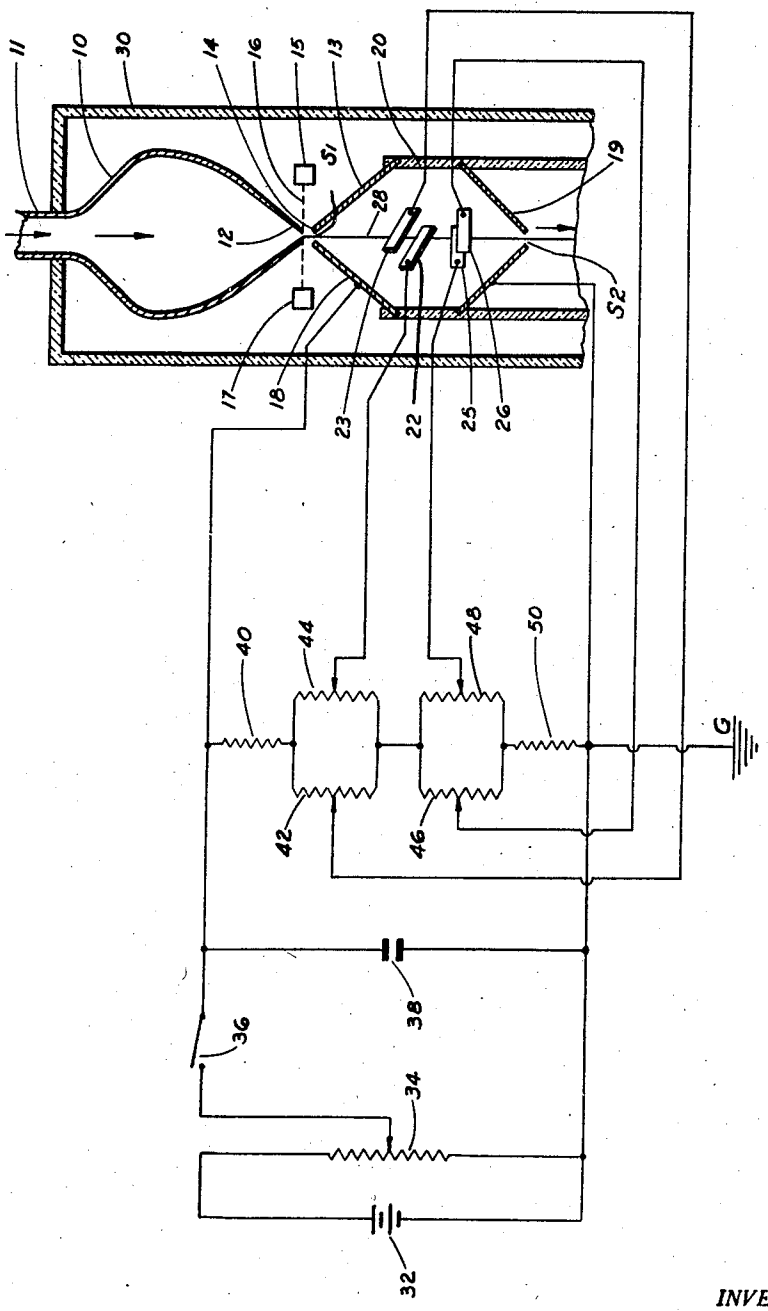
Dec. 31, 1946. H. W. WASHBURN 2,413,668

MASS SPECTROMETRY

Filed Nov. 21, 1944



INVENTOR.
HAROLD W. WASHBURN
BY
Christie & Angus
ATTORNEYS

Patented Dec. 31, 1946 2,413,668

UNITED STATES PATENT OFFICE

2,413,668

MASS SPECTROMETRY

Harold W. Washburn, Pasadena, Calif., assignor to Consolidated Engineering Corporation, Pasadena, Calif., a corporation of California

Application November 21, 1944, Serial No. 564,425

5 Claims. (Cl. 73—18)

1

This invention is concerned with mass spectrometry and particularly with the analysis of mixtures with a mass spectrometer. It provides a novel head or ionizing apparatus for a mass spectrometer.

The mass spectrometer is adapted for use in both quantitative and qualitative analyses. It has been employed for scientific studies such as the measurement of isotope ratios and more recently for other work such as the analysis of complex mixtures of hydrocarbons. It is essentially an apparatus for producing ions and sorting them according to the ratio of their mass to their charge, i. e. according to their specific mass. A sample to be analyzed, for example a gas mixture, is ionized in a chamber preferably by electron bombardment and the resulting ions are propelled by an electrical field through an aperture into an analyzer. There the ions under the influence of a magnetic or electric field are sorted according to their specific mass, ions of low specific mass pursuing a different path than ions of high specific mass. Assorted ions are collected and discharged the quantity of each kind of ions being measured by the amount of current that they discharge upon collection.

As a result of my investigations, I have developed an improved apparatus for converting molecules of a sample to be analyzed into ions and propelling and collimating the ions thus formed into a beam which may be propelled into an analyzer and there separated into a plurality of divergent beams under the influence of a magnetic or electrical field. The ionizing chamber or "head" of my apparatus may be employed with a variety of types of mass spectrometers, in which the head itself is outside the main magetic field. Thus, it may be used to great advantage with the form of mass spectrometer in which the head is outside of the magnetic field which is employed to separate the ions of the beam into a plurality of divergent beams. This type of instrument is illustrated at page 213, of Review of Scientific Instruments, vol. 11, 1940.

In heretofore customary types of mass spectrometers, ionization of molecules of a sample has been carried out for example, by electron bombardment in the space between a pusher electrode independently energized and a second electrode which ordinarily has been provided with a slit through which the ions are propelled as a result of a potential developed between the pusher electrode and the slit electrode. I have found that it is possible to construct a mass spectrometer of simple design in which no pusher electrode per se is provided. Thus my invention contemplates in a mass spectrometer or spectrograph the combination which comprises a first chamber having a constricted outlet and an inlet for molecules to be ionized, the wall of the chamber at least in the neighborhood of the outlet being of electrically conductive material, a second chamber having a constricted inlet adjacent to and substantially coaxial with the outlet but separated therefrom by a small gap, the wall of the second chamber at least in the neighborhood of the inlet thereto being of conductive material, means for projecting an electron beam across the gap transverse to the axis of the inlet of the second chamber and the outlet of the first chamber in contact with molecules passing out of that outlet, an electrode disposed in the second chamber, and means for establishing an ion propelling potential in the second chamber between the inlet of the second chamber and the electrode.

2

In this type of apparatus, there is no pusher electrode. Instead, the ions formed by electron bombardment in the neighborhood of the beam are attracted into and propelled through the second chamber by a negative potential established at the electrode disposed in the second chamber, for example, at its outlet. With this arrangement it is unnecessary to provide a magnetic field in the ionization chamber since the electron beam travels only across the narrow slit or gap. This permits simplicity of construction. The structure of the invention permits simultaneous recording of a wide range of specific masses. Moreover, it minimizes surface effects, since no ions collide with collimating slits unless they are highly energized and so relatively immune to small changes in surface potential.

It is desirable to provide auxiliary electrodes within the second chamber along the path of the beam therethrough. These electrodes may, but need not, be maintained increasingly negative in the direction of passage of the electron beam and the voltage applied on them should be such that the beam is brought to a focus at some point along its path of travel.

In the preferred form of my apparatus, I provide at least one auxiliary electrode mounted to one side of the beam path, means being provided for impressing a potential on that electrode to affect the focussing of the beam. Preferably, I provide at least one set of auxiliary electrodes, the members of the set being mounted opposite each other on the two sides of the beam path with means for impressing a different potential upon the two electrodes of the set so that a

potential difference between the two electrodes may be employed to affect the focussing of the beam. If desired, a plurality of such sets of auxiliary electrodes may be placed along the beam path within the second chamber. For focussing purposes, it is desirable that lines drawn between the electrodes of each set make different angles with the path of the beam.

These and other features of my invention will be more thoroughly understood in the light of the accompanying single figure which is a schematic diagram of a head for a mass spectrometer constructed in accordance with a preferred modification of my invention.

Referring to the drawing, it will be observed that the apparatus comprises a first chamber **10** provided with a gas inlet **11** and a constricted gas outlet **12**. Preferably this chamber has a metal wall, but in any event that portion of its wall adjacent the outlet should be of conductive metal to facilitate leakage from the electrical field into the portion of that chamber adjacent the outlet. thereby aiding in the propulsion of ions from the first chamber **10** through the apparatus. As shown in the drawing, the first chamber preferably tapers to the outlet which may be in the form of a narrow slit. Adjacent the first chamber **10**, but separated from it by a gap is a second chamber **13**. This chamber has an inlet **14** adjacent the outlet of the first chamber and in line with it so that both apertures are coaxial with the path of the ion beam. An electron gun **15** is provided at one side of the gap separating the two chambers. An electron beam **16** is propelled from the gun and passes through the gap between the two chambers to an electron catcher **17**. The electron gun and catcher may be of conventional construction, for example of the construction shown in my copending application Serial No. 513.528, filed December 9, 1943.

The upper end of the second chamber is in the form of an electrode **18** of electrical conductive material and is provided as indicated hereinbefore with a slit S_1 which matches that at the outlet of the first chamber. Similarly the outlet end of the second chamber (the lower end as shown in the drawing) is provided with an electrically conductive electrode **19** provided with a wide slit S_2 through which the ion beam passes into an analyzer (not shown). Within the second chamber, which for the most part is walled with nonconductive material **20**, are disposed a first pair of focussing electrodes **22, 23** and a second pair of focussing electrodes **25, 26**. In the type of apparatus illustrated, the outlet **12** of the first chamber of the inlet S_1 and the outlet S_2 of the second chamber are in the form of slits of elongated cross-section, the long dimension being at right angles to the plane of the drawing. The focussing electrodes of the first pair are disposed opposite each other on the two sides of the ion path **28** and consequently act upon the thickness of the beam whereas the second pair of focussing electrodes **25, 26** are disposed opposite each other at right angles to the first pair and work on the edges of the beam. The electrode pair **22, 23** is more negative than the electrode **18**. Similarly the second pair of focussing electrodes **25, 26** is more negative than the first pair while the electrode **19** having the slit S_2 is the most negative of all and conveniently may be connected to ground.

The two chambers of the head are enclosed within an envelope **30** which is evacuated by conventional means such as a pump (not shown).

For the current supply for the head, a battery **32** or other constant voltage supply is provided. This voltage supply is connected to the ends of a potentiometer **34**. The positive end of this potentiometer and its slider are connected through a switch **36** to a condenser **38**. A potential divider circuit is connected across this condenser and takes the form of a resistor **40** connected in series with a first pair of poteniometers **42, 44** and a second pair of potentiometers **46, 48**. The potentiometers of each pair are connected in parallel and the second pair of potentiometers is connected through a common point in series with a resistor **50** to ground. The negative end of the potential dividing network is connected not only to ground but also to the second or outlet electrode S_2. The inlet electrode **18** having the slit S_1 is connected to the positive side of the potential dividing network, that is to the upper end of the resistor **40** as shown in the drawing. The first pair of auxiliary or focussing electrodes **22, 23** are connected respectively to the sliders of the potentiometers **44, 42** and the second pair of auxiliary or focussing electrodes **25, 26** are connected respectively to the sliders of the potentiometers **48, 46**. In this fashion, the electrode **18**, the first pair of focussing electrodes **22, 23**, the second pair of focussing electrodes **25, 26** and the outlet electrode **19** are increasingly more negative so that ions formed at the gap between the two chambers by electron bombardment of the gas molecules are attracted into and propelled through the second chamber. By adjusting the settings of the two pairs of potentiometers, one or more transverse voltage components may be set up within the second chamber to change the focussing of the ion beam therein.

In the operation of the apparatus illustrated, a sample of gas is admitted into the first chamber under low pressure and molecules of this sample eventually arrive in the neighborhood of the outlet **12**. As the molecules escape from the outlet **12**, they are bombarded by electrons and become ionized and the electrical field created by the electrode **18** and the other more negative electrodes within the second chamber tends to attract the ions and propels them through the second chamber toward the analyzer. The movement of the ions into the second chamber is aided by a field leakage which is emphasized by the conductive walls of the first chamber in the neighborhood of the outlet **12**.

When the ion beam has been formed and focussed by proper adjustment of the potentiometers, the analysis proceeds. For example, the condenser **38** may be charged from the power source **32**. When the switch **36** is opened, the condenser is discharged through the potential dividing network, so that there is a gradual decrease in voltage in all electrodes of the second chamber. As the voltage decreases, the path of the beam within the analyzer tends to change so that divergent beams therein are swept one after the other over a conventional collector (not shown). This permits the several ion beams to be discharged sucessively at the collector. A galvanometer or other conventional means connected to the collector thus indicates or records a series of ion currents, which is the mass spectrum of the material undergoing analysis.

Although the auxiliary electrodes are increasingly negative in the example illustrated, they need not be, and in some cases it may be desirable to have them, or some of them, more positive than the main electrodes.

My invention permits the simplification of an ionization chamber for a mass spectrometer, without reducing the stability or sensitivity of the instrument as a whole.

I claim:

1. In a mass spectrometer, the combination which comprises a first chamber having a constricted outlet and an inlet for molecules to be ionized, the wall of the chamber at least in the neighborhood of the outlet being of electrically conductive material, a second chamber having a constricted inlet adjacent to and substantially coaxial with the outlet but separated therefrom by a small gap, the wall of the second chamber at least in the neghborhood of the inlet thereto being of conductive material, means for projecting an electron beam across the gap transverse to the axis of the inlet of the second chamber and the outlet of the first chamber in contact with molecules passing out of that outlet, an electrode disposed in the second chamber, and means for establishing an ion propelling potential in the second chamber between the inlet of the second chamber and the electrode.

2. In a mass spectrometer, the combination which comprises a first chamber having a constricted outlet and an inlet for molecules to be ionized, the wall of the chamber at least in the neighborhood of the outlet being of electrically conductive material, a second chamber having a constricted inlet adjacent to and substantially coaxial with the outlet but separated therefrom by a small gap, the wall of the second chamber at least in the neighborhood of the inlet thereto being of conductive material, means for projecting an electron beam across the gap transverse to the axis of the inlet of the second chamber and the outlet of the first chamber in contact with molecules passing out of that outlet, an electrode disposed in the second chamber, and means for establishing an ion propelling potential in the second chamber between the inlet of the second chamber and the electrode to form an ion beam therebetween, an auxiliary electrode mounted on one side of the ion beam, and means for impressing a potential on that electrode to affect the focussing of the ion beam.

3. In a mass spectrometer, the combination which comprises a first chamber having a constricted outlet and an inlet for molecules to be ionized, the wall of the chamber at least in the neighborhood of the outlet being of electrically conductive material, a second chamber having a constricted inlet adjacent to and substantially coaxial with the outlet but separated therefrom by a small gap, the wall of the second chamber at least in the neighborhood of the inlet thereto being of conductive material, means for projecting an electron beam across the gap transverse to the axis of the inlet of the second chamber and the outlet of the first chamber in contact with molecules passing out of that outlet, an electrode disposed in the second chamber, and means for establishing an ion propelling potential in the second chamber between the inlet of the second chamber and the electrode to form an ion beam therebetween, a set of auxiliary electrodes mounted opposite each other on the two sides of the ion beam, and means for impressing a potential between the electrodes of the set to affect the focussing of the ion beam.

4. In a mass spectrometer, the combination which comprises a first chamber having a constricted outlet and an inlet for molecules to be ionized, the wall of the chamber at least in the neighborhood of the outlet being of electrically conductive material, a second chamber having a constricted inlet adjacent to and substantially coaxial with the inlet but separated therefrom by a small gap, the wall of the second chamber at least in the neighborhood of the inlet thereto being of conductive material, means for projecting an electron beam across the gap transverse to the axis of the inlet of the second chamber and the outlet of the first chamber in contact with molecules passing out of that outlet, an electrode disposed in the second chamber, and means for establishing an ion propelling potential in the second chamber between the inlet of the second chamber and the electrode, to form an ion beam therebetween, a plurality of sets of auxiliary electrodes, the electrodes of each set being mounted opposite each other on opposite sides of the ion beam, and means for impressing potential across the ion beam between the electrodes of each set.

5. In a mass spectrometer, the combination which comprises a first chamber having a constricted outlet and an inlet for molecules to be ionized, the wall of the chamber at least in the neighborhood of the outlet being of electrically conductive material, a second chamber having a constricted inlet adjacent to and substantially coaxial with the outlet but separated therefrom by a small gap, the wall of the second chamber at least in the neighborhood of the inlet thereto being of conductive material, means for projecting an electron beam across the gap transverse to the axis of the inlet of the second chamber and the outlet of the first chamber in contact with molecules passing out of that outlet, an electrode disposed in the second chamber, and means for establishing an ion propelling potential in the second chamber between the inlet of the second chamber and the electrode, the gap and the electrode being outside any magnetic field.

HAROLD W. WASHBURN.