

Aug. 16, 1955

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2,715,692

ION PRODUCING APPARATUS

Filed Sept. 20, 1946

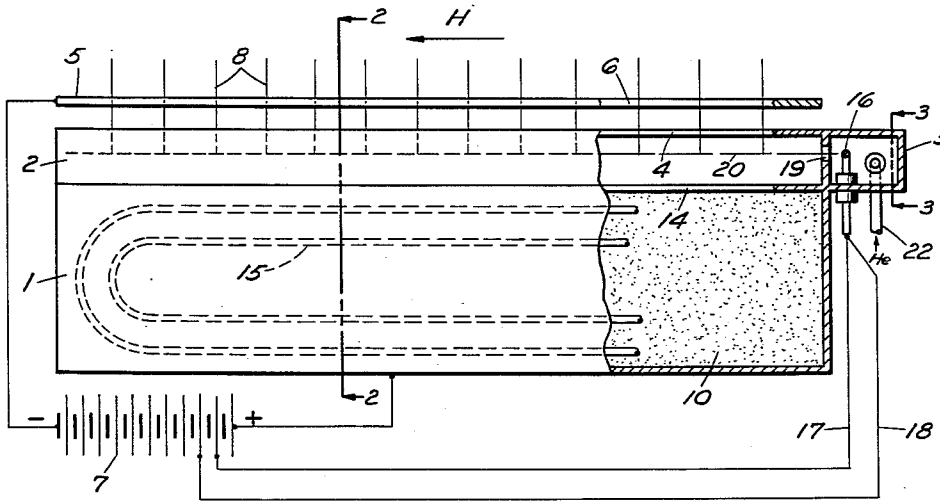


FIG. 1.

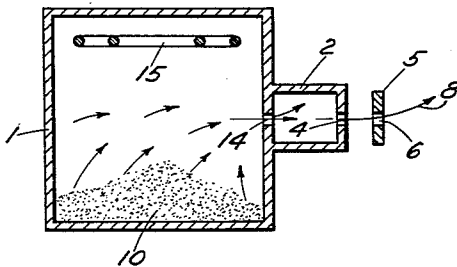
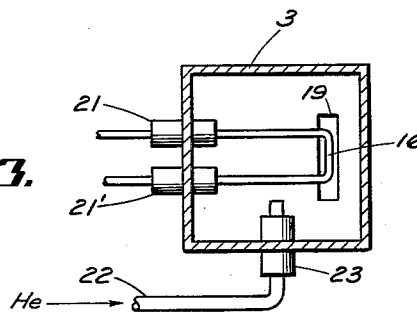


FIG. 2.

FIG. 3.



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1

2,715,692

ION PRODUCING APPARATUS

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Application September 20, 1946, Serial No. 698,338

16 Claims. (Cl. 313—63)

This invention relates generally to ion producing apparatus, and more particularly, to improvements in that type of ion producing apparatus which is particularly applicable for use in an electromagnetic isotope separating unit commonly known as a calutron.

In such calutrons, a beam of positive ions of the charge material, the isotopes of which it is desired to separate, is formed and projected at a high velocity into an evacuated region traversed by a substantially uniform magnetic field perpendicular to the direction of projection of the ion beam. Due to the influence of the magnetic field upon the moving charged particles, each particular ion is caused to describe a circular path having a radius proportional to the square root of its mass. As a result, the original single ion beam is split into more or less distinct component beams, each consisting solely of ions of a particular mass weight. Because of a geometric focusing action, these component isotopic beams are most distinctly resolved after the completion of 180° of their circular path, and the individual isotopes may be separately collected at a suitable receiver located at this point.

Perhaps the most critical portion affecting the operation of such a calutron unit is that portion concerned with the production of positive ions of the charge material and the projection thereof in the form of an ion beam. Conventionally such apparatus comprises a hollow elongated chamber having an inlet extending along one entire side thereof through which vapor of the charge or source material is permitted to enter. Opposite this inlet, and extending substantially the entire length of the chamber is a slit-like aperture through which the ionized particles are withdrawn in the form of a beam. At one end of this chamber there is disposed a small slot through which an ionizing electron stream enters the ionization chamber to bombard and thus ionize the vaporized molecules of the charge material. A filamentary cathode is positioned adjacent this slot and external to the chamber to provide the primary electrons for this ionizing discharge.

One problem which is encountered in the operation of such ion producing apparatus is the rapid deterioration of the filamentary cathode. In operation, the filamentary cathode is subject to intense bombardment by the positive ions of the charge material which are formed in the electron stream. In the most common present use of a calutron unit, the charge material is a compound of a high atomic weight element, and accordingly, the filamentary cathode is subject to bombardment by very heavy ions, resulting in rapid wear and breakdown of the filamentary cathode itself. For the foregoing reasons, it is found that in the operation of a calutron unit, frequent replacement of the filamentary cathode is required. This is not only undesirable by reason of the initial cost of the filamentary cathode itself, but more particularly, by reason of the loss of operating time required to replace the cathode, and the complications in overall design incident to the pro-

2

vision of means for replacing the cathode while maintaining the high vacuum within the unit.

A more important difficulty encountered in the operation of such ion producing apparatus is that of maintaining a steady non-hazy ionizing electric discharge along the entire length of the ionization chamber. It will be apparent that if the ionizing arc is hazy or irregular, the positive ion beam, itself, becomes erratic. This, of course, results in poor separation and reception of the individual isotope beams. In the past, in order to overcome instability in the operation of the ionizing arc, it has been necessary to increase the supply of source material vapor into the ionizing chamber by increasing the operating temperature and thus the vapor pressure. Such an increase in the vapor pressure of operation of the ionization chamber is accompanied by many undesirable effects. In the first place, the higher the pressure of operation, the greater is the ratio of unionized to ionized particles which spew out of the ionization chamber and into the tank region. Unionized particles which are present in the separating region interfere with the ion beam, itself, thus causing scattering of the beam and poor separation and collection of the isotopes; deposit on the tank walls and accelerating electrodes thus changing critical dimensions and providing a cleaning and recovery problem; and reduce the overall efficiency of operation from loss of charge material.

For all of the above reasons and many other incidental reasons, it would obviously be desirable to be able to provide an extremely stable and steady ionizing arc at a low charge vapor pressure. The present inventor has conceived that substantial improvement in the stability and uniformity of the ionizing arc can be obtained by the introduction of an additional gas into the electron stream at one end thereof, thus providing additional positive ions to support the discharge and neutralize the space charge of the electron stream. It has been found that in this manner a steady ionizing arc can be obtained in an ionization chamber which is run colder and at a lower charge vapor pressure than was heretofore required, thus reducing charge consumption; reducing gunking or depositing of charge material on portions of the unit; providing a steady uniform positive ion beam; and generally increasing the efficiency of separation and collection of the component isotopes of the charge material.

The inventor has further conceived that by injecting the additional or auxiliary gas into the electron stream at a point at and around the filamentary cathode, deterioration of the filamentary cathode may be greatly inhibited, thereby reducing the frequency and number of replacements of this cathode required. This desirable result appears to occur by reason of the fact that the positive ions of the additional gas form a protective sheath or layer around the surface of the filamentary cathode, preventing bombardment of the cathode by the heavy positive ions of the charge material, itself. Preferably, for this purpose the additional gas employed is of a low atomic weight so that bombardment of the cathode by positive ions of the additional gas will be less effective in eroding the cathode than bombardment by positive ions of the charge material.

Accordingly, it is the primary object of the present invention to provide novel ion beam producing apparatus particularly adapted for use in a calutron.

Another object of the present invention is to provide ion producing apparatus wherein an auxiliary or additional gas is utilized in order to provide additional positive ions to support the ionizing electric discharge and to neutralize the space charge thereof.

Still another object of the present invention is to pro-

vide ion producing apparatus of the type utilizing an ionizing electric discharge, wherein an auxiliary or additional gas is introduced into the electric discharge at one end thereof for the purpose of improving the stability of the discharge.

A further object of the present invention is to provide ion producing apparatus of the type utilizing an ionizing electron stream to bombard molecules of the material to be ionized, wherein an auxiliary or additional gas is introduced into the electron stream at and around the cathodic end thereof.

Still a further object of the present invention is to provide ion producing apparatus of the type utilizing an electric discharge from a filamentary cathode to bombard and ionize the vaporized molecules of the charge material wherein means are provided for operating the filamentary cathode in a gaseous medium of an auxiliary or additional gas, whereby bombardment of the cathode by positive ions of the charge material is prevented and the life of the filament is increased.

Other objects and advantages of the present invention will become apparent from the following description, when taken in connection with the accompanying drawings, wherein,

Fig. 1 is a plan view, partially in section, of ion producing apparatus constructed according to the principles of the present invention;

Fig. 2 is a sectional view taken along the line 2—2 of Fig. 1; and

Fig. 3 is a sectional view taken along the line 3—3 of Fig. 1.

Referring now to the drawings, the ion producing apparatus itself embodies three more or less distinct but communicating chambers, namely a vaporizing chamber 1, an ionization chamber 2, and an auxiliary gas chamber 3. This whole apparatus normally occupies a position at the bottom of the front side of a conventional calutron unit. The ions formed in the ionization chamber 2 are withdrawn in the form of an ion beam, schematically indicated at 8, through an elongated slot 4 by the accelerating electrode 5, which electrode also has a slot 6 adjacent slot 4 in the ionization chamber. Accelerating electrode 5 is maintained at a high negative potential with respect to the ion producing apparatus by means of a suitable source of direct voltage, indicated schematically by battery 7. Thus, the ions are withdrawn from the ionization chamber 2 in the form of beam 8, which beam traverses the slot 6 in accelerating electrode 5, and due to the influence of the transverse magnetic field, indicated schematically at H, describes a circular path in a vertical plane, and is simultaneously separated into component isotope beams, which are separately collected in suitable receiving apparatus positioned at the top of the front side of the calutron unit.

The vaporizing chamber 1, which may be rectangular in shape, as shown, contains a suitable amount of charge material in its solid form, as schematically indicated at 10. At the top of the vaporization chamber 1 there is provided a suitable heating element, schematically indicated by coil 15, which serves to heat the charge material to its vaporization point, whereupon the vapor of the charge material diffuses through an elongated slot 14 in one side of the vaporization chamber 1 into the ionization chamber 2.

A filamentary cathode 16 is disposed externally to the ionization chamber 2 at one end thereof. Opposite terminals of filamentary cathode 16 are connected to spaced points near the positive end of battery 7, as by leads 17 and 18. It will be apparent, therefore, that the filamentary cathode 16 as a whole is maintained at a small negative potential with respect to the ion producing apparatus proper so that the ion producing apparatus becomes an anode for cathode 16. The ionizing electric discharge between cathode 16 and the ion pro-

ducing apparatus proper is collimated by the magnetic field H, whereby the electric discharge proceeds through the collimating slot 19 and along the entire length of the ionization chamber 2 to the opposite end thereof.

As in the conventional apparatus, the ionizing electron stream, schematically indicated at 20, bombards the vaporized molecules of the charge material to provide positive ions of the charge material which then are withdrawn through slot 4 in the form of a beam by accelerating electrode 5, as was previously described.

According to the principles of the present invention, the filamentary cathode 16 is inclosed within an auxiliary gas chamber 3. Thus, the terminals of filamentary cathode 16 are brought out of the chamber 3 and connected to leads 17 and 18 through suitable sealing and insulating arrangements, schematically indicated at 21 and 21'. A tube 22 is also provided, one end of which projects into the interior of auxiliary chamber 3 through another sealing and insulating arrangement 23. The exterior end of tube 22 is connected to a suitable source, not shown, of the additional or auxiliary gas, such as helium, which is to be used.

In operation, the auxiliary gas introduced into auxiliary chamber 3 diffuses through collimating slot 19 into and along the ionization chamber 2, and more particularly along the ionizing electron stream 20. The atoms of this auxiliary gas are ionized by electron stream 20, whereby additional ions are provided to support the discharge itself and to neutralize the space charge of the discharge. In this manner, it has been found that the ionizing electric discharge is rendered substantially more stable than is otherwise possible, resulting in the numerous advantages previously mentioned. Also, it is found that the additional gas provides a sheath of protective positive ions around the filamentary cathode 16, thus preventing bombardment of the cathode by the heavy positive ions of the charge material and inhibiting wear and deterioration of the cathode.

Although many different gases could be employed as the additional gas to effect to some degree the above-described advantages, the characteristics of the additional gas for greatest effectiveness are lightness and stability. It will be apparent that if an additional gas of low atomic weight is utilized, it will readily diffuse through the collimating slot 19 out into and along the ionizing electron stream 20, and thus be in a position to accomplish its purpose in stabilizing the electric discharge. Also, the lighter the additional gas employed, the smaller will be its effect in scattering the ion beam, itself, in the tank region. With respect to the longevity of the cathode 16, it is desirable for the additional gas to be as light as possible in order that erosion of cathode 16 due to bombardment by positive ions of this gas will be small. It is also desirable that the gas employed be highly stable, preferably an inert gas, so that it will not react with the cathode 16 and with other portions of the calutron unit thereby facilitating cleaning and chemical recovery after a run has been completed. Other gases, besides helium, which are particularly well suited for the purposes to be served are argon, neon, nitrogen, and hydrogen.

Since many changes in the above construction and many apparently widely different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description, or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Apparatus for developing gaseous ions of a source material comprising an ionization chamber, means for traversing said chamber with an ionizing electron stream, means for introducing vapor of the source material into said chamber at one position to be ionized by said electron stream, and separate means, removed from said source

gas introducing means, for introducing an additional gas into said chamber at a different position.

2. Apparatus for developing gaseous ions of a source material comprising an ionization chamber, means for traversing said chamber with an ionizing electron stream, means disposed along the length of said electron stream for introducing vapor of the source material into said chamber to be ionized by said electron stream, and means disposed at one end of said electron stream for introducing an additional gas into said chamber.

3. Apparatus for developing gaseous ions of a source material comprising an ionization chamber, means for traversing said chamber with an ionizing electron stream, means for introducing vapor of the source material into said chamber in a direction transverse to said electron stream to be ionized by said stream, and means for introducing an additional gas into said chamber in a direction parallel to said electron stream.

4. Apparatus for developing gaseous ions of a source material comprising an ionization chamber, means for traversing said chamber with an ionizing electron stream, two gas inlets for said chamber disposed at different positions with respect to said electron stream, means for introducing a vapor of the source material into said chamber through one of said inlets to be ionized by said electron stream, and means for introducing an additional gas into said chamber through the other of said inlets.

5. An apparatus for developing gaseous ions from a vaporizable source compound comprising means defining an elongated restricted region for gas ionization having a slit-like aperture extending in the direction of its elongation substantially coextensive therewith, means for directing a stream of accelerated electrons from one end of said region to the other end thereof, means for introducing into said region intermediate the ends thereof a vapor of said source compound, means for introducing an auxiliary gas into said electron stream adjacent an end of said elongated region, and means for withdrawing ions of said vapor from said region through said slit-like aperture along the entire length thereof.

6. An apparatus for developing gaseous ions from a vaporizable source compound comprising means defining an elongated restricted region for gas ionization having a slit-like aperture extending in the direction of its elongation substantially coextensive therewith, means for introducing a vapor of said source compound into said region intermediate the ends thereof, means for establishing an arc discharge through said region in the direction of its elongation to establish a discharge path containing positive ions of said vapor, means for introducing into said discharge path at an end thereof an additional gaseous medium, and means for withdrawing ions of said vapor from said region through said slit-like aperture along the entire length thereof.

7. Apparatus for developing gaseous ions of a source material comprising an ionization chamber, means for traversing said chamber with an ionizing electron stream, means for introducing vapor of the source material into said chamber to be ionized by said electron stream, and means for introducing an additional gas into said chamber at the point of origin of said electron stream.

8. Apparatus for developing gaseous ions of a source material comprising an ionization chamber, means for traversing said chamber with an ionizing electron stream, means for introducing vapor of the source material into said chamber to be ionized by said electron stream, and means for introducing an additional gas into said electron stream at the cathodic end thereof.

9. Apparatus for developing gaseous ions of a source material comprising an ionization chamber, means for traversing said chamber with an ionizing electron stream, means disposed along the length of said electron stream for introducing vapor of the source material into said chamber to be ionized by said electron stream, and means disposed at the cathodic end of said electron stream for

directing an additional gas into and along said electron stream.

10. An apparatus for developing gaseous ions from a vaporizable source compound comprising means defining an elongated restricted region for gas ionization having a slit-like aperture extending in the direction of its elongation substantially coextensive therewith, means for introducing a vapor of said source compound into said region intermediate the ends thereof, means for establishing an arc discharge through said region in the direction of its elongation to establish a discharge path containing positive ions of said vapor, means for introducing an auxiliary gaseous medium into said discharge path at the cathodic end thereof, and means for withdrawing ions of said vapor from said region through said slit-like aperture along the entire length thereof.

11. Apparatus for developing gaseous ions comprising an ionization chamber containing molecules of the gas to be ionized, said chamber having a slot at one end thereof, an auxiliary gas chamber adjacent said ionization chamber and communicating therewith by means of said slot, means for establishing an arc discharge traversing said ionization chamber and extending through said slot, and means for introducing an additional gas into said auxiliary chamber.

12. Apparatus, as claimed in claim 11, wherein said auxiliary chamber is disposed at the cathodic end of said arc discharge.

13. Apparatus for developing gaseous ions comprising an ionization chamber containing molecules of the gas to be ionized, said chamber having a slot at one end thereof, an auxiliary gas chamber adjacent said ionization chamber and communicating therewith by means of said slot, a source of electrons disposed within said auxiliary chamber and substantially contiguous with said slot, means for accelerating electrons from said source to form an electron stream extending through said slot and traversing said ionization chamber, and means for introducing an additional gas into said auxiliary chamber.

14. Apparatus for developing gaseous ions comprising an ionization chamber containing molecules of the gas to be ionized, said chamber having a slot at one end thereof, an auxiliary gas chamber adjacent said ionization chamber and communicating therewith by means of said slot, a source of electrons disposed within said auxiliary chamber adjacent said slot, means for establishing a magnetic field traversing said chamber and extending through said slot, means for maintaining said ionization chamber electrically positive with respect to said electron source, whereby an arc discharge is established in the direction of said magnetic field, and means for introducing into said auxiliary chamber a relatively inert gas of low atomic weight.

15. Apparatus for developing gaseous ions from a vaporizable source compound comprising means defining an elongated restricted region for gas ionization having a slit-like aperture extending coextensive therewith, means for introducing a vapor of said source compound into said region intermediate the ends thereof, means for establishing an arc discharge through said region in the direction of its elongation to establish a discharge path containing positive ions of said vapor, a separate gas chamber adjacent said region and having a collimating slot accommodating said arc discharge, means for introducing an additional gas into said chamber, and means for withdrawing ions of said vapor from said region through said slit-like aperture along the entire length thereof.

16. Apparatus for developing gaseous ions from a vaporizable source compound comprising means defining an elongated restricted region for gas ionization having a slit-like aperture extending in the direction of its elongation substantially coextensive therewith, a separate gas chamber adjacent said region and communicating therewith by means of a common opening therebetween, a filamentary cathode disposed within said chamber and

7

adjacent said opening, means for establishing an arc discharge from said cathode through said opening and along the entire length of said region, means for introducing into said region intermediate the ends thereof a vapor of said source compound, means for introducing an additional gas into said chamber and means for withdrawing ions of

5

8

said vapor from said region through said slit-like aperture along the entire length thereof.

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