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Hull et al.

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[54] **METHOD FOR ADJUSTING THE ION BEAM HEIGHT IN A MASS SPECTROMETER**

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[52] **U.S. Cl.** **250/283**

[51] **Int. Cl.** **H01j 39/34**

[58] **Field of Search**... 250/41.9 G, 41.9 SB, 41.9 D, 250/105; 350/271, 275

[56] **References Cited**

UNITED STATES PATENTS

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Primary Examiner—William F. Lindquist

[57] **ABSTRACT**

An adjustable mass spectrometer aperture permitting the selection of either the portion of the ion beam with a minimal off mid-plane aberration or a larger portion of the beam when high resolution is not required. The location of the aperture may be adjusted with respect to the mid-plane. Additionally, the entire beam may be intercepted for metastable ion energy spectrometry.

7 Claims, 3 Drawing Figures

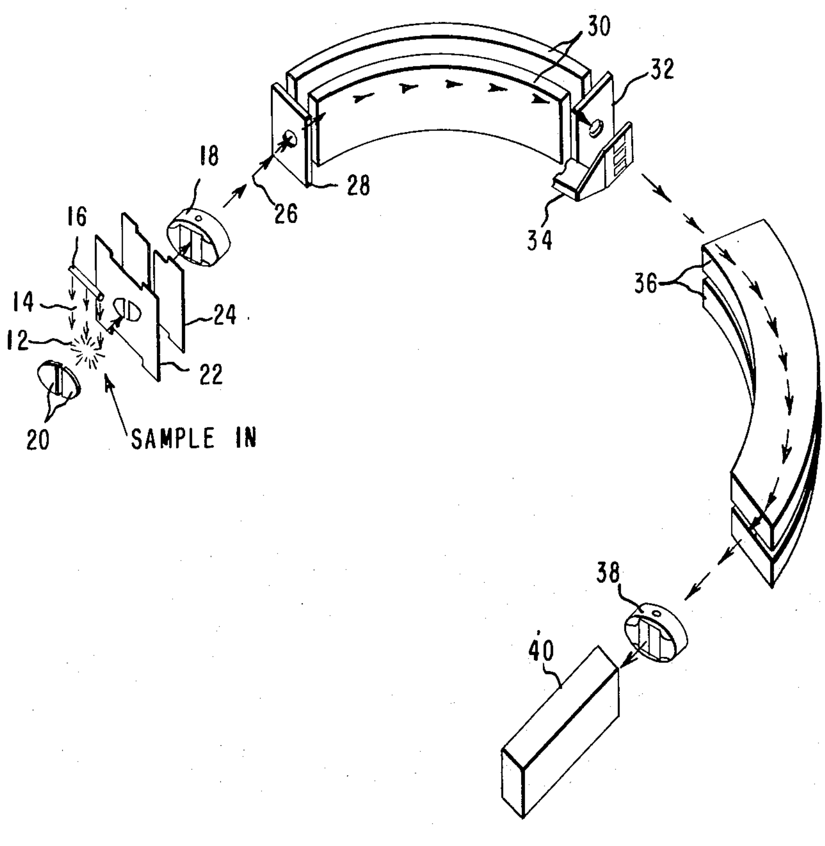

FIG. 1

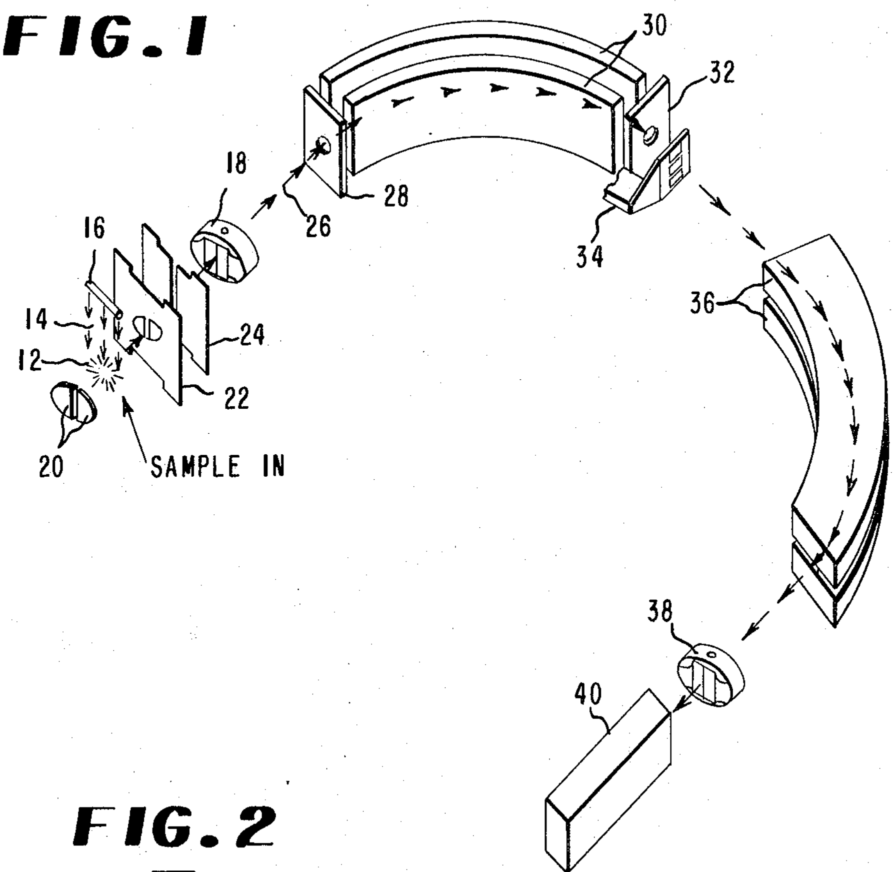

FIG. 2

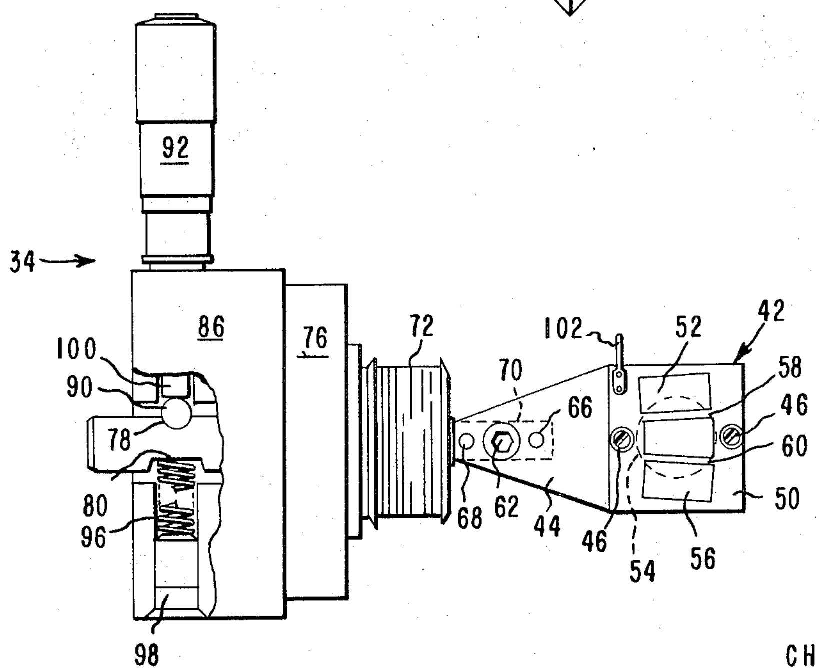

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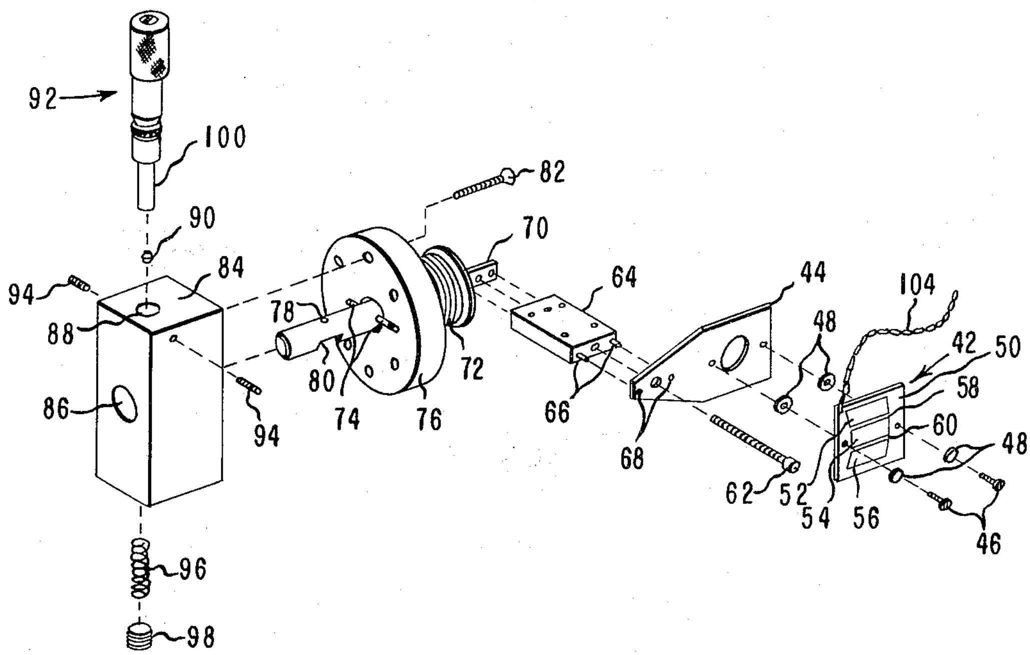
FIG. 3



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METHOD FOR ADJUSTING THE ION BEAM HEIGHT IN A MASS SPECTROMETER

BACKGROUND OF THE INVENTION

This invention relates to a novel aperture for mass spectrometry that allows either increased resolution by reducing off mid-plane aberrations in the ion beam, or conversely, greater sensitivity.

Mass spectrometers generally operate by differentially deflecting the paths of substantially all ions formed from the ion source. This differential deflection allows the selection and detection of ions having a particular mass to charge ratio. The trajectory of each deflected ion defines a particular plane for that ion. The ion-trajectory planes for all ions center about and aggregate upon a particular plane known as the ion beam plane.

A mass spectrometer's resolution is its ability to separate ions having different mass-to-charge ratios. This, in turn, depends upon the instrument's capability to focus ions having the same ratio at one particular location after passage through its analyzer. One impediment to higher resolution is that, looking down upon the ion beam plane, the pencil of ions at the object point (where the ions diverge from prior to entering the spectrometer's analyzer sector) has a finite cross section rather than being infinitesimally small. Larger ion-pencil cross-sections at the object point necessarily cause larger images for each mass-to-charge ratio when the ions are focused after their passage through the analyzer sector. The result is decreased resolution. Thus, one method to increase spectrometer resolution is to provide a narrow object slit width which physically reduces the cross section of the ion pencil at the object point.

U.S. Pat. No. 3,187,179 issued June 1, 1965 to R. D. Craig et al and U.S. Pat. No. 3,546,450 issued Dec. 8, 1970 to P. Burns show various adjustable slit mechanisms for reducing the width of the pencil of ions at the source for greater resolution. Conversely, these slits may also be opened to produce a greater pencil cross section, and hence more ions at the source, which reduces resolution, but increases sensitivity.

Similarly, the slit width at the image point after the analyzer also delimits the spectrometer's resolution capabilities. The larger slit width permits passage of ion pencils with greater cross sections into the collector. This increases the chances that ions with charge-to-mass ratios different than the particular ions being focused at the image slit will pass through the slit and reduce resolution. Accordingly, U.S. Pat. No. 2,887,582 issued May 19, 1959 to R. D. Craig and U.S. Pat. No. 2,946,886 issued July 26, 1960 to B. A. Peters et al show adjustable collector slits for controlling the size of the beam width at the image point of the spectrometer. The slit width may be reduced for greater resolution or opened to allow for more ions and hence greater sensitivity.

SUMMARY OF THE INVENTION

An additional source of resolution loss, however, is the height or length of the ion pencil (as opposed to width or cross section) formed at the source and admitted into the spectrometer through the object slit. As the ions pursue their trajectory, they encounter fringing fields at the perimeters of the various analyzing sectors. Since these fields have varying intensities at different distances from the ion beam plane, the ions will experience fringing fields of different magnitudes depending upon their distances from the ion beam plane. As a result these ions undergo differing deflections in their passage through the spectrometer analyzer. Consequently, ions having the same mass-to-charge ratio will be focused as different locations after passing through the analyzer and ions with different mass to charge ratios will be focused at the same spot, thus causing a decrease in resolution.

The present invention provides an adjustable beam height aperture which, at a particular point in the ion trajectory, prevents the passage of ions located beyond a predetermined distance from the ion beam plane. This serves to reduce the deleterious effect of the fringing fields upon spectrometer resolution.

Alternatively, the present beam height aperture may be adjusted to aloow the passage of a larger beam height which, while decreasing the spectrometer's resolution, increases its sensitivity. As a further possibility, where the analyzer includes an electrostatic sector, the adjustable beam height aperture may be used to block and detect the entire ion beam after its passage through the electrostatic sector. This allows for metastable ion energy spectrometry.

Specifically, in a spectrometer which bends the paths of the ions and which has a source, analyzer, and collector, the aperture includes first and second blocking means located on opposite sides of the ion beam plane for blocking portions of the ion beam, the distance between these blocking means being the ion beam height. The aperture further includes means for adjusting the ion beam height to any of at least two distinct values. Means for adjusting the blocking means with regards to the ion beam plane may also be included.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** shows an electric magnetic double focusing mass spectrometer including an adjustable beam height aperture of the present invention.

FIG. **2** gives a side view partially cut away of an embodiment of an adjustable beam height aperture.

FIG. **3** displays an exploded view of the aperture of FIG. **2.**

DETAILED DESCRIPTION OF THE INVENTION

In the double focusing mass spectrometer of FIG. **1,** the sample is ionized at the source in ionizing area **12** by electron beam **14** produced by filament **16.** These ions are accelerated and focused at the adjustable object slit **18** by repellers **20,** slit **22,** and focusing electrodes **24.** The subsequent ion beam **26** passes through the entrance slit **28** to the electrostatic analyzing sector composed of electric field plates **30.** After traversing the electrostatic sector, the beam then passes through the electric analyzer exit slit **32** to the adjustable beam height aperture **34** of the present invention. The ions passing through adjustable height aperture then enter the magnetic analyzing sector composed of magnetic pole pieces **36,** through the adjustable image slit **38,** and into the collector **40,** an electron multiplier, for example.

The embodiment of an adjustable beam height aperture **34** shown in greater detail in FIG. **2** and in exploded view in FIG. **3,** has a tab assembly **42** attached by screws **46** and insulating washers **48** to arm **44.** Tab assembly **42** itself is composed of plate **50** to which are welded three blocking means which are barriers or blocking plates **52, 54** and **56.** The aperture **58** between plates **52** and **54** had a height of 0.080 inch and aperture **60** between plates **54** and **56** has a height of 0.040 inch. Aperture **60,** being the smaller of the two, provides greater resolution, and aperture **58** allows for greater sensitivity. Screw **62** in turn attaches arm **44** to stand-off block **64,** which has bosses **66** that fit into holes **68** on arm **44** for proper alignment. Stand-off block **64** similarly attaches to shaft **70,** which passes in an air-tight manner through bellows **72** and flange **76** and has dowel **74** which fits into suitable depressions on flange **76.** Shaft **70,** on its other end, has hemispherical depression **78** and rectangular cut-out **80.** Screw **82** attaches flange **76** to block **84** which has opening **86** to accommodate the end of shaft **60.** Block **84** also has opening **88** which on one end accommodates sphere **90** and micrometer **92,** and, on the other end, spring **96** and set-screw **98.** When the components are assembled as shown in FIG. **2** the micrometer **92** pushes against sphere **90** which rests in hemispherical depression **78** of shaft **70.** On the other side of shaft **70,** spring **96** rests in rectangular cut-out **80** and its tension is adjusted by set-screw **98.** Set-screws **94** retain micrometer **92** within block **84.**

When the turning of the handle of micrometer **92** extends plunger **100,** this pushes on sphere **90** which extends the near end of shaft **70** (with hemispherical depression **78**) downwards. Since shaft **70** pivots about dowel **74,** this downward force on one end forces the other end upwards to which is attached stand-off block **64,** arm **44,** and tab assembly **42,** all of which is elevated because of their fixed spacial relationship to shaft **70.** Conversely, when micrometer plunger **100** is retracted, spring **96** forces the end of shaft **70** with rectangular cut-out **80** upwards. The far end of shaft **70** pivots downward and takes with it stand-off block **65,** arm **44,** and tab assembly **42.** Thus, the adjustment of the handle of micrometer **92** (which may be accurately marked for reproducibility) permits the upwards or downwards relocation of tab assembly **42.** This will bring either of the apertures **58** or **56** into the ion beam plane or may place plate **54** in the ion beam plane to intercept all of the ions. In addition to alternating between apertures **58** and **60,** the adjustment of micrometer **92** also serves to adjust the exact position of either aperture when it is already at the ion beam plane. This locates the aperture symmetrically with respect to the ion beam plane and thus allows passage of the part of the ion beam which provides the highest spectrometer resolution.

Bellow **72** and flange **76** serve as the interface between the vacuum for the ion beam and the atmospheric pressures for micrometer **92.** Bellow **72** is sufficiently flexible to allow the upwards and downwards motion of shaft **70.**

In FIG. **1,** adjustable beam height aperture **34** is located just after the exit slit **32** of the electrostatic analyzer **30** which provides (kinetic) energy separation of the ions. To obtain a metastable ion energy spectrum, aperture **34** is adjusted to block the total ion beam passing through exit slit **32** of the electrostatic analyzer. This may be done for example by positioning plate **54** of the tab assembly **42** at the ion beam plane itself. The ions striking tab assembly **42** are detected via beam monitor lead **104** which attaches to lead **102** of tab assembly **42.** The ions that will pass through exit slit **32** depend upon the strength of the field in the electrostatic analyzer **30** and the accelerating voltage provided to the ions prior to their passage through object slit **18.** Varying either the accelerating voltage or the electrostatic analyzer voltage permits detection of the kinetic energy sepctrum of the ions passing through slit **32.** Metastable ion spectra are of particular interest where a parent ion fragments to produce a daughter ion. The kinetic energy of the daughter ion will bear the same proportion to the kinetic energy of its parent ion as does its mass to its parent ion's mass. Thus by determining its kinetic energy and knowing the mass and kinetic energy of the parent ion, the mass of the fragment ions thus produced can be obtained.

While the particular embodiment of an adjustable beam height aperture described above operates by replacing one aperture of a fixed height composed of plates rigidly affixed to each other with an alternate aperture with a different fixed height, other embodiments may be readily envisioned. One such alternate would be to provide a single plate or shield above the ion beam plane and a second such shield or plate below the ion beam plane and have them adjustable with regards to each other and with regards to the ion beam plane, which would accomplish the purposes of the present invention.

What is claimed is:

1. A method, for use with a mass spectrometer having a source for producing an ion beam;

an ion collector; and

an analyzer located between said source and said collector which bends the path of the ions to be analyzed, thereby locating an ion beam plane, for altering the sensitivity of mass spectrometer while simultaneously having an opposite effect upon the resolution of said spectrometer comprising:

a. disposing first blocking means on one side of said ion beam plane;

b. disposing second blocking means on the opposite side of said ion beam plane from said first blocking means, the distance between said first and second blocking means perpendicular to the ion beam plane being the ion beam height; and

c. adjusting the ion beam height to any of at least two distinct values whereby an increase in resolution with consequent decrease in sensitivity can be achieved by decreasing the beam height to block out more ions which have been subjected to the fringing fields of the analyzer, and an increase in sensitivity with consequent decrease in resolution can be achieved by increasing the beam height to pass more ions which have been subjected to the fringing fields of the analyzer.

2. The method of claim **1** wherein the adjusting of said ion beam is accomplished by replacing said first and second blocking means with alternate first and second blocking means having a different distance between them perpendicular to said ion beam plane.

3. The method of claim **1** further comprising the step of adjusting said first and second blocking means with respect to said ion beam plane while maintaining said ion beam height constant.

4. The method of claim **1** wherein said analyzer comprises an electric sector followed by a magnetic sector and wherein the steps of disposing said first and second blocking means comprises locating said means for adjusting said ion beam height between said magnetic and electric sectors.

5. The method of claim **1** wherein said first and second blocking means are rigidly and permanently affixed to one another and wherein the step of adjusting said ion beam height comprises replacing said first and second blocking means with alternate blocking means.

6. The method of claim **5** wherein the step of replacing said first and second blocking means with alternate blocking means comprises replacing said first and second blocking means with alternate first and second blocking means.

7. The method of claim **5** wherein the step of replacing said first and second blocking means with alternate blocking means comprises replacing said first and second blocking means with means for blocking the total ion beam whereby metastable ion energy spectra may be obtained.

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