

March 24, 1964

TAMOTSU NODA ETAL

3,126,477

MULTIPLE DISPERSION MASS SPECTROMETER

Filed Jan. 3, 1961

4 Sheets-Sheet 1

Figure 1

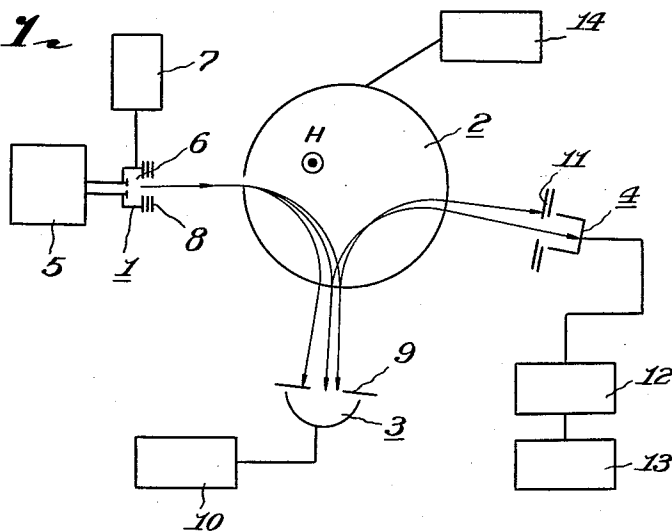
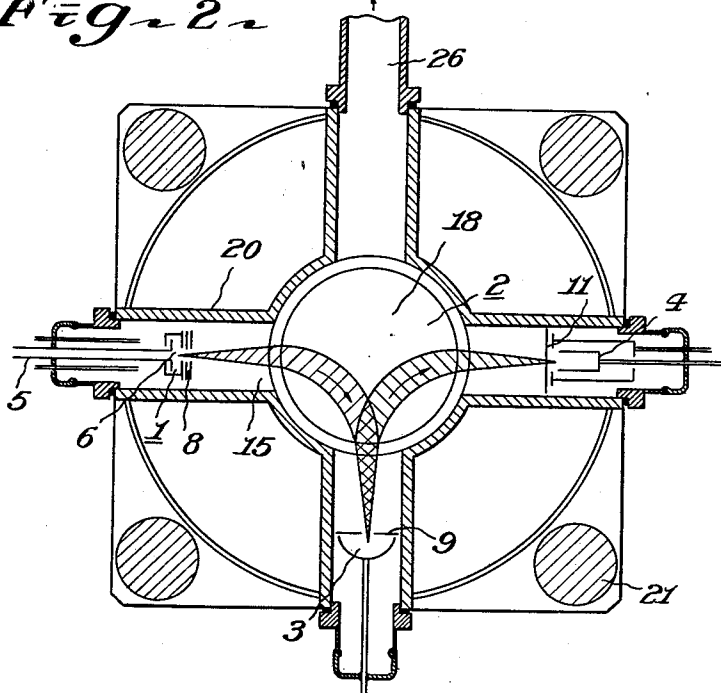


Figure 2



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Fig. 3

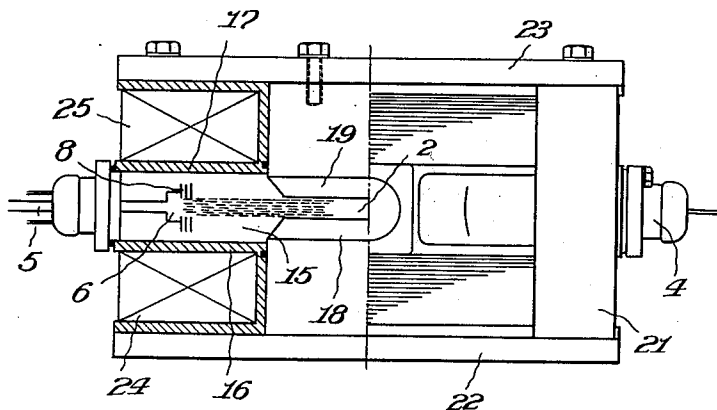
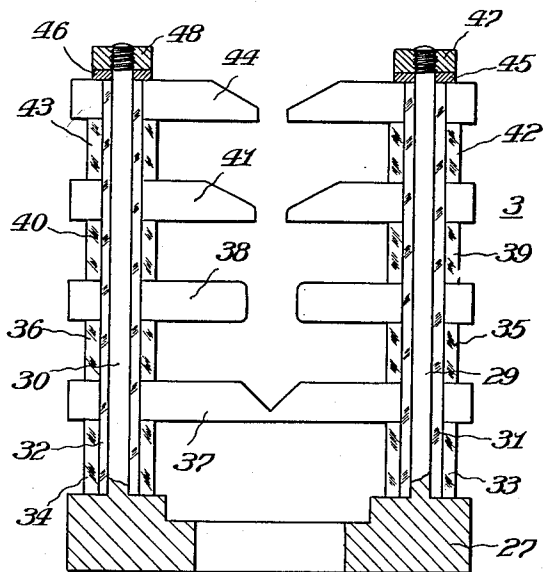


Fig. 4



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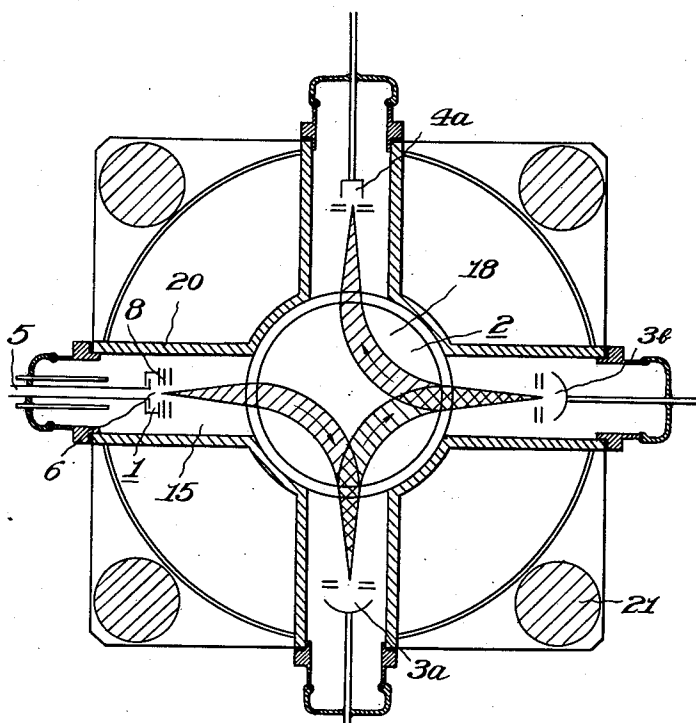
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Fig. 5



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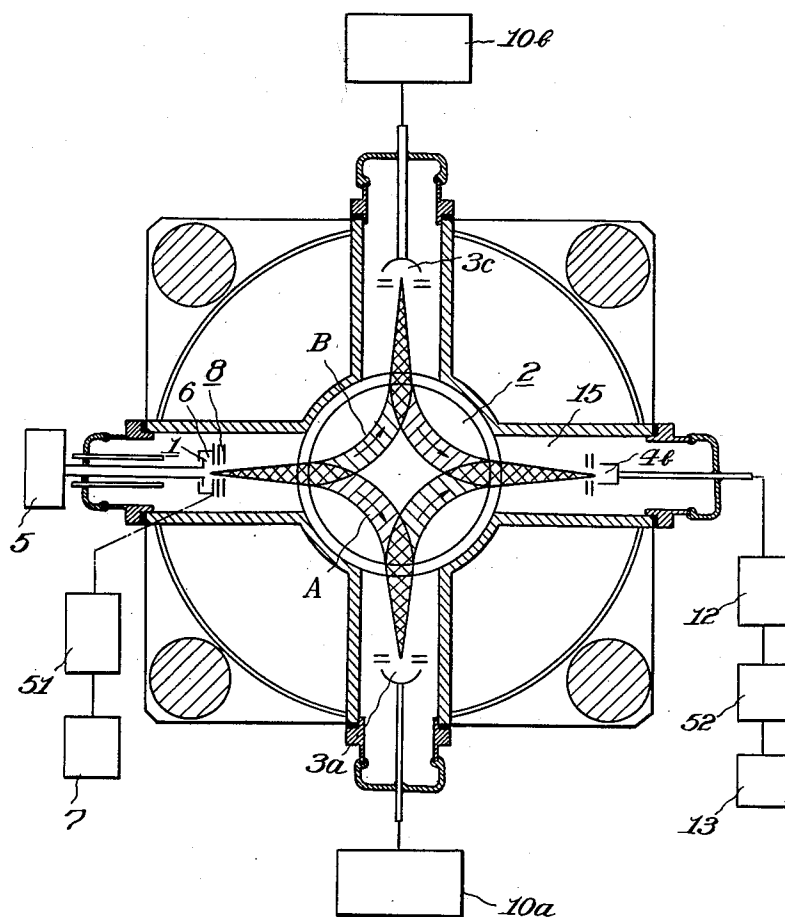
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Fig. 6



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MULTIPLE DISPERSION MASS SPECTROMETER
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Filed Jan. 3, 1961, Ser. No. 80,231

Claims priority, application Japan Jan. 12, 1960

8 Claims. (Cl. 250—41.9)

This invention relates to mass spectrometers, and more particularly it relates to a new and improved mass spectrometer of multiple dispersion type, which has high resolving power even of small and compact size.

The ordinary method practiced heretofore in order to increase the resolving power of a mass spectrometer has been to enlarge the radius of ion orbit. Consequently, the electromagnet and analyser tube have become bulky, and the entire apparatus has unavoidably tended to be one of massive scale.

It is an object of the present invention to provide a mass spectrometer wherein high resolving power is obtainable without enlargement of the apparatus.

It is another object of the invention to provide, as one modification, a mass spectrometer by the use of which both positive and negative ions can be analysed in a simple manner.

The said objects and advantages have been achieved by the multiple dispersion mass spectrometer of this invention, wherein the same magnetic field is utilized a plural number of times through the use of ion mirrors, whereby the same effect as that of increasing the radius of ion orbit is obtained.

The details of the invention as well as the manner, in which the objects of the invention may best be achieved, will be understood more fully from a consideration of the following description taken in conjunction with the accompanying drawings throughout which the same or equivalent parts are designated by the same reference numerals, and in which:

FIG. 1 is a schematic diagram indicating the arrangement of one embodiment of the multiple dispersion mass spectrometer of this invention;

FIG. 2 is a cross sectional view showing a specific example of construction of the analyser part of the embodiment of FIG. 1;

FIG. 3 is an elevational view, partly in section, showing a specific example of construction of the embodiment of FIG. 2;

FIG. 4 is an elevational view, in section, showing the construction of an ion mirror suitable for use in the embodiment of the invention;

FIG. 5 is a cross sectional view showing an analyser part suitable for use in another embodiment of the invention; and

FIG. 6 is an entire assembly diagram of another embodiment of the invention.

Referring, firstly, to FIGS. 1, 2, 3, and 4, an ion source 1 is disposed in a suitable position confronting a uniform magnetic field 2, around which are suitably disposed an ion mirror 3 and an ion collector 4. The ion source 1 is composed of an ionization chamber 6 communicating with a sample introduction unit 5, an ion source power supplier 7, and an accelerating electrode 8. The sample gas supplied from the sample introduction unit 5 is ionized in the ionization chamber 6 and led to the uniform magnetic field 2 by the accelerating electrode 8. The uniform magnetic field 2 is of H Gauss for the purpose of deflecting the projected ion beam in accordance with a specific mass (M/e), and its configuration is so determined that the deflected ion beam, when it is reflected by the ion mirror 3, is again subjected to a similar deflec-

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tion, in the said uniform magnetic field, as the first deflection. A magnetic field limited to an area circular in cross-section can be used as the uniform magnetic field which is so arranged that an ion beam is injected from the ion source 1 toward the center of the circular magnetic field, where the said ion beam is deflected 90 degrees.

The ion mirror 3 having a slit 9 is disposed so as to confront the position where the ion beam is injected to the uniform field from the ion source 1 is deflected and exits from the said uniform magnetic field. Said ion mirror is connected to an ion mirror power supplier 10, which supplies thereon a voltage approximately equal to the accelerating voltage, and forms an electric field of semi-circular configuration below the slit 9. The ion beam reflected by the ion mirror 3 is introduced again into the uniform magnetic field, deflected again through a similar path as the ion beam led to the ion mirror 3, finally received by the ion collector with a slit 11 located in the path of the said reflected beam. The said ion collector is connected to a recording device 13 through an amplifier 12. The uniform magnetic field 2 is caused by an electromagnet which is excited by an exciting power supplier 14.

The special details of the construction of this embodiment will be understood by reference to the following description taken in conjunction with FIGS. 2, 3, and 4. An analysing chamber 15, to which are attached the aforesaid ion source 1, ion mirror 3, and ion collector 4, is composed of coil cores 16 and 17, magnet poles 18 and 19, and side walls 20. The magnet poles 18 and 19 are fixed to a lower base plate 22 and an upper base plate 23, respectively, the said base plates being connected by magnetic yokes 21. Exciting coils 24 and 25 are wound around the coil cores 16 and 17, respectively, and the uniform magnetic field 2 is formed between the magnet poles 18 and 19. The analyser chamber 15 is connected to a vacuum pump (not shown) through an exhaust pipe 26.

The respective positions of the ion source 1, ion mirror 3, and ion collector 4 are determined as aforescribed. The ion mirror 3 is shown in the illustrations with a semi-circular symbol suggesting a semi-circular electric field. FIG. 4 illustrates one example of an actual construction of the ion mirror. Supporting rods 29 and 30 are embedded, at their lower ends, rigidly in a base 27 and are covered with insulating pipes 31 and 32, respectively. A reflection electrode 37 is retained in position by spacers 33, 34 and 35, 36 which are made of insulation material, and which are put on the pipes 31 and 32. Above the said electrode 37, three electrodes 38, 41, and 44 are successively retained by spacers 35 and 36, 39 and 40, and 42 and 43, respectively. The above members are supported by the supporting rods 29 and 30, and clamped by the nuts 47 and 48 and metal washers 45 and 46.

Said electrode 44 (grounded) is so positioned as to cut off unnecessary ion beams. Said electrode 38 functions to decelerate and accelerate the ion beam. The reflection electrode 37 is so constructed as to create a semi-circular electric field for driving back the ion beam. Said electrode 41 is to adjust the electric field due to the electrode 38.

The embodiment of the multiple dispersion mass spectrometer of this invention, constructed as described above, is operated generally in the following manner. The sample to be analysed is introduced from the sample introduction unit 5 into the ionization chamber 6, ionized therein, accelerated by the accelerating electrode 8, and led to the uniform magnetic field 2. In the uniform magnetic field 2, the ion beam is deflected in accordance with the specific mass (M/e), similarly as in the case of an ordinary mass spectrometer, and only the ions in a certain small range of specific mass pass through the slit 9 and

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reach the ion mirror 3. The ion beam which has reached the ion mirror 3 is decelerated by the electric field created by the ion mirror 3, stopped, then accelerated again in inverse direction by the said electric field and led again to the uniform magnetic field 2. This ion beam reflected by the ion mirror 3 and led to the uniform magnetic field 2 is deflected again in the said uniform magnetic field and received by the collector 4 through the slit 11. The ion current thus obtained is amplified by the amplifier 12 and recorded by the recording device 13.

In another embodiment of the invention as illustrated in FIG. 5 two ion mirrors are used, and the ion beam is caused to pass three times through the uniform magnetic field. More specifically, the ion beam, which is led from the ion source 1 to the uniform magnetic field 2 and deflected toward an ion mirror 3a as described above, is driven back to the uniform magnetic field 2 and deflected toward another ion mirror 3b in the second step, and similarly to the second step, the ion beam is driven back to the uniform magnetic field by the ion mirror 3b and deflected toward an ion collector 4a. The ion collector 4a is so situated as to receive the ion beam which has been deflected three times by the uniform magnetic field 2.

The present invention may be modified yet in another manner, as indicated in FIG. 6, whereby both positive and negative ions can be analysed in a simple manner. In the embodiment illustrated in FIG. 6, an ion source 1, two ion mirrors 3a and 3c, and an ion collector 4b are arranged at suitable positions around a uniform magnetic field 2, the ion mirrors 3a and 3c being situated at opposing positions, and the ion source 1 being situated opposite to the ion collector 4b. For analysis of both positive and negative ions, a polarity switch 51 and a selector 52 are added to the elements of the preceding embodiments, the polarity switch being connected between the ionization chamber 6 and the ion source power supplier 7, and the selector 52 being connected between an amplifier 12 and recording device 13. The selector 52 is so adapted as to operate synchronously with the polarity switch 51.

In the operation of the embodiment of the above construction, the electric potential of the ionization chamber 6 is switched by means of the polarity switch 51, whereby, of the positive ions and negative ions resulting from the ionization of the sample gas in the ionization chamber 6, a positive ion beam A is led to the uniform magnetic field 2, reflected by the ion mirror 3a, led again to the said magnetic field 2 and received by the ion collector 4b, while a negative ion beam B is led to the field 2, reflected by the ion mirror 3c, led again to the field 2, and received by the ion collector 4b. The positive and negative ion currents through the ion collector 4b are amplified by the amplifier 12, then are selected by the selector 52, whereby the positive ions and negative ions are analysed according to their respective deflections in the uniform magnetic field and recorded by the recording device 13.

From the foregoing description it will be apparent that, in the multiple dispersion mass spectrometer of this invention, since the ion beam received by the collector is deflected a plurality of times in the uniform magnetic field, even in case wherein ions with small difference in specific mass exhibit only a small dispersion by a single deflection, the dispersion is increased by repeated deflections, and it is thus possible to increase the resolving power of the apparatus similarly as in the case wherein the ion orbits are enlarged in radius.

It will be appreciated, furthermore, that since an ion source, ion mirrors, and an ion collector are arranged around a uniform magnetic field which serves to deflect an ion beam two or three times, the entire apparatus can be made relatively small and compact. If necessary, it is possible to use three or more ion mirrors to increase the resolving power of the apparatus.

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Moreover, by the use of a modification as represented by the embodiment shown in FIG. 6, it is possible to analyse both positive and negative ions in a simple manner.

While particular embodiments of the invention have been described, it will, of course, be understood that the invention is not to be limited thereto, since many modifications may be made, and it is contemplated by the appended claims to cover all such modifications as fall within the true spirit and scope of the invention.

What we claim is:

1. A multiple dispersion mass spectrometer comprising a uniform magnetic field of circular cross-section, an ion source for emitting an ion beam into the field radially thereof, for dispersion therein, an ion mirror adjacent to the field upon which at least a part of the dispersed beam impinges after passing through the field for reflecting it radially into the magnetic field, and an ion beam collector adjacent to the magnetic field for receiving at least a part of the dispersed beam after passing through the field from the mirror, said ion source, mirror and collector being peripherally spaced about the magnetic field.

2. A multiple dispersion mass spectrometer comprising a uniform magnetic field of circular cross-section, an ion source for emitting an ion beam into the field radially thereof, for dispersion therein, an ion mirror adjacent to the field upon which the beam converges after passing through the field for again reflecting the beam into the magnetic field, a second ion mirror adjacent to the magnetic field for receiving the converged beam after passing through the field from the first mirror and for again reflecting the beam into the field, and an ion beam collector adjacent to the magnetic field for receiving the converged beam after passing through the field from the second mirror, said ion source, mirrors and collector being peripherally spaced about the magnetic field.

3. A multiple dispersion mass spectrometer as defined by claim 2, including means for switching the accelerating voltage of the ion beam source between positive and negative polarity to cause emission of a positive or negative ion beam, a recorder, means coupled to the collector and selectively responsive to the positive and negative ion beams for transmitting signals to the recorder.

4. A multiple dispersion mass spectrometer as defined by claim 1 including means provided with an opening positioned in front of the mirror for passing only a dispersed part of the beam.

5. A multiple dispersion mass spectrometer as defined by claim 1 including a second mirror adjacent to the field and located between the ion beam collector and first mirror for reflecting a dispersed part of the beam after passing through the field from the first mirror.

6. A multiple dispersion mass spectrometer as defined by claim 5 including a second means provided with an opening positioned in front of the second mirror for passing only a dispersed part of the beam.

7. A multiple dispersion mass spectrometer as defined by claim 5, said ion beam collector provided with means forming an opening for receiving only a dispersed part of the beam.

8. A multiple dispersion mass spectrometer as defined by claim 7, including means for switching the accelerating voltage of the ion beam source between positive and negative polarity to cause emission of a positive or negative ion beam, a recorder, means coupled to the collector and selectively responsive to the positive and negative ion beams for transmitting signals to the recorder.

References Cited in the file of this patent

UNITED STATES PATENTS

2,824,987	Weissenberg et al. _____	Feb. 25, 1958
2,908,816	Poole _____	Oct. 13, 1959