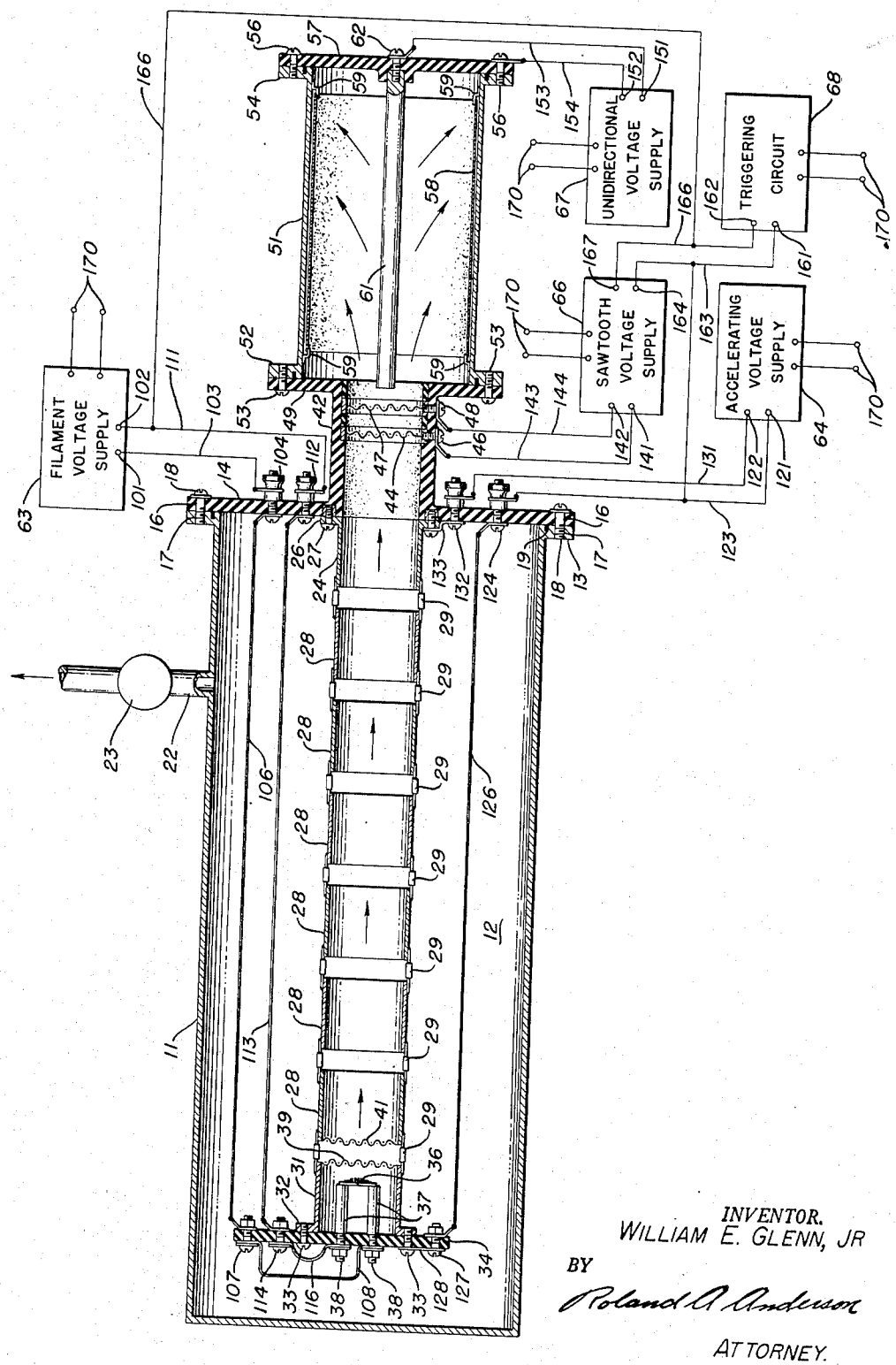
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ISOTOPE SEPARATOR

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ISOTOPE SEPARATOR

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This invention relates to an isotope separator and more particularly to an apparatus for separating ions according to their respective masses.

The art of mass spectrometry has been greatly developed during recent years; however, the apparatus which has been designed heretofore, has required the use of a magnetic field, complex control circuits, and intricate detecting equipment resulting in bulky and difficult-to-handle installations. These types of mass spectographs have been based on the theory that ions projected through a magnetic field are forced into curved paths according to their mass. Thus, with detecting equipment appropriately disposed along the ion paths, it is possible to determine the presence of ions of different masses in a test material. The present invention allows the determination of the mass of the ions present in a test material without the use of magnetic field and with a minimum of effort on the operator's part. The present invention lends itself to mass production methods of manufacture and because of its simplicity can be made at a very reasonable cost.

It is therefore an object of this invention to provide a new and improved isotope separator.

Another object of the present invention is to provide a linear isotope separator wherein a magnetic structure is not necessary.

Still another object of this invention is to provide an apparatus of extreme sensitivity for determining the mass numbers of ions.

A still further object of this invention is to provide a method of separating and recovering a plurality of isotopes in small quantities.

Another object of the present invention is to provide a compact and easily manufactured isotope separator characterized by its simplicity of operation.

Other objects and advantages will be apparent in the following description and claims considered together with the accompanying drawing which shows a sectional view of the isotope separator and its associated electronic equipment.

Referring to the drawing in detail, there is shown an envelope 11 defining a vacuum chamber 12 therein. One end of the envelope 11 is open and formed with an outwardly extending flange 13. A centrally apertured cover plate 14, made of an insulating material such as hard rubber, has a plurality of holes 16 drilled to match a similar number of holes 17 drilled and tapped in the flange 13. Thus the cover plate 14 can be secured to the flange 13 by bolts 18. To provide an airtight connection between the cover plate and flange, a rubber gasket 19 is fitted in a groove provided in the face of the flange 13. As a means of evacuating the chamber 12, the envelope 11 is provided with an exhaust outlet 22 communicating with a conventional vacuum pump 23.

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Mounted centrally on the inner surface of the cover plate is a first copper tube section 24 having substantially the same diameter as the central aperture in the cover plate 14 and having a flange 26 bolted to the cover plate with bolts 27. A series of tube sections 28, similar to the first section 24 without the flange 26, are mounted in axial alignment and in spaced-apart relation by means of two or more resistors 29 soldered between each successive pair of tube sections. The resistors 29 mounted in such a manner serve to support the series of tube sections 28 as a unit and also to distribute a voltage across the gaps formed, as will be explained more fully hereinafter. The series of tube sections 28 is terminated in a tube section 31, which is similar to the first tube section 24, and having a flange 32. Attached to the flange 32 by bolts 33 is a terminal board 34 made of an insulating material such as that used for the cover plate 14. A ribbon-like filament 36 of a material such as tungsten or nickel-chromium alloy is mounted on pillars 37 which in turn are fastened to the terminal board 34 by bolts 33 in such a manner that the filament 36 is centrally located within the tube section 31. Extending across the open end of the tube section 31 is a screen-type grid structure 39. A similar grid structure 41 is mounted across the opposing end of the adjacent tube section 28.

A cylindrical tube 42 made of insulating material and having the same inner diameter as the central aperture of the cover plate 14, is formed on the cover plate on the side opposite the copper tube section 24. Extending across the cylindrical tube 42 is a screen-type grid structure 44 similar to the grid structure 39. An electrical connection 46 extends from the grid structure 44 to the exterior of the cylindrical tube 42. A similar grid structure 47 spaced apart along the longitudinal axis of the cylindrical tube 42 extends thereacross. An electrical connection 48 extends from the grid structure 47 to the exterior of the cylindrical tube 42. A wide flange 49 having substantially twice the diameter of the cylindrical tube 42 extends outwardly from the second end of the cylindrical tube. A metallic cylinder 51 which, in the preferred embodiment, has an inside diameter substantially twice that of the inside diameter of the cylindrical tube 42 and has one end thereof fastened by means of an outwardly extending flange 52 and bolts 53 to the wide flange 49. The other end of the metallic cylinder 51 has an outward flange 54 which is fastened by means of bolts 56 to a cover plate 57 made of insulating material. Means for retaining a photographic film 58 on the interior surface of the cylinder 51 comprising spring clips 59 is provided. Axially disposed within the cylinder 51 is a metallic rod 61 which, in the preferred embodiment, has a diameter at least 0.1 the diameter of the cylinder 51 and which is supported

at one end by a machine screw 62 extending through the cover plate 57.

The accompanying electronic equipment comprises a filament voltage supply 63, an accelerating voltage 64, a saw-tooth voltage supply 66, a unidirectional voltage supply 67, and a triggering circuit 68, all of which are conventional electronic components. The filament voltage supply has two terminals 101 and 102. The terminal 101 is connected by a wire 103 to a terminal 104 on the external face of the cover plate 14. Internally the terminal 104 is connected by a lead 106 to a terminal 107 on the board 34 which is in turn connected by a wire 108 to one of the bolts 38 and thus to one side of the filament 36. The terminal 102 is connected by a lead 111 to a terminal 112 on the cover plate 14 which is internally connected by a wire 113 to a terminal 114 on the board 34. The terminal 114 is further connected by a lead 116 to the other bolt 38 which is electrically connected to the other side of the filament 36. Thus it is seen that the voltage of the filament power supply 63 is connected across the filament 36.

The accelerating voltage supply 64 has two terminals 121 and 122. The terminal 121 is connected by a lead 123 to a terminal 124 on the cover plate 14 which is internally connected by a wire 126 to a terminal 127 on the board 34. The terminal 127 is in turn connected electrically by a conductor 128 to one of the bolts 33. The terminal 122 is connected by a wire 131 to a terminal 132 on the cover plate 14 and the terminal 132 is in turn connected by a lead 133 to the flange 26 of the first tube section 24. Therefore the accelerating voltage between the terminals 121 and 122 of the accelerating voltage supply 64 is impressed across the series of tube sections 24, 28, and 31.

The saw-tooth voltage supply 66 has two output terminals 141 and 142. The terminal 141 is connected by a lead 143 to the electrical connection 46 of the grid structure 44 in the cylindrical tube 42. The terminal 142 is connected by a lead 144 to the electrical connection 48 of the grid structure 47. Thus the saw-tooth voltage is applied across the two grids 44 and 47 in the cylindrical tube 42.

The unidirectional voltage supply 67 has two output terminals 151 and 152. The terminal 151 is connected by a lead 153 to the machine screw 62 in the center of the cover plate 57, which is electrically connected to the metallic rod 61. The terminal 152 is connected through a lead 154 to one of the bolts 56 which is electrically connected to the metallic cylinder 51. Thus it is seen that the voltage from the unidirectional voltage supply 67 is connected between the cylinder 51 and rod 61.

The triggering circuit 68 has two output terminals 161 and 162. The terminal 161 is connected by a lead 163 to the terminal 124 and to a terminal 164 on the saw-tooth voltage supply 66. The terminal 162 is connected by a lead 166 to the terminal 112 and to a terminal 167 on the saw-tooth voltage supply 66.

Each of the electronic components 63, 64, 66, 67, and 68 are supplied operating voltage from a commercial source of power 170.

Now consider the operation of the above-described apparatus and circuits with a test material coated on the filament 36, the apparatus assembled, and the chamber 12 evacuated. Under these conditions the source of power 170 is energized and the filament voltage supply 63 furnishes a heater voltage across the filament 36. With the heating of the filament, ions of the test material are formed in the region of the filament 36.

The accelerating voltage supply 64 has the positive terminal 121 connected to the tube section 31 and the negative terminal 122 connected to the tube section 24. Thus a potential difference exists along the length of the tube sections 31, 28, and 24 with the resistors 29 distributing the voltage across the gaps between the tube sections. Since the potential difference created along the tube sections 31, 28, and 24 is positive in the region of the filament 36 and negative at the tube section 24, the positive ions of the test material formed by the heat of the filament 36 will be attracted away from the region of the filament 36. It is well known that a charged particle will be accelerated by an electric field and that the acceleration is proportional to the product of the value of the electric field and the mass unit of the charged particle. The mass unit of the charged particle is the ratio of the charge to mass of the particle. From this it is seen that ions having small mass will have short times of flight and that ions of heavier mass will have longer times of flight.

To counteract the defocusing tendency of the electric field at the gap adjacent to the filament 36 because of the proximity of the filament 36, the screen-type grids 39 and 41 are disposed across the adjacent openings of the two tube sections 31 and 28. Since the screen grid 39 covers the opening of the tube section 31, a negative pulse of voltage from the triggering circuit 68 is applied between the screen grid 39 and the filament 36 at a predetermined interval to withdraw the ions from the region of the filament 36 in a beam and to project them into the accelerating force of the electric field present at the following gap. Thus the ions are accelerated through the tube sections 28 toward the grid structure 44 in the tube 42.

The triggering circuit 68 which applies a trigger pulse between the filament 36 and grid 39 and extracts ions from the filament also applies the same trigger pulse to the saw-tooth voltage supply 66. The trigger pulse is delayed for a predetermined time within the saw-tooth voltage supply 66 and initiates a saw-tooth pulse at a time when the lightest ions from the filament 36 are arriving at the grid 44. The saw-tooth pulse is applied between the grids 44 and 47, thus the light ions which arrive at the grid 44 when the saw-tooth voltage is near zero are accelerated very little. These light ions then enter the space between the cylinder 51 and rod 61. The light ions, having a relatively low energy are deflected sharply by the unidirectional voltage 67 applied between the cylinder 51 and rod 61. The relatively light ions thus strike the film 58 in a circumferential band near the entrance end of the cylinder 51 and irradiates a band on the film. The heavier ions arrive at the grid 44 later than the light ions and therefore at a time when the saw-tooth voltage between the grids 44 and 47 is higher. The heavier ions thus have a higher energy imparted to them by the saw-tooth voltage than do the light ions. The heavier ions so energized enter the space between the cylinder 51 and rod 61 and are gradually deflected by the unidirectional voltage therebetween until they strike the film 58 in a circumferential band near the closed end of the cylinder 51. Thus it is seen that ions are separated according to their respec-

tive masses, and the relative amount of each ion present is determined by the degree of exposure of the corresponding bands on the film.

In the presently described embodiment of the invention the cylinder 51 has a diameter substantially twice that of the cylindrical tube 42; the rod 61 has a diameter substantially 0.1 the diameter of the cylinder 51 and the length of the cylinder is substantially twice its diameter. With these dimensions it has been a simple matter to separate as many as ten ions of successive mass numbers for a given set of operating voltages and conditions. It is readily apparent that many of the parameters involved may be adjusted to shift the range of masses of ions detectable or to extend the range thereof.

If it is desirable to collect ions as well as to separate ions of different masses it is possible to utilize a cylinder 51 having circumferential slits therein instead of a film. Ion collecting chambers would then be disposed outside of the cylinder 51 communicating with the slits.

As well as being useful for micro-chemistry work, the present invention is useful in the petroleum industry and in the control of some chemical and manufacturing processes.

It is to be noted that the filament 36 may be replaced with numerous types of ion generators which readily adapt themselves to ionizing continuously-changing test materials. Nor is it desired to limit the type of material which may be tested to solids which can be coated on the filament, for it is apparent that the filament 36 can be replaced with apparatus for ionizing a vapor or gas.

While the salient features of this invention have been described in detail with respect to one embodiment, it will, of course, be apparent that numerous modifications may be made within the spirit and scope of the present invention and it is therefore not desired to limit the invention to the exact details shown except insofar as they may be defined in the following claims.

What is claimed is:

1. An isotope separator for determining the mass units of a test material comprising an evacuated chamber, means for ionizing said test material, electric field means for linearly accelerating said ions through said chamber in accordance with their mass units, a pair of accelerating grids disposed in the path of said ions, means connected between said grids for impressing linearly varying voltage, an electrostatic deflecting chamber disposed in the path of said ions beyond said accelerating grids, and means for collecting said ions within said deflection chamber.

2. An isotope separator for determining the mass units of a test material comprising an evacuated chamber, a plurality of linearly disposed tube sections within said chamber, means for ionizing said test material disposed at one end of said tube sections, electrical means for establishing accelerating electric fields between said tube sections whereby said ions are accelerated and linearly separated in accordance with their mass units, a pair of accelerating grids disposed transversely in the path of said ions in spaced-apart relation, accelerating voltage means applied between said accelerating grids, an electrostatic ion deflector disposed adjacent said grids and parallel to the path of said ions for the lateral deflection of said ions, and means for determining the disposition of said ions in said electrostatic ion deflector.

3. An isotope separator for determining the mass units of a test material comprising an evacuated chamber, a plurality of linearly disposed tube sections within said chamber, means for ionizing said test material at one end of said tube sections, resistance means connected between said tube sections, electrical means connected across said linearly disposed tube sections for establishing accelerating electric fields between said tube sections, ion accelerating grids disposed at the other end of said tube sections, an electrostatic deflection chamber disposed in the ion path beyond said accelerating grids whereby said ions are deflected radially outward from their normal paths, and ion collecting means disposed in the path of the deflected ions.

4. An isotope separator for separating a test material according to its mass units comprising an evacuated chamber, means for ionizing said test material, electric field means for linearly accelerating said ions through said chamber for linearly separating said ions according to their mass units, accelerating grids disposed in the path of said ions, a saw-tooth accelerating voltage applied between said accelerating grids whereby ions are accelerated according to the voltage existing between said accelerating grids at their time of arrival thereat, an axial electrode disposed in the path of said ions beyond said accelerating grids, a closed cylindrical electrode disposed coaxially about said axial electrode, a unidirectional voltage applied between said axial electrode and said cylindrical electrode, and a photographic film affixed to the interior surface of said cylindrical electrode.

5. A isotope separator for separating ions according to their mass units comprising a time-of-flight mass spectrograph for linearly bunching ions according to their mass units, accelerating means disposed in the path of said ions, whereby said ions are forwardly accelerated according to their time of arrival at said accelerating means, electrostatic means for radially deflecting said ions from the ion path, and ion collection means disposed in the path of the deflected ions.

6. An isotope separator for separating ions according to their mass units comprising a time-of-flight mass spectrograph for linearly bunching ions according to their mass units, accelerating grids disposed in the path of said ions, a saw-tooth accelerating voltage applied between said accelerating grids whereby ions are accelerated according to the voltage existing between said accelerating grids at their time of arrival thereat, an axial electrode disposed in the path of said ions beyond said accelerating grids, a cylindrical electrode enclosing said axial electrode and coaxial therewith, a unidirectional voltage applied between said axial electrode and said cylindrical electrode, and ion detecting means affixed to the interior surface of said cylindrical electrode.

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