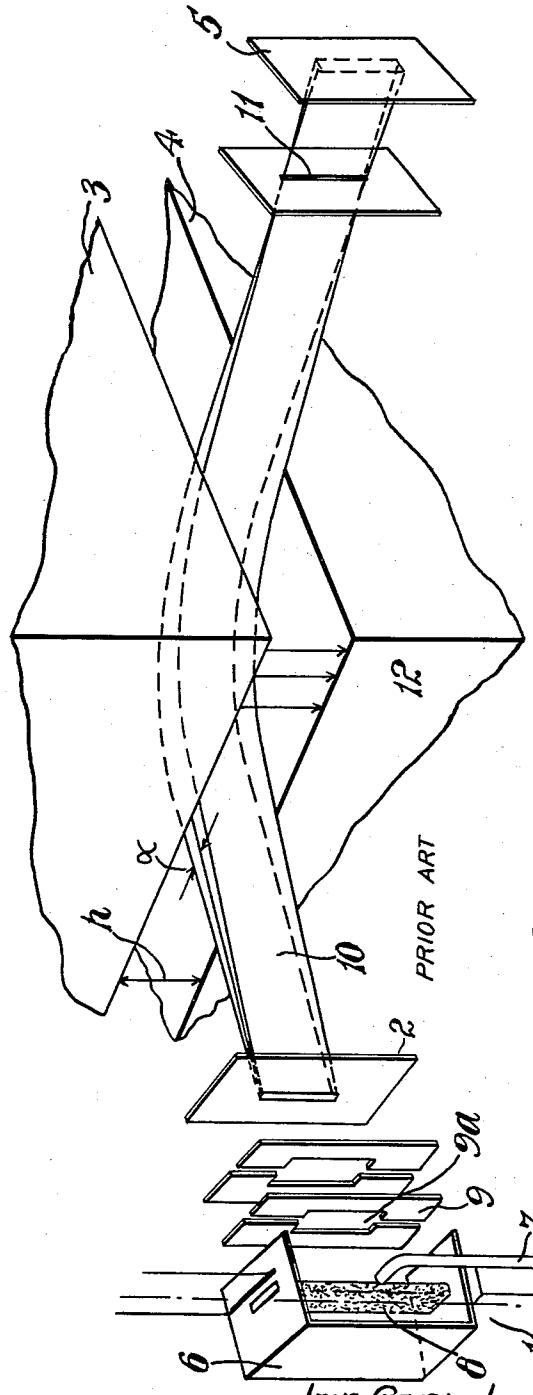
Feb. 25, 1964 J. GEERK ETAL 3,122,631

APPARATUS FOR FOCUSING A LINE TYPE ION BEAM ON A MASS SPECTROMETER ANALYZER

Filed Feb. 2, 1961 3 Sheets-Sheet 1



PRIOR ART

Fig. 1

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3 Sheets-Sheet 2

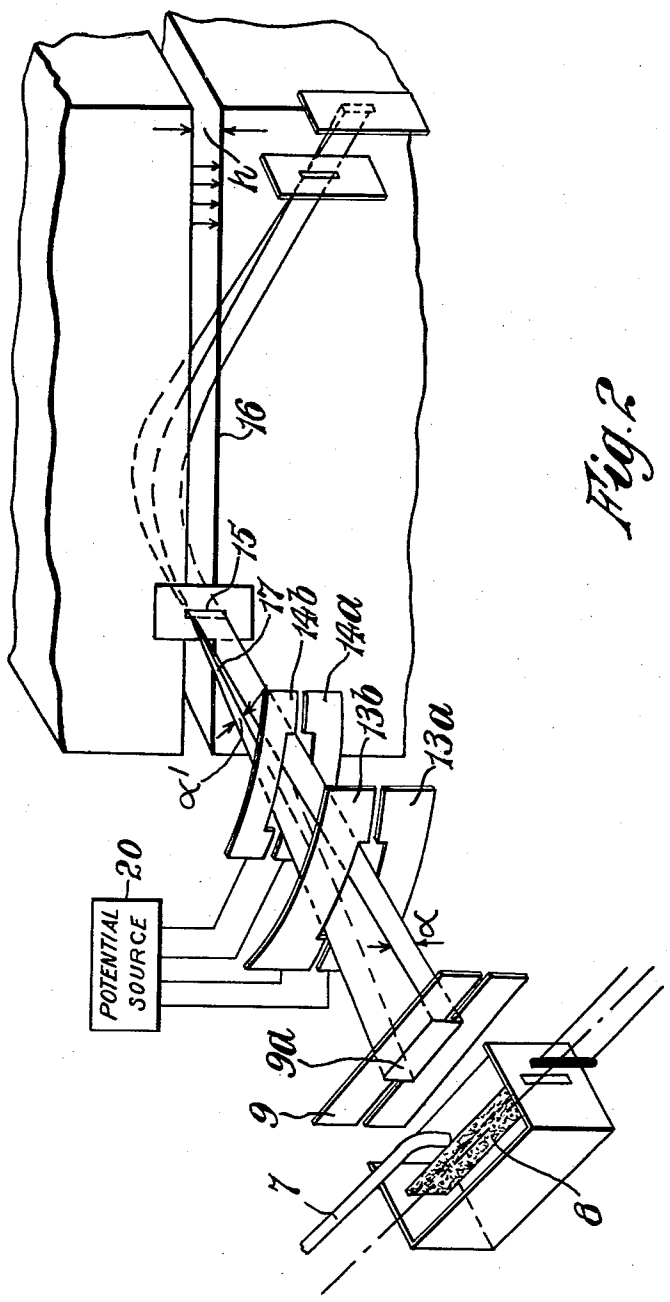

Fig. 2

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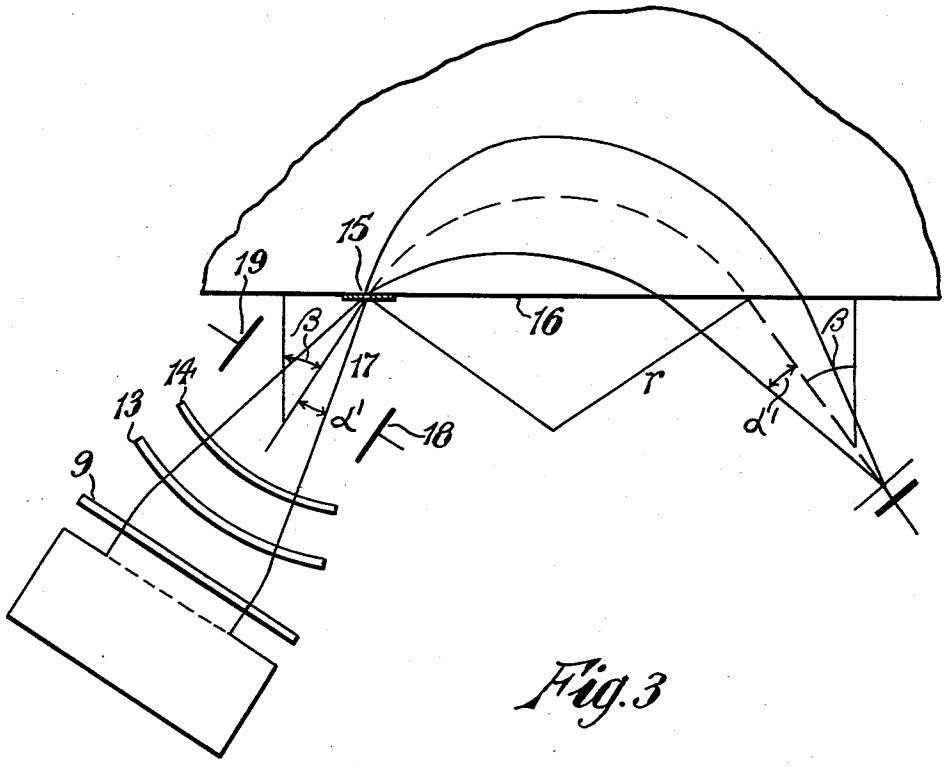

Fig. 3

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APPARATUS FOR FOCUSING A LINE TYPE ION BEAM ON A MASS SPECTROMETER ANALYZER

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7 Claims. (Cl. 250—41.9)

This invention relates to an impulse spectrometer, particularly a mass spectrometer, having an ionization zone in the form of a line or band, and a magnetic field, focusing in a higher order, as the analyzer. Ordinary impulse spectrometers are so constructed that the band-shaped ionization zone is directed parallel to the direction of the magnetic lines of force of the analysing magnetic field. In this arrangement the ion yield is limited to the size of the air gap in the magnet field. In order to avoid this disadvantage, Bernhard has disposed the band-shaped ionization zone perpendicularly to the direction of the magnetic lines of force of the analysing magnetic field, and at the same time the electrical lens system provided for accelerating and bundling the ion rays were constructed in such a manner that the projections of the ion rays starting from the ionization band form parallel straight lines to one another on a plane at right angles to the magnetic lines of force, until they enter the magnetic field. The focusing action of the analyzer is then substantially dependent on the accuracy of this parallelism. Since this parallelism can be achieved only approximately with means known hitherto, the resolving power of an impulse spectrometer of this type described in "Angewandte Physik" (Applied Physics), Springer Verlag, Berlin, Gottingen, Heidleberg, for February 1957, does not comply with the requirements imposed in most cases.

According to the invention a high ion yield can be achieved without impairing the resolving power in an impulse spectrometer having an ionization zone in the form of a line or band and a magnetic field, focusing in a higher order generally as described in Duckworth, Mass Spectroscopy 22–24 (University Press, Cambridge, 1958), as the analyzer, by disposing the ionization zone perpendicularly to the direction of the magnetic field and providing an electrode system focusing on a point from the ionization zone to the entry into the magnetic field.

One embodiment of the invention is illustrated by way of example in the accompanying drawing, in which:

FIGURE 1 shows diagrammatically the construction and mode of operation of a mass spectrometer of conventional design,

FIGURE 2 shows similarly the construction and mode of operation of a mass spectrometer according to the invention, and

FIGURE 3 shows a plan view corresponding to FIGURE 2.

The mass spectrometer of conventional design diagrammatically illustrated in FIGURE 1, consists essentially of an ion source 1 with ion optical system 2 defining an inlet gap or slit, a mass analyzer in the form of an electromagnet with pole shoes 3, 4 and an ion collector 5 with measuring apparatus connected thereto.

The ion source consists of a metal box 6 of oblong shape, into which the gas to be analysed is introduced through a pipe 7. Ionization of gas particles is effected by electron bombardment, for example along a band 8. Ions are drawn out of the ionization box 6 by means of a drawing or acceleration electrode 9 with gap 9a, and are fed in the form of a pencil beam of rays 10, approximately of the height of the air gap h between the

pole shoes 3 and 4 to the homogeneous magnetic field between the said pole shoes. In the magnetic field the ions are diverted with different intensity in dependence on their mass, so that the outlet a focusing of the ions separated according to masses is obtained. Through the variation of the magnetizing current, the ions of different mass can be fed separately through an outlet gap or slit 11 to the collector 5 and the analyzer.

In this known mass spectrometer the band-shaped ionization zone 8 is disposed parallel to the direction of the lines of force 12 in the magnetic field. Consequently, it is only from a length of the ionization band which corresponds to the height h of the air gap that ions can in practice be drawn off and used for analysis.

In order to increase this ion yield, in the mass spectrometer according to the invention illustrated in FIGURES 2 and 3 the ionization zone 8 is disposed perpendicularly to the direction of the lines of force, and between the ion source and the magnetic field an electrode system is provided through which the ions coming from different length elements of the ionization band are focused at one point or to a line of the length h. In a similar manner to the electrode system of the conventional mass spectrometer illustrated in FIGURE 1, a drawing electrode 9 with outlet gap 9a is provided for this purpose.

The ions accelerated in the direction of the outlet gap or window 9a leave this gap in the form of a substantially parallel pencil beam of rays with a small opening angle α corresponding to the aperture of the ion source.

A focusing electrode system having electrodes 13 and 14 (FIG. 3) is made to act on this ion ray pencil beam which is directed substantially parallel. This electrode system is so constructed that it produces an electric force line field as exactly radial as possible, and at the focusing center of which an inlet gap or slit 15 to the analyzing magnetic field is situated. This inlet gap is at or very near the magnetic field boundary.

For the purpose of producing the electrical radial field, the electrodes 13 and 14 are constructed as cylindrically curved concentric metal sheets having a common axis lying in the inlet gap 15. They each consist of two portions 13a 13b and 14a 14b (FIG. 2) divided symmetrically relative to the radial middle plane, these portions having separate voltage supply provided by potential source 20 so that by the application of different potentials further deflections and corrections can be made in the direction perpendicular to the focusing plane.

In order to obtain exact focusing despite the different inclinations of the directions of incidence of the ions in relation to the boundary line 16 of the magnetic field—the inclinations differing by the angle $2\alpha'$, a magnetic field focusing in a higher order is provided. For this purpose the magnetic field and ion optical system are so disposed in relation to one another that the centers of the gap openings lie on a straight line 17 which goes through the position of the inlet gap 15 and forms with the perpendicular to the magnetic field boundary 16 an angle $\beta=35°16'$ (see FIGURE 3).

For any necessary deflection of the ion pencil beam in the direction perpendicular to the inlet gap 15 before entry into the magnetic field, an electrode pair 18, 19 is provided which lies between the electrode 14 and the inlet gap 15 to the magnetic field and can be connected to suitable deflection voltages.

Many modifications and other constructions are possible within the scope of the invention. In particular, instead of or in addition to a concentric curvature of the electrodes provided, flat or less curved or irregularly curved electrodes with portions of different potentials

may also be provided for the purpose of producing a focusing radial field.

We claim:

1. Spectrometric apparatus comprising,

spaced pole piece means defining a magnetic field aligned along a first direction,

means adjacent to the region between said pole piece means defining an inlet gap having its length aligned along said first direction,

means adjacent to the latter region but spaced from said inlet gap defining means defining an outlet gap having its length aligned along said first direction,

means defining a line source of ions outside said region aligned generally perpendicular to said first direction,

accelerating electrode means between said source and said inlet gap defining means for directing rays of ions from said source toward said inlet gap,

focusing electrode means between said accelerating electrode means and said inlet gap defining means for establishing an electric field focusing said rays substantially into a line substantially coinciding with said inlet gap when said ions pass through said gap,

and collector means separated from said region by said outlet gap defining means for receiving said ions after passing through said region and said outlet gap.

2. Spectrometric apparatus in accordance with claim 1 wherein said focusing electrode means comprises a curved electrode defining a surface characterized by radii normal to said surface passing through said inlet gap.

3. Spectrometric apparatus in accordance with claim 2 wherein said focusing electrode means comprises a plurality of said curved electrodes spaced between said accelerating electrode means and said inlet gap.

4. Spectrometric apparatus in accordance with claim 1 wherein a substantially straight line at least partially defines said region,

and the center line of said rays subtends an angle with the perpendicular to the latter straight line of substantially 35°16′.

5. Spectrometric apparatus in accordance with claim 2 wherein said curved electrode comprises two spaced segments symmetrical about the radial middle plane included by said rays,

and means for applying different potentials to said segments.

6. Spectrometric apparatus in accordance with claim 3 wherein each of said curved electrodes comprises two spaced segments symmetrical about the radial middle plane included by said rays,

and means for applying different potentials to each of said segments.

7. Spectrometric apparatus in accordance with claim 1 and further comprising,

means for deflecting said rays along the direction of said line source of ions.

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