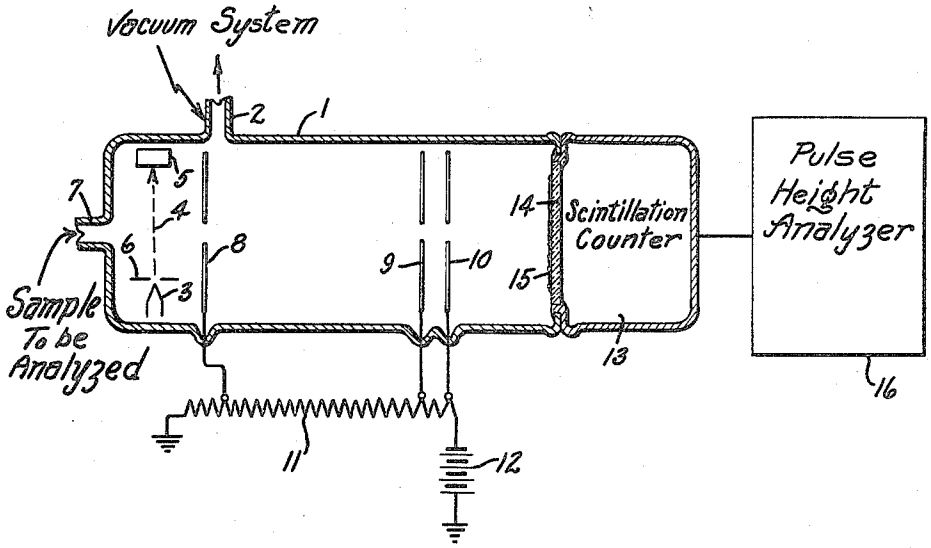
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MASS SPECTROMETER

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# MASS SPECTROMETER

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This present invention relates to a mass spectrometer, and more particularly to an extremely simple type of mass spectrometer for mass analysis.

Mass spectrometers are instruments which are capable of physically effecting a qualitative and quantitative chemical analysis of a material such as a gas. In operation, the material to be analyzed is introduced into the mass spectrometer tube where it is ionized in an ionization chamber. The resulting ions are then separated in accordance with their mass-to-charge ratios by passing them through a magnetic or electrostatic field to induce a spatial separation of the ions into separate beams having characteristic mass-to-charge ratios. The separate beams are then physically moved past a collector electrode, and the resulting discharge of each beam at the collector electrode is measured and plotted in order to provide an indication of the composition of the gas under test. For further information concerning mass spectrometers, reference is made to a textbook entitled, "Isotopic Tracers and Nuclear Radiations" written by W. E. Siri, published by the McGraw-Hill Book Co., Inc. in 1949, Chapter 9.

The mass spectrometers known in the art are very complex and expensive instruments since they are required to read extremely small qualities with very great accuracy. Also, the building of a mass spectrometer tube involves precise construction, since beams of ions are being swept through a given area in space and this area must be so limited that only one beam at a time can enter. The present invention eliminates many of the difficulties of previously known mass spectrometers and considerably reduces the expense of such instruments.

It is, therefore, one object of this invention to provide a mass spectrometer which is simpler to construct than those previously known in the art.

It is another object of this invention to provide a mass spectrometer in which the dimensions of the tube and the elements thereof are not critical as to their size and disposition.

Other objects and advantages will appear as the description of the invention proceeds.

Briefly stated, in accordance with the invention, there is disclosed a mass spectrometer which ionizes a material being tested and accelerates the resulting ions so that they are all at the same energy level. Thus far the present invention is identical with that of an ordinary mass spectrometer. In accordance with the present invention, however, the ions are accelerated entirely as a single beam, deflection and spatial separation of the ions into a plurality of distinctive beams with subsequent deflection of the separated beams being unnecessary. Next the accelerated ions are converted into corresponding electrical pulses having amplitudes that are respectively proportional to the masses of the respective ions, and then the pulses are electrically analyzed in order to determine the nature of the ionized material. By working with electrical pulses rather than separate ion beams, much



of the precision construction of the mass spectrometer tube can be eliminated and the analyzing portion of a mass spectrometer can also be simplified.

The features of this invention which are believed to be novel and patentable are pointed out in the claims which form a part of this specification. For a better understanding of the invention, reference is made in the following description to the accompanying drawing in which the sole figure represents a schematic view of a mass spectrometer assembly in accordance with the invention, the tube itself being shown in cross section.

In the sole figure, there is shown a cross-sectional view of a hermetically sealed mass spectrometer tube 1 having an opening 2 therein leading to a vacuum system for evacuating the tube. Disposed within the tube 1 and schematically shown in the figure, is a source of electrons 3 for emitting a stream of electrons 4 toward an electron trap 5, the stream being guided toward the trap by a slotted plate 6. The filament source of electrons is, of course, connected to a potential source (not shown) for causing it to emit electrons. It should be understood that there are many types of such electron sources known in the art and that the present invention in no way depends upon a particular type shown in the figure.

Tube 1 has another opening 7 therein, into which opening is passed a gas sample to be analyzed in the mass spectrometer. This gas sample enters into the tube area where electron beam 4 causes it to become ionized. In this area, the atoms or molecules of the gas are struck by the electrons in beam 4 and electrons are ejected therefrom, some of the atoms or molecules of the gas thus being converted into ions. The resulting ions are then accelerated by means of slotted plates 8, 9 and 10 until they are all at same energy level and travelling down the length of the tube 1.

Plates 8, 9 and 10 are connected to different points along a resistor 11, the resistor being connected across a source of potential 12. The plates are all, therefore, at varying positive potentials and serve to attract and accelerate the ion beam.

All of the foregoing recited elements, 1 to 12, are similar to elements found in mass spectrometers presently known in the art, and the present invention in no way depends upon their size or position in the tube. For example, instead of using a gas sample for analysis, a solid sample could be heated and vaporized, and the resulting vapor could then be ionized and accelerated in the tube. Moreover, the number of plates and their potentials could be varied provided only that the acceleration of the ions to a given equal energy level is achieved.

Referring again to the sole figure, there is shown connected to the end of tube 1 an element 13 for converting each accelerated ion into an electrical pulse having an amplitude that is proportional to the mass of the ion. Various elements for accomplishing this result are well known in the art. The element illustrated in the figure is a scintillation counter with a glass side 14 and having a scintillation material coating 15, such as a phosphor, on this side and exposed to the accelerated ions within the tube 1. A suitable scintillation counter that could be used in this invention is an instrument made by the General Electric Company, Catalog No. 121C196, entitled, "Portable Radiation Probe" and illustrated in a publication bearing the number GEC823. As is explained in this publication, when a particle strikes the scintillation material, it gives off light and this light is amplified by a photomultiplier tube. This tube then produces a large electrical output pulse whose amplitude is proportional to the mass of the particle striking the scintillation material and the energy with which the particle struck the material. Since

all of the particles striking the scintillation material in the present invention have the same energy, it will be apparent that the output of the scintillation counter will be an electrical pulse having an amplitude that is directly proportional to the mass of the particle causing the scintillation.

It should be understood that there are other instruments known in the art which will convert the energy of accelerated particles into electrical pulses having amplitudes that are respectively proportional to the masses of their respective particles. Another suitable device for performing this conversion, would be a proportional counter; and still another suitable device would be an ion chamber. The former devices are fully explained in chapter 11 of the Siri textbook noted above, while the latter device is set forth in chapter 12 of this text. It should be made clear, however, that if an ion chamber is used to replace device **13**, it should be an ion chamber having an extremely short ion path region in order to insure that any ionization occuring will be proportional only to the mass of the particles and not to their path length in the ion chamber. Further modifications of proportional counters and ion chambers in order to make them more suitable for use in the present invention will readily occur to those skilled in the art, and since the present invention is not limited to any particular embodiment of such devices, such modifications will not be discussed at this time.

The output of device **13** is connected to a device **16** for electrically analyzing the electrical pulse output from device **13** in order to determine the nature of the ionized material or gas. This analyzer may be the one disclosed in an article by C. W. Johnstone entitled, "A New Pulse-Analyzer Design," published in the January 1953 issue of Nucleonics, pages 36–41, by the McGraw-Hill Publishing Co., Inc. This publication discloses one type of an analyzer that is suitable for use in the present invention; however, such analyzers are well known in the art and the invention is not limited to any particular analyzer or type of analyzer. These instruments are often used with scintillation counters in radiation analyses, gamma rays causing a scintillation counter to emit flashes of light which are converted into electrical pulses, and the pulse height analyzer then plotting the number of electrical pulses from the scintillation counter against the energy of the individual pulses. In such analyses, the amplitude of each electrical pulse fed into the analyzer is proportional only to the energy of the gamma ray causing the pulse, and the instrument therefore plots the number of pulses versus the amplitude of the pulses, which amplitude is proportional to the gamma ray energy. However, when used with the present invention, the analyzer effectively plots the number of pulses versus the masses causing the pulses, since the latter quantity is proportional to the amplitude of the electrical pulses.

The pulse-height analyzer **16**, therefore, the electrical pulse input into it and plots the number of electrical pulses versus the amplitude of each electrical pulse. By noting on the plot the pulse heights at which the various pulses occur, the elements that were ionized to cause the electrical pulses can be identified; and by noting the number of pulses at any given pulse height, the percentage of the various elements relative to the elements in the material under an analysis can be determined.

In operation, a sample to be analyzed is fed into tube **1** through opening **7** where it is ionized by electron beam **4** and accelerated by plates **8**, **9** and **10** until the ions strike the scintillation phosphor **15**. The phosphor gives off a light scintilation every time in ionized particle strikes it, and the intensity of light so given off will be directly proportional to the mass of the particle striking the phosphor. The light from phosphor **15** is picked up by the scintillation counter **13**, and the photomultiplier tube within this device converts the light into electrical pulses proportional to the intensity of the light flashes. These electrical pulses are then plotted by the pulse-height analyzer **16** and the resulting graph enables the operator of the device to make a qualitative and quantitive analyses of the material under analysis.

From the foregoing, it will be seen that there has been disclosed a mass spectrometer containing considerably fewer elements than a conventional mass spectrometer, and that these elements are not critical in either their spacings or their dimensions. This simple instrument is considerably easier and cheaper to manufacture than a conventional mass spectrometer; and, while this instrument may not be quite as sensitive as a conventional mass spectrometer in determining the nature of very minute traces in a sample under analysis, it can be used effectively where the extreme accuracy of a mass spectrometer is not desired. For example, the present invention could be used to analyze compounds containing a few major elements. One of the factors which influences the accuracy of the instrument of the present invention is the possibility of "pile-up"; that is, of a plurality of particles striking the scintillation phosphor **15** at the same instant. However, because of the extremely fast response time of the scintillation counter **13** and the pulse height analyzer **16** relative to the number and duration of the pulses provided by the particles, and the statistics involved under such circumstances, the errors introduced are of a sufficiently small magnitude so as not to unduly affect the operation of the instrument.

While there has been described what is at present considered a preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention; and it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A mass spectrometer comprising, means for ionizing a material to be analyzed, means for accelerating the resulting ions in a single beam, said ions being accelerated to the same energy level, means for converting the accelerated ions from said single beam into corresponding electrical pulses having amplitudes that are respectively proportional only to the masses of the respective ions, and means for analyzing said electrical pulses to determine the nature of the ionized material.

2. A mass spectrometer comprising, means for ionizing a material to be analyzed, means for accelerating the resulting ions in a single beam, said ions being accelerated to the same energy level, means for converting the accelerated ions from said single beam into corresponding electrical pulses having amplitudes that are respectively proportional only to the masses of the respective ions, and means for determining the number of said electrical pulses at various pulse amplitudes in order to determine the nature of the ionized material.

3. A mass spectrometer comprising, means for ionizing a material to be analyzed, means for accelerating the resulting ions in a single beam, each of said ions being accelerated to the same energy level, means for converting each accelerated ion from said single beam into a corresponding light flash having an intensity that is proportional only to the mass of its corresponding ion, means for converting each light flash into a corresponding electrical pulse having an amplitude that is proportional to the intensity of its corresponding light flash, and means for electrically analyzing the resulting electrical pulses in order to determine the nature of the material that was ionized.

4. A mass spectrometer comprising, means for ionizing a material to be analyzed, means for accelerating the resulting ions in a single beam, each of said ions being ac-

celerated to the same energy level, means for converting each accelerated ion from said single beam into a corresponding light flash having an intensity that is proportional only to the mass of its corresponding ion, means for converting each light flash into a corresponding electrical pulse having an amplitude that is proportional to the intensity of its corresponding light flash, and means for determining the number of the resulting electrical pulses at various pulse amplitudes in order to determine the nature of the material that was ionized.

5. A mass spectrometer comprising, means for ionizing a material to be analyzed, means for accelerating the resulting ions in a single beam, each of said ions being accelerated to the same energy level, scintillation counter means for converting each accelerated ion from said single beam into a corresponding electrical pulse having an amplitude that is proportional only to its mass, and means for determining the number of the resulting electrical pulses at various pulse amplitudes in order to determine the nature of the material that was ionized.

6. A mass spectrometer comprising, means for ionizing a material to be analyzed, means for accelerating the resulting ions in a single beam, each of said ions being accelerated to the same energy level, scintillation counter means for converting the accelerated ions from said single beam into corresponding electrical pulses having amplitudes that are respectively proportional only to the masses of the respective ions, and pulse height analyzer means for plotting the number of said electrical pulses at various pulse amplitudes in order to determine the nature of the ionized material.

7. A mass spectrometer comprising, an evacuated tube containing means for ionizing a gas admitted at one end of said tube and means for accelerating the resulting ions down the length of said tube in a single beam until they are all at the same energy level at the other end of said tube, means at said other end of said tube for converting the accelerated ions from said single beam into corresponding electrical pulses having amplitudes that are respectively proportional only to the masses of the respective ions, and means coupled to the output from the last-named means for determining the number of said electrical pulses at various pulse amplitudes in order to determine the nature of said gas.

8. A mass spectrometer comprising, an evacuated tube containing means for ionizing a gas admitted at one end of said tube and means for accelerating the resulting ions down the length of said tube in a single beam until they are all at the same energy level at the other end of said tube, means at said other end of said tube for converting the accelerated ions from said single beam into corresponding flashes of light having intensities that are respectively proportional only to the masses of the respective ions, means coupled to the output from the last-named means for converting said flashes of light into corresponding electrical pulses having amplitudes that are respectively proportional to the intensities of their respective flashes of light, and means coupled to the output from the last-named means for determining the number of said electrical pulses at various pulse amplitudes in order to determine the nature of said gas.



9. A mass spectrometer comprising, an evacuated tube containing means for ionizing a gas admitted at one end of said tube and means for accelerating the resulting ions down the length of said tube in a single beam until they are all at the same energy level at the other end of said tube, scintillation counter means at said other end of said tube for converting the accelerated ions from said single beam into corresponding electrical pulses having amplitudes that are respectively proportional only to the masses of the respective ions, and pulse height analyzer means coupled to the output from said scintillation counter means for plotting the number of said electrical pulses at various pulse amplitudes in order to determine the nature of said gas.


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