

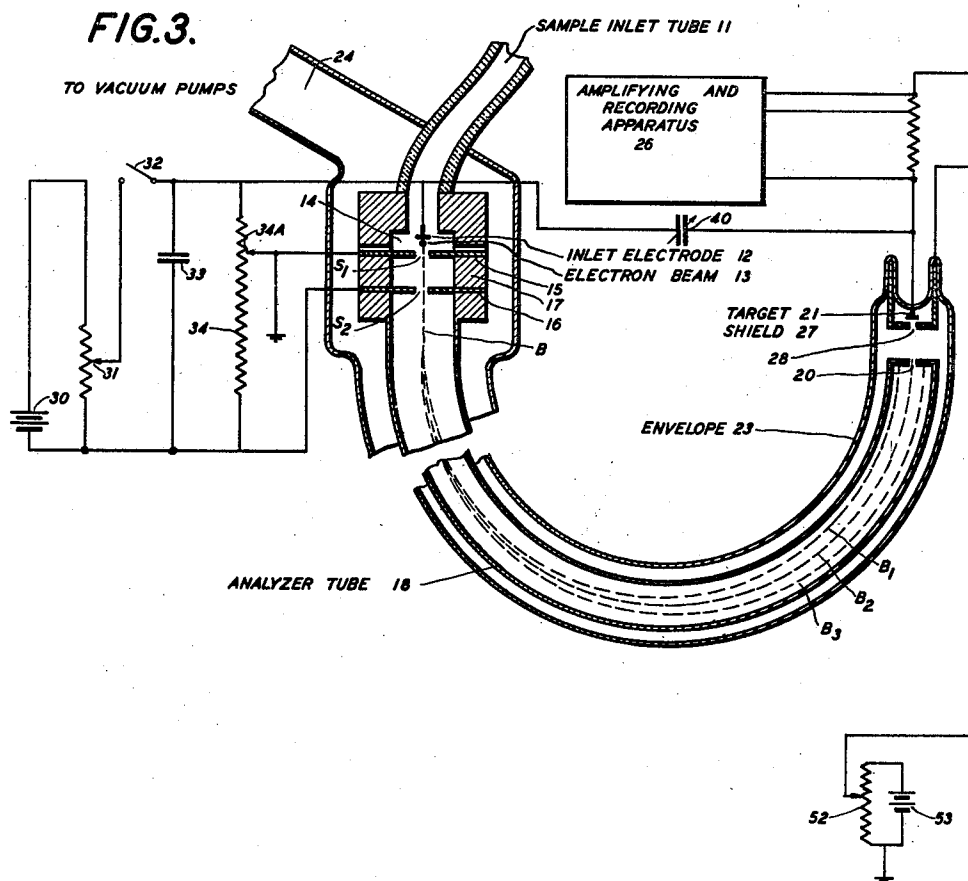
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MASS SPECTROMETER

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2 SHEETS—SHEET 2



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MASS SPECTROMETER

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This invention is concerned with mass spectrometers and provides improvements which permit the suppression of so-called "ghosts" on a mass spectrogram and also the minimizing of "zero shift." Moreover, the invention makes it possible to determine the mass spectrum of only those ions having kinetic energy in excess of a given amount and thus permits determination of the energy distribution of ions produced from a sample. Although applicable to mass spectrometers in general, it is particularly useful to those of the type of which sorting of ions in the analyzer is conducted in a substantially constant magnetic field, focussing of ions on the collector electrode being accomplished by variation of the potential which propels the ions toward the collector.

A mass spectrometer is an apparatus for ionizing molecules and sorting them in a magnetic field according to specific mass. In general, it comprises an ionization chamber in which a heterogeneous mixture of molecules is ionized, usually by electron bombardment or by thermal effect, an analyzer in which a magnetic field is established, a plurality of electrodes for impressing a potential on the ions in the chamber and propelling them as a heterogeneous beam into the analyzer (wherein the ions are separated into a plurality of divergent homogeneous beams), a target or collector electrode at the exit of the analyzer, means for focussing any one of the homogeneous beams on the target, either by varying the propelling potential or the magnetic field, and means for recording and amplifying the current collected at the target. The currents corresponding to the several homogeneous ion beams are indices of the abundance of each of the several kinds of ions formed from the sample. The record of the several currents is a mass spectrum or spectrogram.

The mass spectrometer is adaptable to both qualitative and quantitative chemical analysis, and a typical mass spectrogram produced by a recording galvanometer comprises a series of vertical peaks rising along a horizontal base or zero line at points corresponding respectively to the masses of the several ions created from the sample. The height of each peak is (or should be) a quantitative measure of the amount of the corresponding kind of ion. However, in many instances, the mass spectrogram is complicated by the presence of "ghosts," i. e. small peaks, probably due to the presence of metastable ions or to ions that have been slowed through collision with occluded gas molecules on interior metallic

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surfaces of the spectrometer and consequently form so-called "secondary rays." See "Mass Spectra and Isotopes" by Aston, second edition, 1942 (Longmans, Green & Co.) pp. 61-63. Sometimes the ghosts appear separately as small relatively wide peaks or bumps rising from the baseline. At other times, the ghosts coincide with and mask or increase "true" peaks that represent identifiable stable components. At still other times, the ghost takes the form of a very wide shallow peak or bump that overlies several true peaks, thus giving the impression that the base or datum line has risen, and again complicating the measurement of true peak heights. In short, since the ghosts may appear separately or overlapping true peaks, they interfere with accurate interpretation of mass spectra by giving the false impression that the sample contains a small proportion of a component which actually is absent or, in the case of overlap, an excessive value for the quantity of a component that is present.

As a result of my investigations, and irrespective of theories as to what causes "ghosts," I have developed improvements in mass spectrometry which permit the elimination of ghosts in a mass spectrum and also the elimination of base line shift, which, as indicated above, is believed to be merely another form of ghost.

As I have already indicated, the ions produced in the ionization chamber are propelled by electrical potentials established between a plurality of electrodes disposed in the path of the ion beam. A spectrometer may be constructed with only two such electrodes; but in order to form narrow beams which are easily focussed on the target, more than two propelling electrodes should be employed. For example, a spectrometer may have a pusher electrode in the ionization chamber itself, an intermediate electrode having a first slit (S_1) at the exit of the ionization chamber and a terminal electrode at the entrance of the analyzer having a second slit (S_2) in line with S_1 and the pusher electrode. A potential established between the pusher and the intermediate electrode forces the ions to flow out of the ionization chamber through the aperture S_1 . Additional potential impressed between the intermediate and terminal electrodes further accelerates the ions and propels them through S_2 into the analyzer. The two slits aid in collimating the beam passing into the analyzer. The potentials impressed between the pusher and S_1 and between S_1 and S_2 (adjacent the entrance to the analyzer) should be in the same di-

rection, so as to aid each other in propelling the ions, and customarily the pusher is positive with respect to both S_1 and S_2 , S_2 being perforce negative with respect to S_1 . However, in such an arrangement either S_1 or S_2 (i. e. the electrodes in which they are disposed) may be at ground potential, and there are advantages to both such arrangements. My invention is applicable to either.

I have discovered that by providing an auxiliary potential producing means for imposing in the neighborhood of the target an auxiliary potential opposing the movement of ions from the analyzer to the target, it is possible to prevent the appearance of ghosts. Thus, by providing an interconnection between the circuit which supplies the propelling potential for the ions and the target or a suppressor grid disposed in the front of the target in the path of the ions issuing from the analyzer with auxiliary potential producing means in the interconnection, ghosts may be eliminated. There should be means for suitably adjusting the potential at the target (Fig. 3) or grid (Figs. 1 and 2). By suitably adjusting this potential, it is possible to prevent ions that have no kinetic energy at the point of their formation, say in the path of the electron beam in the ionization chamber, from reaching the target. In such case, a spectrum is produced from only those ions that have initial kinetic energy. Such a result is useful in analyzing the conditions under which ionization occurs. Moreover, by adjusting the potential at the target or grid to other values, it is possible to suppress ions having less than any given kinetic energy so that the spectrum produced represents only those ions having kinetic energy above a certain level. This is desirable, not only for the determination of energy distribution of an ion beam but also because in many instances it permits a spectrum to be simplified by the elimination of certain peaks which may be without significance in the particular case. This permits more rapid calculation of numerical results from the spectrogram.

Especially when the spectrometer is of the type in which the magnetic field is kept constant and the shifting of beams with respect to the target accomplished by variation of the propelling potential, it is desirable to connect a condenser, preferably a variable one, between the target and the circuit which produced the propelling potential. In this fashion, the capacity coupling between the target and suppressor grid in one case (or between the target and the end of the analyzer tube if no suppressor grid is interposed) may be neutralized. This prevents erratic creep of the baseline of the spectrum.

In a mass spectrometer in which an intermediate propelling electrode (say the electrode containing S_1) is grounded, the condenser may be connected directly between this electrode and the target.

If the terminal propelling electrode (say that containing S_2 and connected to the analyzer) is grounded, the condenser should be connected into the circuit supplying the propelling potential with a resistance in the circuit between the condenser and the ground. In such an arrangement, the suppressor grid is placed between the analyzer and the target, this suppressor grid being connected to a portion of the circuit that is positive with respect to the terminal electrode, i. e. either to the intermediate electrode containing the slit S_1 , or to a point in the network between the pusher and the intermediate electrode through a

battery, means being provided for varying the potential at the suppressor grid, as described hereinbefore.

In either arrangement, i. e. with S_1 or S_2 grounded, the target preferably is protected by a shield or grid. In most types of apparatus, the shield should be connected to ground. For example, in a mass spectrometer in which the target is connected to ground through a high resistance which is shunted by an amplifier that is a part of the indicating or recording apparatus, the shield should be connected directly to ground, by-passing the large resistance. In such an arrangement the condenser which connects the target to the circuit supplying propelling potential should be connected ahead of the large resistance shunted by the amplifier.

These and other aspects of my invention are described in detail hereafter with reference to the accompanying drawings in which:

Fig. 1 is a schematic diagram illustrating a mass spectrometer equipped for the practice of the invention with a terminal propelling electrode, i. e. that at the analyzer, connected to ground:

Fig. 2 is a diagram illustrating a modification of the arrangement of Fig. 1; and

Fig. 3 is a further diagram illustrating the application of the invention to a spectrometer, having an intermediate propelling electrode grounded.

Referring to Fig. 1, the spectrometer per se comprises a cylindrical head or block 10, the rear of which connects with a sample inlet tube 11 made of insulating material. Within the head, in the path of the gas from the inlet tube, there is a pusher or inlet electrode 12 in the form of a conductive plate insulated from the rest of the apparatus.

An electron beam 13 is produced within the head in the space immediately below the pusher by means of an electron gun (not shown). The space in the head in which the electron beam passes is known as the ionization chamber 14. The front of the ionization chamber is formed by an intermediate propelling or collimating electrode 15 which is electrically connected to the head and is provided with a slit S_1 that is substantially in line with the pusher electrode and with the path of electron beam. A propelling or collimating electrode 16 provided with a second slit S_2 in line with the slit S_1 and the electron beam is spaced in front of the first collimating electrode by a ring 17 of insulating material.

The head of the apparatus is connected to an analyzer tube 18 through the slit S_2 . The analyzer tube in this particular type of spectrometer is bent in a semi-circle and encloses an analyzer chamber 19.

In the operation of the spectrometer, a sample of gas to be analyzed is admitted to the ionization chamber through the gas inlet tube. Molecules of the gas sample are bombarded by electrons of the beam and are thus ionized. The resulting ions are propelled as an unsorted ion beam into the analyzer tube by means of electrical potentials established between the pusher and the two collimating electrodes. Thus, the slits S_1 and S_2 through which the ions pass cause the ions to emerge into the analyzer as a thin ribbon, a cross-section of which is defined approximately by the cross-section of the slits. In the analyzer the unsorted ion beam is separated into a plurality of diverging homogeneous ion beams B_1 , B_2 , B_3 by means of a magnetic field produced in the analyzer tube as well as in the

head of the apparatus by an electro-magnet (not shown).

Any one of the diverging ion beams may be focused on an exit slit 20 at the far end of the analyzer tube so that it passes therethrough and strikes an ion collector or target 21.

The head 10 of the spectrometer and the attached analyzer tube 18 are enclosed within an envelope 23 through the wall of which the sample inlet tube projects. A high degree of vacuum is maintained within the envelope by means of vacuum pumps (not shown) connected to a gas outlet 24.

The target or collector electrode is connected to ground through a high resistance 25. This resistance is shunted by an amplifying and indicating or recording apparatus 26. Preferably, this amplifier is a current amplifier of the negative feed-back type so as to minimize the effect of the high resistance.

Within the envelope and substantially surrounding the target is a metallic shield 27 in the form of a cylinder with a disk at its end interposed between the end of the analyzer tube and the target. This disk has an aperture or slit 28 in line with the target and the exit slit of the analyzer tube.

The electrical circuit which produces the propelling potentials within the head of the mass spectrometer is shown at the left of Fig. 1.

A battery or other direct current supply 30 is connected in an energizing network to the ends of a potentiometer 31. The positive end of this potentiometer and its slider are connected through a switch 32 in this network to a condenser 33. The negative end of the potentiometer 31 is connected to the opposite side of condenser 33. A potential dividing network is connected across this condenser and takes the form of a potentiometer 34 connected in series with a second resistance 35. A lead connected intermediate the resistances 34 and 35 is connected to the terminal propelling electrode 16 and to ground. The potentiometer 34 has a slider 34A which is connected to the intermediate propelling electrode 15, which contains the slit S₁. Since the terminal propelling electrode 16 is electrically connected to the analyzer tube, this latter is also grounded.

The pusher electrode is connected to the potential dividing network between the condenser and potentiometer 34. This represents conventional means for connecting a power supply to the electrodes of a mass spectrometer and thus forms no part of the present invention. Substantially similar means are described and illustrated in United States Letters Patent 2,413,668 issued to me on December 31, 1946.

The path of the ion beams B₁, B₂, B₃ with respect to the exit slit and the target may be changed either by varying the magnetic field or the propelling potentials. The latter method is preferable and may be practiced as follows:

The switch 32 in the energizing network is closed and the condenser 33 is charged to an appropriate level. Then the switch is opened and the condenser is permitted to discharge through the potential dividing network and through the propelling electrodes in the head of the spectrometer. In this way, the propelling potentials between the several electrodes gradually decay while maintaining relative values. The potentials in the head may be adjusted relative to each other by suitably adjusting the slider of the potentiometer 34, such adjustments

being made to give optimum results at the target.

A variable condenser 40 is connected from the target to the circuit supplying the propelling potentials. The condenser is connected between the target and the large resistance 25 in such fashion that the path to ground is via the target, the condenser and the resistance 35.

A suppressor grid 41 is interposed between the end of the analyzer and the shield surrounding the target. It is apertured to permit the passage of ion beams, this aperture being in line with the exit slit and the slit 28 in the shield. The suppressor grid is connected to the intermediate electrode 15, this connection being made through an auxiliary potential source which, in the instant case, comprises a potentiometer 50 shunted by a battery 51. By varying the setting of the slider of the potentiometer more or less of the auxiliary potential may be impressed on the suppressor grid with the advantages already described. Thus, the suppressor grid may be maintained at the potential of the intermediate electrode or adjusted to suit operating conditions for the suppression of ions having more or less kinetic energy.

The apparatus of Fig. 2 is the same as that of Fig. 1, like parts being indicated by like numbers, save in the following particulars: The suppressor grid, instead of being connected to the intermediate electrode, is connected into the network which supplies the propelling potential. Specifically, the suppressor grid is connected through the slider of the potentiometer 50 (the potentiometer being shunted by a battery 51) through a tap 43 which is connected to the upper portion of the potentiometer 34 below a small portion 34B of the resistance of this potentiometer. The position of the tap 43 is chosen to take off to the suppressor grid a potential approximating that existing in the ionization chamber in the region of the electron beam. This latter potential depends upon the geometry of the ionization chamber. If the path of the electron beam is halfway between the pusher and the intermediate electrode, the potential at that point will be the average of the respective electrodes, so that the resistance 34B should be about equal to the resistance 34C between the tap 43 and the slider 34A. With this arrangement, even though no auxiliary potential be introduced from the battery 51, ions that lack initial kinetic energy will be suppressed.

To summarize, the result of the circuits illustrated in Figs. 1 and 2, the battery 51 or other D. C. potential source may be employed to produce at the suppressor grid a current of such strength, direction and potential that it just repels the ions responsible for ghosts and prevents them from passing through the grid toward the target. The same circuit arrangements permit adjustment of the potential at the suppressor grid to a value such that only those ions with initial kinetic energy will pass to the target. Other adjustments may be made so that only those ions having certain amounts of kinetic energy will pass the grid and strike the target.

The apparatus of Fig. 3 varies in several particulars from those of Figs. 1 and 2, but in general is adapted to accomplish the same purpose. Parts that are common to the three types of apparatus are indicated by like numbers. However, it should be noted that the condenser 40 is directly connected between the target and the inlet or pusher electrode, instead of being connected to ground through the resistance 35. Secondly,

the intermediate electrode 15 containing the slit S_1 is grounded and the terminal propelling electrode 16 containing the slit S_2 is made negative with respect to the intermediate electrode. The analyzer tube is electrically connected to the terminal propelling electrode and is at the same potential. Thirdly, the suppressor grid is eliminated and an auxiliary potential to oppose movement of certain ions from the analyzer to the target is imposed on the target itself, by means of a variable auxiliary D. C. potential source connected between the target and ground. Thus, the slider of a potentiometer 52 is connected to the target and this potentiometer is shunted by a battery 53, the lower end of the potentiometer (as shown in Fig. 3) being connected to ground. By appropriately setting this potentiometer 52, the potential at the target may be set to a value appropriate for the particular type of ion suppression required.

In all three types of apparatus illustrated, an electromagnet (not shown) is provided. The analyzer tube and the ionization chamber are both disposed between the poles of the magnet so that the lines of force between the poles are substantially perpendicular to the plane of the drawings. This is a conventional and well-understood type of structure. In this general type, focussing, i. e. shifting of the homogeneous beams with respect to the exit slit of the analyzer, may be accomplished by varying the magnetic field or, as described hereinbefore, by varying the propelling potential. Variation of the propelling potential is, however, preferred since variation of the magnetic field when it encloses the ionization chamber may bring about erratic results.

In the operation of the various apparatus illustrated, the capacitance of the condenser between target and propelling circuit is adjusted to neutralize the capacity coupling between the target and suppressor grid (Figs. 1 and 2) or between the target and the end of the analyzer tube (Fig. 3). In general, this adjustment will serve thereafter for the analysis of subsequent unknown samples and readjustment will seldom be necessary.

The principles underlying the suppression of ghosts with the several types of apparatus of the invention are as follows:

A metastable ion may be formed by electron bombardment, for example when a molecule of normal butane of mass 58 is subjected to bombardment, it may lose an electron and sometimes becomes metastable, so that it may later lose a methyl group and attain mass 43. When this methyl group is lost in the vicinity of the second slit, which is experimentally shown to be the case, kinetic energy of the ion is reduced and the resulting ion behaves as though it had mass 32, in the sense that it takes the same path in the analyzer as do oxygen ions. Such ions, however, move with less energy than do the oxygen ions.

"Slow" ions may result from inelastic interaction with the fields of the instrument, including fields of very small dimension in the vicinity of the walls of the instrument, or of other ions, with the result that they travel with low energy as a secondary beam in the analyzer.

Like the secondary beams formed of metastable ions, the beam of slow ions may coincide with a beam to be detected or it may occur separately.

Both types of secondary beams are characterized by lower energy than the beams to be detected and may be prevented from reaching the

target by an opposing potential maintained in the neighborhood of the target. This opposing potential is obtained by means of any one of the three combinations illustrated, in that a potential of required value opposing that propelling the ions is produced at the target or at the suppressor grid.

I claim:

1. In a mass spectrometer having an ionization chamber, means for ionizing molecules in the chamber, an analyzer, a circuit for producing a potential to propel ions formed from the molecules as a beam into the analyzer, means for sorting the ions of the beam in the analyzer according to specific mass and a target for catching the sorted ions, the combination which comprises means connected to the circuit for producing in the neighborhood of the target a potential opposing those of the sorted ions, and means for varying the opposing potential.

2. In a mass spectrometer having an ionization chamber, means for ionizing molecules in the chamber, an analyzer, a circuit for producing a potential to propel ions formed from the molecules as a beam into the analyzer, means for sorting the ions of the beam in the analyzer according to specific mass, and a target for catching the sorted ions, the combination which comprises shielding means disposed around the target, auxiliary potential-producing means connected to the circuit for producing in the neighborhood of the target a potential opposing the movement of the sorted ions toward the target and including an auxiliary electrode disposed adjacent the target exteriorly of said shielding means.

3. In a mass spectrometer having an ionization chamber, means for ionizing molecules in the chamber, an analyzer, a circuit for producing a potential to propel ions formed from the molecules as a beam into the analyzer, means for sorting the ions of the beam in the analyzer according to specific mass, and a target for catching the sorted ions, the combination which comprises shielding means disposed around the target and connected to ground, a variable condenser through which the target is connected to the circuit, and auxiliary potential-producing means connected to the circuit for producing in the neighborhood of the target a potential opposing the movement of the sorted ions toward the target.

4. In a mass spectrometer having an ionization chamber, means for ionizing molecules in the chamber, an analyzer, a circuit for producing a potential to propel ions formed from the molecules as a beam into the analyzer, means for sorting the ions of the beam in the analyzer according to specific mass, and a target for catching the sorted ions, the combination which comprises shielding means disposed around the target, a condenser connected between the target and the circuit, auxiliary potential-producing means connected to the circuit for producing in the neighborhood of the target an auxiliary potential opposing the movement of the sorted ions toward the target, and means for varying the auxiliary potential.

5. In a mass spectrometer having an ionization chamber, means for ionizing molecules in the chamber, an analyzer, a circuit for producing a potential to propel ions formed from the molecules as a beam into the analyzer, means for sorting the ions of the beam in the analyzer according to specific mass, and a target for catching

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the sorted ions, the combination which comprises a resistance through which the target is connected to ground, indicating means shunt-connected across the resistance, and a variable condenser connected between the target and the circuit, auxiliary potential-producing means connected to the circuit for producing in the neighborhood of the target an auxiliary potential opposing the movement of the sorted ions toward the target, and means for varying the auxiliary potential.

6. In a mass spectrometer having an ionization chamber, means for ionizing molecules in the chamber, an analyzer, a circuit for producing a potential to propel ions formed from the molecules as a beam into the analyzer, means for sorting the ions of the beam in the analyzer according to specific mass, and a target for catching the sorted ions, the combination which comprises shielding means disposed around the target and connected to ground, a resistance through which the target is connected to ground, indicating means shunt-connected across the resistance, a condenser connected to the target in parallel with the resistance and also connected to the circuit, and auxiliary potential producing means connected to the circuit for producing in the neighborhood of the target an auxiliary potential opposing the movement of sorted ions toward the target.

7. In a mass spectrometer having a chamber in which molecules are converted into ions and an analyzer communicating with the chamber in which the ions are sorted according to specific mass, the combination which comprises a first propelling electrode disposed in the chamber, an intermediate propelling electrode and a terminal propelling electrode both disposed along the line of communication between the chamber and the analyzer, the terminal electrode being connected to ground, a circuit connected to the three propelling electrodes for establishing a potential between the first and intermediate electrodes with the first electrode positive with respect to the intermediate and a potential between the intermediate electrode and the terminal electrode with the latter negative with respect to the intermediate electrode, a target operatively associated with the analyzer for collecting the sorted ions, a condenser connected between the target and the circuit and to ground through a resistance in the circuit, an auxiliary potential source, and a suppressor grid disposed between the analyzer and the target and connected to one of the propelling electrodes other than the terminal electrode through the auxiliary potential source.

8. Apparatus according to claim 7 provided with a resistance through which the suppressor grid is connected to the first electrode.

9. In a mass spectrometer having a chamber in which molecules are converted into ions and an analyzer communicating with the chamber in which the ions are sorted according to specific mass, the combination which comprises a first propelling electrode disposed in the chamber, an intermediate propelling electrode and a terminal propelling electrode both disposed along the line of communication between the chamber and the analyzer, the terminal electrode being connected to ground, a circuit connected to the three propelling electrodes for establishing a potential between the first and intermediate electrodes with the first electrode positive with respect to the intermediate and a potential between the intermediate electrode and the terminal electrode with

the latter negative with respect to the intermediate electrode, a target electrode operatively associated with the analyzer for collecting the sorted ions, and a condenser connected between the target electrode and the circuit and to ground through a resistance in the circuit, an auxiliary potential source, and a suppressor grid interposed between the analyzer and the target electrode and connected to a portion of the circuit that is positive with respect to the terminal electrode through the auxiliary potential source.

10. Apparatus according to claim 9 in which the condenser is variable.

11. In a mass spectrometer provided with means for forming ions, an analyzer, a circuit for producing a potential to propel the ions through the analyzer, and a target electrode for receiving the ions thus propelled, the combination which comprises an auxiliary potential producing means for imposing in the neighborhood of the target an auxiliary potential opposing the movement of ions from the analyzer toward the target and including an auxiliary electrode disposed adjacent the target, and means for varying the auxiliary potential.

12. In a mass spectrometer provided with means for forming ions, an analyzer, a circuit for producing a potential to propel the ions through the analyzer, and a target electrode for receiving the ions thus propelled, the combination which comprises an auxiliary potential producing means for imposing in the neighborhood of the target an auxiliary potential opposing the movement of ions from the analyzer toward the target, means for varying the auxiliary potential, and a condenser connected between the target and the circuit.

13. In a mass spectrometer provided with means for forming ions, an analyzer, a circuit for producing a potential to propel the ions through the analyzer, and a target electrode for receiving the ions thus propelled, the combination which comprises an auxiliary potential producing means for imposing in the neighborhood of the target an auxiliary potential opposing the movement of ions from the analyzer toward the target, means for varying the auxiliary potential, and a variable condenser connected between the target and the circuit.

14. In a mass spectrometer provided with means for forming ions, an analyzer, a circuit for producing a potential to propel the ions through the analyzer, and a target electrode for receiving the ions thus propelled, the combination which comprises an auxiliary potential producing means for imposing in the neighborhood of the target an auxiliary potential opposing the movement of ions from the analyzer toward the target and including an auxiliary electrode disposed adjacent the target, means for varying the auxiliary potential, and a shield disposed between the target and auxiliary electrode.

15. In a mass spectrometer provided with means for forming ions, an analyzer, a circuit for producing a potential to propel the ions through the analyzer, and a target electrode for receiving the ions thus propelled, the combination which comprises an auxiliary potential producing means for imposing in the neighborhood of the target an auxiliary potential opposing the movement of ions from the analyzer toward the target and including an auxiliary electrode disposed adjacent the target, means for varying the auxiliary potential, and a shield disposed between the target

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and the auxiliary electrode and connected to ground.

16. In a mass spectrometer provided with means for forming ions, an analyzer, a circuit for producing a potential to propel the ions through the analyzer, and a target electrode for receiving the ions thus propelled, the combination which comprises a suppressor grid disposed between the analyzer and the target, an auxiliary potential producing means connected to such grid for imposing on the suppressor grid an auxiliary potential opposing the movement of ions from the analyzer toward the target, and means for varying the auxiliary potential.

17. In a mass spectrometer provided with means for forming the ions, an analyzer, a circuit for producing a potential to propel the ions through the analyzer, and a target electrode for

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receiving the ions thus propelled, the combination which comprises an auxiliary potential producing means connected to the target for imposing in the neighborhood of the target an auxiliary potential opposing the movement of ions from the analyzer toward the target, and means for varying the auxiliary potential.

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