermined and relatively great distance past the second electrode, and an indicator for determining the relative times at which the signals are produced by the detector.

9. A mass spectrometer including, means for providing a plurality of electrons, means for providing a first region, means for normally preventing a movement of the electrons through the region, means for introducing a plurality of molecules into the first region, means for imparting an instantaneous pulse of energy to the electrons to produce a movement of the electrons through the region for ionization of different molecules introduced into the region, means for providing a substantially constant electrical field in the first region for a movement of the ions through the region and a separation of the ions on the basis of their mass, means for detecting the ions after their travel through a particular distance past the first region in accordance with the time required for the ions to travel through the distance, and means for indicating the relative times at which the ions of different mass are detected.

10. A mass spectrometer including, a filament for emit-

ting a plurality of electrons, a first electrode disposed at a particular distance from the filament, an electrical circuit for applying a voltage on the electrode relative to the voltage on the filament to prevent the movement of electrons past the electrode, an electrical circuit for applying an instantaneous pulse of voltage on the electrode relative to the voltage on the filament to produce a movement of the electrons past the electrode, a backing plate disposed in a direction transverse to the movement of electrons, a second electrode separated from the backing plate by a particular distance to define with the plate a region through which the electrons flow upon their movement past the first electrode, means for introducing molecules into the region between the backing plate and the second electrode for ionization by the electrons, an electrical circuit for applying a substantially constant voltage difference between the backing plate and the second electrode to produce an electrical field for the movement of the ions towards the electrode and a separation of the ions on the basis of their mass, a detector disposed at a particular distance past the second electrode to produce signals in accordance with the time required for the different ions to travel through the particular distance, and an indicator for indicating the signals produced by the detector.

11. A mass spectrometer including, a backing plate, a first electrode aligned with the backing plate at a particular distance from the plate, means for introducing a plurality of molecules into the region between the backing plate and the first electrode, means for providing a plurality of electrons, a second electrode disposed in the path of the electron flow, an electrical circuit for biasing the electrode to prevent the flow of electrons through the region between the backing plate and the first electrode, an electrical circuit for applying instantaneous pulses of voltage to the second electrode to produce a movement of the electrons through the region between the backing plate and the first electrode for an ionization of molecules introduced into the region, electrical means for producing a substantially constant electrical field in the region between the backing plate and the first electrode for a movement of the ions through the region and a separation of the ions on the basis of their mass, a detector disposed at a particular distance from the first electrode to produce signals upon the movement of the ions through the distance, and an indicator for indicating the different signals produced at the detector.

12. A mass spectrometer, including, means for providing a first region, means for providing a plurality of electrons, means for imposing a substantially constant

force on the electrons to prevent the electrons from moving through the first region, means for introducing a plurality of molecules into the first region, means for imposing a force of a relatively short duration on the electrons to produce a movement of electrons through the first region for ionization of the molecules, means for imposing a substantially constant electrical force in the first region to produce a movement of the ions through the first region and a separation of the ions on the basis of their mass, a detector disposed at a particular distance past the first region to produce signals upon the movement of the ions through the region, and means for indicating the different signals produced at the detector.

13. A mass spectrometer, including, a filament for emitting a plurality of electrons, a first electrode disposed at a particular distance from the filament, an electrical circuit for normally applying a voltage on the electrode relative to the voltage on the filament to restrain the electrons from movement towards the electrode, a pulse forming circuit for applying pulses of voltage on the electrode relative to the voltage on the filament to provide the electrons with energy for movement past the electrode, a backing plate disposed in substantially parallel relationship to the electrode at a position past the electrode and on one side of the electron flow, a second electrode disposed in substantially parallel relationship to the backing plate at a particular distance from the plate and on the opposite side of the electron flow from the backing plate, means for introducing a plurality of molecules into the region between the backing plate and the second electrode for ionization by the electrons, an electrical circuit for applying between the backing plate and the second electrode a relatively constant voltage difference of a polarity to produce a movement of the ions towards the electrode and a separation of the ions on the basis of their mass, a detector disposed at a particular distance past the second electrode to produce signals in accordance with the time required for the ions of different mass to travel through the particular distance, and an indicator for indicating the detection of the ions of different mass.

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