

June 3, 1958

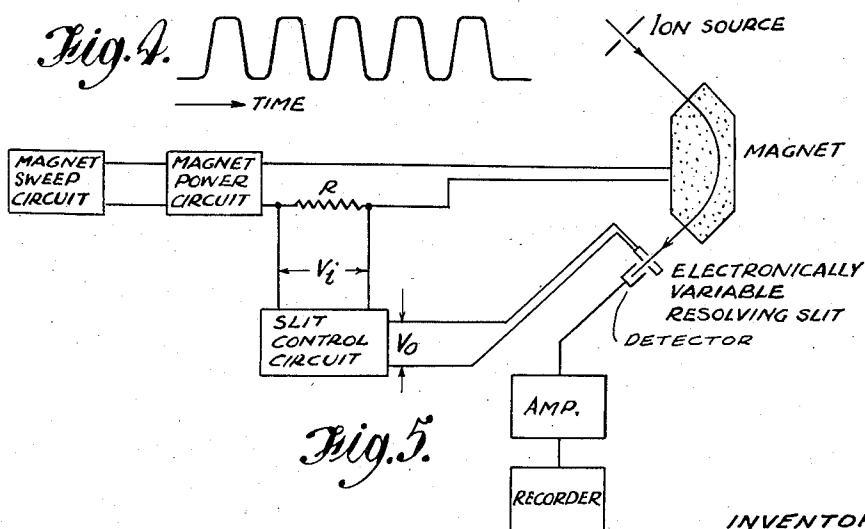
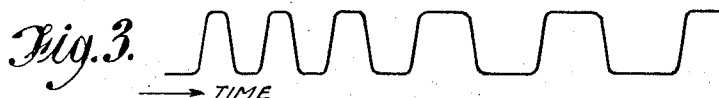
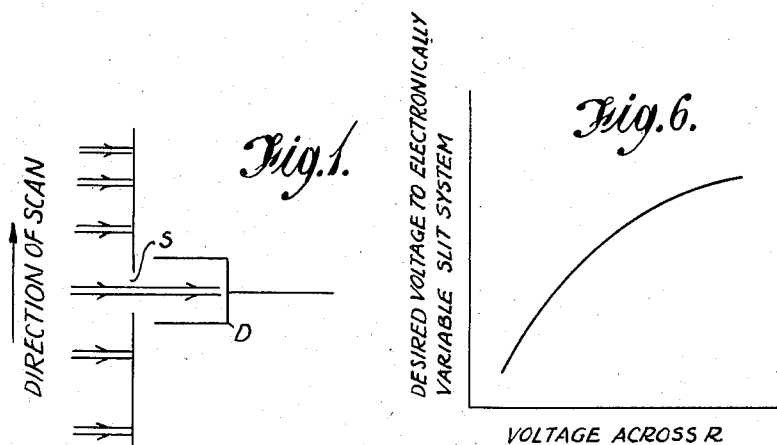
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2,837,653

MASS SPECTROMETERS

Filed Nov. 30, 1956

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 7.

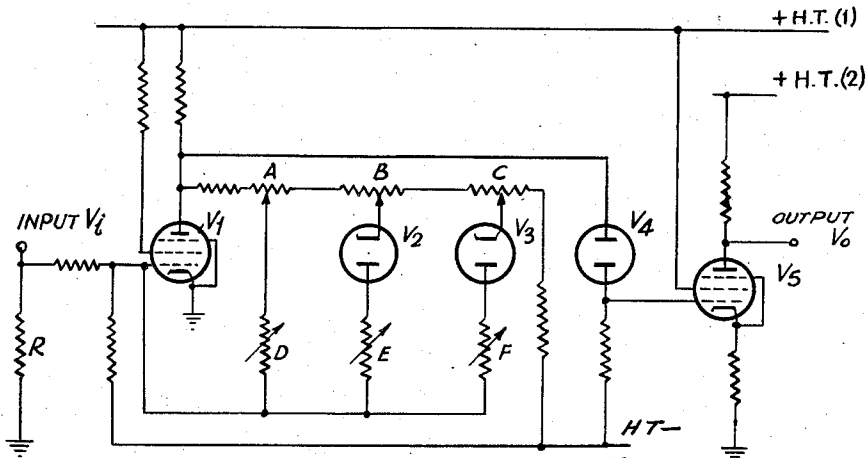


Fig. 11.

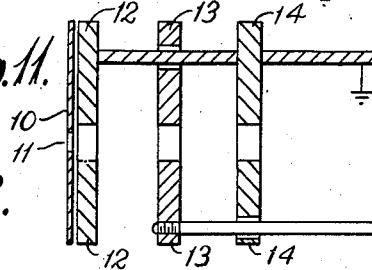


Fig. 8.

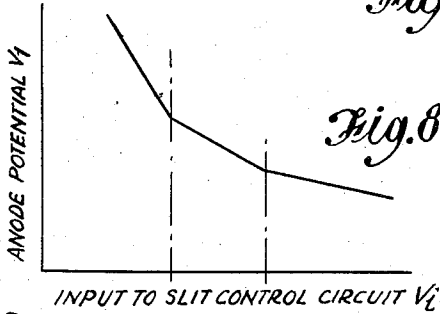


Fig. 10.

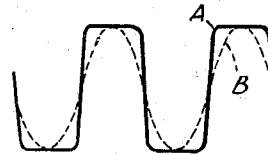
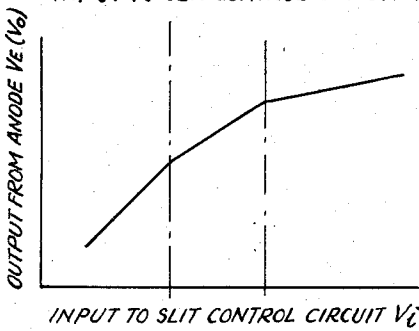


Fig. 9.



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1

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MASS SPECTROMETERS

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Application November 30, 1956, Serial No. 625,420

Claims priority, application Great Britain December 1, 1955

6 Claims. (Cl. 250-41.9)

This invention relates to mass spectrometers and has an important application in mass spectrometers in which the effective width of the resolving slit may be varied electrically.

A mass spectrometer is an instrument for analysing ionic radiation. The radiation is formed into a beam and projected through a magnetic field which diffracts it into a spectrum, the lighter ions being diffracted more than the heavy ones. The spectrum consists of a series of discrete lines of approximately equal width, which lines correspond to ions of different mass number.

A fundamental property of the spectrum is that although the line widths for different mass numbers are, to a first approximation, equal, the distance between consecutive lines is inversely proportional to the mass number, i. e. in space, the lines corresponding to ions of greater mass are closer together than those formed by the ions of small mass. Normally the mass spectrum is scanned across a resolving slit placed in front of a detector. This sweeping of the spectrum across the fixed resolving slit is done either by varying the ion accelerating voltage or by varying the magnetic field. The width of such a resolving slit is normally made greater than the width of the individual spectral lines in order that the total ion current at any one mass number can be made to pass through the slit and fall on the detector. The detector is usually an electrode connected to a sensitive amplifier which feeds a paper chart recorder. On this recorder discrete flat top peaks are registered provided that the width of the resolving slit is greater than the width of the spectral lines but less than the distance between consecutive spectral lines and provided also that the time response of the detector system is adequate for the scanning speed used.

It will be clear that a wider resolving slit can be tolerated at the lower mass number than at the higher ones and the main object of the present invention is to take advantage of this so as to provide a more rapid scan system than would otherwise be practical for a given amplifier and recorder system.

The object of the present invention is to provide an improved method of resolving the beam of ion in a mass spectrometer so as to obtain faster scanning.

According to the present invention a mass spectrometer comprises an ion collector with means for varying the width of the resolving slit of said collector inversely in accordance with the mass number of the radiation being received by said collector, together with means for contemporaneously varying the rate of scan of said resolving slit by the ion spectrum so that the time periods during which ions of different mass numbers reach the said collector are substantially of the same duration.

In order that the invention may be more clearly understood reference will now be made to the accompanying drawings, in which:

Figs. 1-4 illustrate graphically the results to be achieved with the invention.

Fig. 5 is a block diagram of one form of apparatus embodying the invention.

2

Fig. 6 shows a typical desired relationship between voltage across R and voltage fed to the electrically variable slit system.

Fig. 7 is an example of a possible slit control circuit. Figs. 8-9 are graphs illustrating the performance of specific parts of the apparatus of Fig. 7 and

Fig. 10—curve A: recorded spectrum for very slow scan; curve B: acceptable recorded spectrum for fast scan.

Fig. 11 is a diagrammatic view of a particular form of the adjustable resolving slit.

In the drawings, Fig. 1 shows graphically how the distance between the spectrum lines, with which the slit is scanned, vary progressively. When such a spectrum is scanned across the slit S placed in front of a detector D, the recording normally obtained will be of the kind shown in Fig. 2.

As a first step towards obtaining conditions for maximum scan speed it is desired to increase the slit width for the lower mass numbers so that the ratio of the peak top width to valley width is constant, and preferably unity, throughout the mass range to be covered. When this objective has been achieved the recorded spectrum will normally appear as shown in Fig. 3.

The second step is to arrange that the time periods for which ions of different mass number of reach the detector are of substantially the same duration. When this has been achieved the recorded spectrum will appear as shown in Fig. 4. It will be appreciated that now the peak shape at every mass number looks substantially the same to the amplifier and recording system. It is therefore easily possible to adjust the overall time for the scan to the minimum consistent with obtaining a given recording accuracy.

It will also be appreciated that whilst for convenience it is assumed that the direction of scan is from heavy to light elements clearly the converse could be employed and the invention is intended to cover such arrangements.

Fig. 5 shows a block diagram of a particular embodiment of the invention in which a constant paper speed pen-chart recorder and a magnetic scanning system are used. The effective width of the resolving slit is varied electrically, for instance, as in copending United States Application Serial No. 458,069, filed Sept. 24, 1954.

The slit control circuit output voltage (V_o) is fed to the electrically variable resolving slit system and thereby determines the effective width of the resolving slit. The slit control circuit input voltage (V_i) is the voltage drop across the resistor R which is in series with the magnet coils. As the spectrum is scanned across the resolving slit the experimental relationship between mass number and magnet current can be determined and in this way a relationship between mass number and voltage across R is obtainable. In another experiment the relationship between the voltage fed to the electrically variable slit system and the effective width of resolving slit is obtained and, since the desired width of resolving slit for each mass number is known from theory, it is therefore possible to establish a relationship between mass number and the voltage fed to the electrically variable slit system. As a final step there is constructed from this information a desired relationship between voltage fed to the electrically variable slit system and voltage developed across R; this may take the form shown in Fig. 6 and it is the purpose of the slit control circuit to produce this desired relationship between V_o and V_i .

It will be appreciated that the invention is not limited only to systems employing magnetic scan but could easily and in similar manner be adapted to one employing electrostatic scan in which the ion accelerating voltage rather than the magnetic field is varied.

One arrangement by means of which the required slit control potential is obtained is shown in Fig. 7 wherein V_1 is an amplifier valve to which variable negative feedback is applied. The input potential is obtained from the resistance R in the magnet supply circuit and when the potential is low, the anode voltage of V_1 is high so that the diodes V_2 and V_3 are not conducting. Some negative feedback is applied to V_1 by the resistor chain between its anode and grid. As the input voltage increases, the anode voltage falls and eventually permits V_3 to conduct. When this happens the negative feedback is increased, and the gain of the amplifier falls. With further increase of input the anode potential falls less quickly than before until V_2 conducts. The negative feedback is then further increased and the gain of the amplifier reduced still more. A graph of input against anode potential V_1 takes the form shown in Fig. 8. V_4 is a neon voltage stabiliser which acts as a voltage dropping device to lower the anode potential of V_1 to a suitable value to apply to the grid V_5 . V_5 also acts as a linear amplifier. When the voltage on the grid of V_5 is a minimum, the voltage output from the anode of V_5 is a maximum, and vice versa. The curve of input obtained from resistance R against output from the anode of V_5 is shown in Fig. 9 and it will be seen that it approximates to the desired curve of Fig. 6. The slopes and positions of the three straight lines of Fig. 9 can be adjusted by the potentiometers A, B, C, D, E and F in the feedback circuit of V_1 . In practice, it has not been found possible to find any sharp change in the slope of the curve and it does in fact approximate to the smooth curve required as in Fig. 6. Nevertheless the curve can be thought of as being in three sections and each section is adjustable by means of its associated two potentiometers.

It is also clear that more diodes could be used in the feedback circuit in order to obtain, if required, an even closer approximation to the desired curve.

The magnet sweep control circuit can be arranged to give varying rates of change of magnetic field with respect to time. These rates may not be linear with respect to time but, by experiment, can be adjusted so that the conditions of Fig. 4 would be obtained as closely as possible using a recorder with zero time constant. When the rate of scan is increased, the time constant of an actual recorder will be such that the true peak shape will not be traced. This is not important so long as the true maximum height and zero are obtained, i. e. so long as a short level portion is obtained both at maximum of peak and at minimum between peaks. This is indicated in Fig. 10 where curve A shows the actual spectrum obtained with a very slow scan and curve B shows the acceptable spectrum obtained with a fast scan. Under these circumstances, the fastest permissible scan of any section of the mass spectrum will be obtained.

According to a particular embodiment of the invention the adjustable resolving slit comprises a slit apertured plate together with an electrostatic lens which controls the cross sectional width of the resolving slit effective for the passage of the ion beam.

With reference to Fig. 11, in the particular embodiment of the invention the resolving slit comprises a plate 10 with slit aperture 11 and an electrostatic lens comprising the earthed slit apertured plates 12 and 14 together with the field forming slit apertured plate 13. Plate 13 is connected to an adjustable positive potential and is separated from plates 12 and 14. The focal length of the electrostatic lens is varied by altering the steady positive potential and this action varies the cross sectional width of the resolving slit effective for the ion beam.

It will be apparent that the above considerations apply to any system of recording.

What we claim is:

1. A mass spectrometer comprising means for project-

ing a beam of ions through a magnetic field whereby the beam is diffracted into a spectrum of a series of lines of ions of successive mass numbers, a collector for said ion beam comprising a detector and a plate, an edge to said plate defining a slit aperture, control means for scanning said beam across said slit aperture by altering the strength of said magnetic field, control means for varying the effective width of said slit aperture inversely in accordance with the mass number of the ions being received by the collector, and means for varying the two said control means so that the time period during which ions of any one mass number reach the detector is substantially of the same duration for all ions.

2. A mass spectrometer comprising means for projecting a beam of ions through a variable magnetic field thereby diffracting the beam into a spectrum of a series of lines of ions of successive mass numbers, a collector for said ion beam comprising a detector and a plate, an edge to said plate defining a slit aperture, an electrostatic lens adjacent to said plate and means for controlling said lens so as to vary the effective width of said slit aperture inversely in accordance with the mass number of ions being received by said detector.

3. A mass spectrometer comprising means for projecting a beam of ions through a variable magnetic field thereby diffracting the beam into a spectrum of a series of lines of ions of successive mass numbers, a collector for said ion beam comprising a detector and a plate, an edge to said plate defining a slit aperture, and an electrostatic lens adapted to vary the effective width of said slit aperture and control means for said electrostatic lens and means for supplying said control means with a voltage proportional to the current producing the said magnetic field.

4. A mass spectrometer comprising means for projecting a beam of ions through a variable magnetic field thereby diffracting the beam into a spectrum of a series of lines of ions of successive mass numbers, a collector for said ion beam comprising a detector and a plate, an edge to said plate defining a slit aperture, control means for varying the effective width of said slit aperture and means for supplying said control means with a voltage proportional to the current producing said variable magnetic field.

5. A mass spectrometer comprising means for projecting a beam of ions through a variable magnetic field thereby diffracting the beam into a spectrum of a series of lines of ions of successive mass numbers, a collector for said ion beam comprising a detector and a plate, an edge to said plate defining a slit aperture, means for varying the effective width of said aperture and electronic control means controlling said means for varying said aperture, said control means comprising a thermionic amplifier with variable negative feedback to give the required characteristic output.

6. A mass spectrometer comprising means for projecting a beam of ions through a variable magnetic field thereby diffracting the beam into a spectrum of a series of lines of ions of successive mass numbers, a collector for said ion beam comprising a detector and a plate, an edge to said plate defining a slit aperture and an electrostatic lens adjacent to said plate and adapted to vary the effective width of said slit aperture, control means for said electrostatic lens, means whereby said control means are controlled by the current producing said magnetic field so as to cause the effective width of said slit aperture to vary inversely in accordance with the mass number of the ions being received by said detector, control means for varying the rate of scan of said slit aperture by said ion beam and means for modifying said two control means contemporaneously so that the time period during which ions of any one mass number reach the detector is substantially of the same duration for all ions.

No references cited.