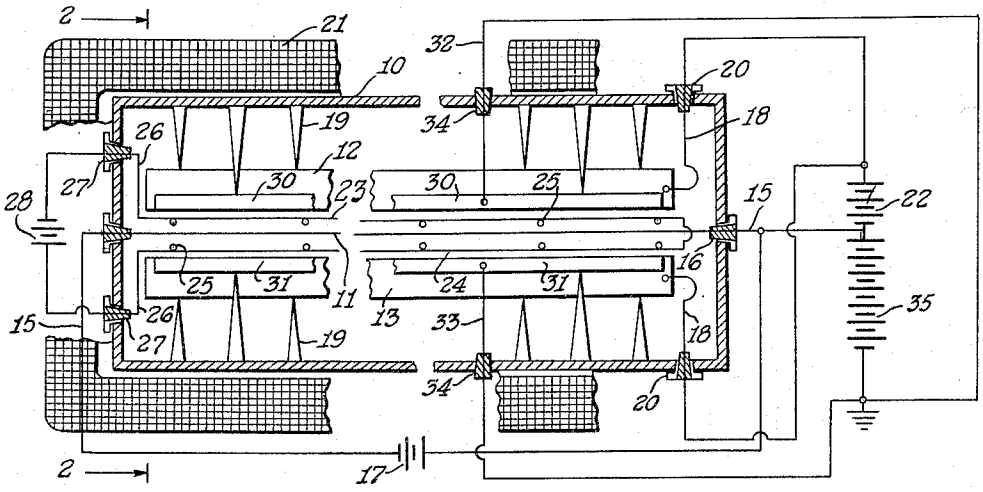
Dec. 21, 1954 R. R. WILSON 2,697,788

ION SOURCE

Filed June 12, 1953

Fig. 1.



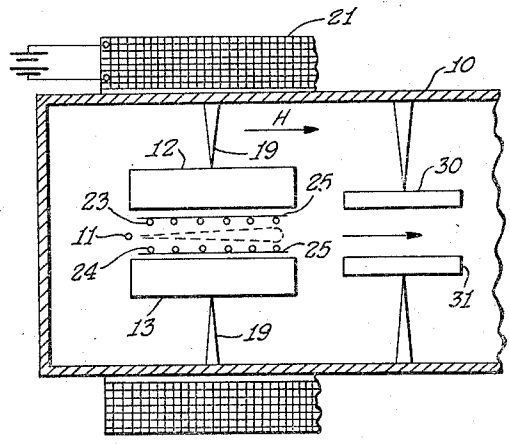


Fig. 2.

INVENTOR

ROBERT R. WILSON

BY

ATTORNEY

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ION SOURCE

Robert R. Wilson, Ithaca, N. Y., assignor to the United States of America as represented by the United States Atomic Energy Commission

Application June 12, 1953, Serial No. 361,297

6 Claims. (Cl. 250—41.9)

This application is a continuation-in-part of application Serial No. 523,290, filed February 21, 1944, now abandoned, and discloses an invention which relates to methods and apparatus for producing ions and more particularly to an improved method and apparatus for producing a copious supply of ions of metals containing a mixture of isotopes such as, for example, cobalt, copper, bismuth and uranium for use especially in the ionic methods of separating the isotopes of these metals.

In some of the isotopic metals which contain isotopes useful for medical, research or industrial purposes, the particularly desired isotope may be contained as a very low percentage of the metal content. Consequently, a large amount of metal must be vaporized and ionized to obtain the required quantity of the desired isotope.

Accordingly, it is a primary object of this invention to provide a method and apparatus capable of producing these ions in sufficient number to permit a large scale separation of the isotopes when utilizing ionic methods of separation.

One effective method for producing ions is by moving electrons. That is to say, a source metal or a salt of the source metal may be ionized, for separating the isotopes of the source metal by subjecting the vapor of this material to bombardment by accelerated electrons in a chamber which has been previously evacuated. The quantity of ions that may be produced by moving electrons can be shown to depend upon the following factors: namely, the number of electrons, the voltage through which they are accelerated and the pressure of the vapor in the chamber.

In order to increase the number of positive ions which shall be available, I set out to provide for an increase in the current of the electrons of the ion source. One way in which the electron current may be increased is to increase the size of the emitting surface. Accordingly, I utilize in the ion source to which this invention relates an emitter of substantial size, for example, a heavy straight wire filament supported to extend parallel to and at the rear of a slot formation, and midway between the edges of the walls thereof. By utilizing a straight wire as a filament, it is possible to use a very narrow slot and to apply the arc potential to the walls of the slot to produce a high field for accelerating the electrons at the filament surface.

Although arc discharges have been utilized as ion sources in various instruments, the ion currents produced in the prior art sources are far short of the requirements of an isotope separator. It has occurred to me that the number of ions developed in an ion source useful for isotope separation could be materially increased by providing an extended filament and slot structure, as explained above, and by utilizing a retarding field which will slow down the electrons flowing through the slot, stop them, and reverse their direction to cause them to return to the filament. I was finally able to provide such a path of flow for electrons when I hit upon the idea of utilizing a magnetic field to cause the accelerated electrons of an arc discharge positioned at one side of a slot formation to be directed into the slot and constrained to move in the direction of the magnetic lines of force.

While it has been known, heretofore, that a magnetic field may be used to collimate an arc discharge, the utilization of a magnetic field having a direction through the slot and transverse of the electric field for accelerating the electrons permitted me to collimate a flow of electrons out of the immediate vicinity of the cathode thereby obtaining a directed flow of electrons through a slot structure. I was thus able to bring within the proximity of the slot edge toward which the electrons are directed a negatively charged body to cause the electrons to slow down, stop, and reverse in direction.

In the above manner, I have been able to increase the length of travel of the electrons, thereby increasing the probability of collision of an electron with a vapor molecule of the material to be ionized to provide for an increase in total ion production. Accordingly, I developed the process of this invention wherein the electrons from the emitting source are directed into the region containing the material to be vaporized, are retarded in velocity, stopped, and then reversed in direction of flow.

In utilizing this method, I discovered also that the electrons by moving more slowly in the neighborhood of the slot edge, nearest the point of ion utilization, considerably enhance the density of ionization within this region. That is to say, the electrons by moving more slowly near the front edge of the slot produce more ions near the point of utilization.

A number of the ions produced by the electron bombardment in the vicinity of the filament, where the electron is influenced by the arc voltage field, will migrate toward the filament (negative potential) neutralizing the space charge produced by the filament electron charge, and thus serving to increase the total initial emission of electrons. It will be apparent that a space charge is also formed by the retarded electrons near the front edge of the slot. I have discovered that this space charge is advantageous in that it may be made to produce a field which extends into the slot and which serves to draw out more ions. That is to say, the concentration of the electrons will be the greatest where their velocity is zero. By adjusting the retarding field so that the velocity of the electrons is a minimum just outside the slot, a field produced by the gradient from a high negative potential outside the slot to a lower negative potential within the slot will act upon the positive ions to withdraw these ions from the slot region. Thus, those ions produced while the electron is influenced by the retarding field will be withdrawn from the slot and accelerated.

I propose, as an object of this invention, therefore, to provide a method for producing ions of isotopic source metals by electron bombardment wherein the electrons are directed from the emitter into a vapor of the material to be ionized, stopped, and their direction of flow reversed to increase their ionizing power.

It is also an object of this invention to provide an ion source for isotope separation of the source metals having an increased electron current produced by a large emitter and a reduced space charge.

It is a further object of this invention to provide in an ion source for isotope separation a field formed by the space charge of retarded electron flow which will be effective in withdrawing the ions from the ionizing region.

It is a still further object of this invention to provide in an ion source a pair of flat electrodes having their greater length in a direction normal to the ion path and to support these electrodes in parallel and spaced relationship to form a slot region, so that a long straight filament for electron emission may be supported at the edge of this slot region.

Still another object of this invention is to provide an ion source with ion accelerating electrodes at the front of the slot region wherein the ions are formed by the electron bombardment and to apply a high negative potential to these electrodes so that the electrons in coasting through the slot region will be retarded by the field of these electrodes, stopped, and reversed in their direction to increase their ionizing power.

Further objects and advantages of this invention will become more apparent from the following detailed description when taken in connection with the accompanying drawings illustrating diagrammatically a preferred embodiment of this invention wherein:

Figure 1 is a front view of an ion source constructed in accordance with the teachings of this invention; and

Figure 2 is an end view of the ion source shown in Figure 1, taken as a section on line 2—2 of Figure 1.

Since, as stated above, this invention is of particular advantage as a method and means for producing a copious supply of ions, especially the ions of heavier metals, it will be appreciated that the invention is not concerned particularly with the method or apparatus for utilizing the developed ions, except insofar as the invention might be regarded, in some aspects, as an improvement in apparatus wherein a relatively very large ion current is to be generated and withdrawn for utilization or consumption, so to speak, at a locality separated from the source. Consequently, the drawings do not show any specific structure for utilizing or collecting these ions.

Since it has been stated above that the invention is especially useful in ionic methods of separating the isotopes of metals, and further since the electrodes which produce the electron retarding field serve also as an accelerator to withdraw the ions from the ionizing region for utilization, it may be pointed out here that this ion source is especially useful with a bunching, analyzing and collecting apparatus, for isotope separation, as described and claimed in my U. S. Patent 2,606,291 issued August 5, 1952.

An isotope separator of the type described in the above-referenced patent consists essentially of equipotential electrodes, maintained at the same steady state potential, as the accelerating electrodes of the ion source to form a field free space for the flow of accelerated ions. An alternating potential of small amplitude and preferably of saw-tooth wave form is applied to the above-mentioned equipotential electrodes to apply a variable acceleration to the ions to cause a bunching of the isotopes differentially, i. e., into ion bunches respectively enriched as to one or another of the isotopes. A radio frequency alternating potential is applied to a deflecting electrode synchronized with the buncher and of proper phase to deflect the bunched ions of the isotopes of the ionized material into different collecting pockets or cups.

Referring now to the drawings which illustrate diagrammatically an apparatus for producing ions in accordance with my invention, the evacuated or sealed envelope **10** supports within its interior, and preferably at one side, a long straight filament **11** of an emitting material such as tungsten or thoriated tungsten. Two flat electrodes **12** and **13**, which are exceedingly long compared to their width, are supported also within the sealed envelope or evacuated chamber so as to define a long narrow slot in front of the filament **11**.

More exactly, these electrodes **12** and **13** are spaced apart in parallel relationship and are supported within the envelope by suitable insulated uprights **19** extending from the chamber walls so that the filament **11** will lie parallel to these electrodes and midway between the rear edge surfaces. Suitable conductive leads **15** are brought out through seals **16** in the envelope for connecting the filament **11** to a voltage source **17** to heat the filament to emitting temperature. The conductive leads **18** extend from the slot forming electrodes **12** and **13** through suitable seals **20** formed in the envelope whereby the electrodes may be connected together electrically and also to the filament **11** through an electron accelerating potential **22**. The potential **22** is thus provided to accelerate the electrons establishing an electron current controllable arc between the filament **11** and the electrodes **12** and **13**.

That the directed flow of electrons may be extended into the region of the slot formed by the electrodes **12** and **13**, a magnetic field having a direction indicated by the arrow H of Figure 2 is established. This field is preferably produced by the energized windings **21** of the electromagnet shown diagrammatically as surrounding the envelope. It is now apparent that the electrons of the arc are subjected to crossed electric and magnetic fields. Consequently, their horizontal path will be helical in the direction of the magnetic field. Strictly speaking the path is helical only in the substantially equipotential region, i. e., not in the crossed field region. In the decelerating region the helix is distorted. In the region of the arc field the helical path is further distorted, especially in the case of an electron which starts out from the filament in a direction crossing the magnetic field.

To provide, in the region between the slot forming, and electron accelerating electrodes **12** and **13**, a vapor of the material to be ionized, there is shown in the drawings filaments **23** and **24**, each comprising rods of suitably electrically conductive material supported by and welded to the transverse conductive rods **25** so as to extend parallel to the electrodes **12** and **13** respectively. The vapor or gas of the metal to be ionized is produced locally within the slot by heating the metal or a salt thereof on these filaments **23** and **24**. As illustrated in Figure 1, I have provided leads **26** which extend through seals **27** formed in the envelope for connecting the groups of filaments **23** and **24** in series with a suitable source of heater voltage **28**.

In front of the slot as illustrated in Figure 1 or to the right of the slot as illustrated in Figure 2 and within the envelope **10**, I have provided two equipotential ion accelerating electrodes **30** and **31**. The conductive leads **32** and **33** extending from these electrodes are brought out through the seals **34** in the envelope so that the electrodes **30** and **31** may be connected to a source of direct current potential **35**. In this manner, these electrodes are maintained at a negative potential of say between 10,000 to 100,000 volts with respect to the slot forming electrodes **12** and **13**. The electrodes **30** and **31** not only serve thus to accelerate the ions formed in the slot but also serve to produce the electron retarding field.

The helical path of the electrons within the slot as governed by the combined action of the electrical field between the filament **11** and the electrodes **12** and **13** and the magnetic field H will also be influenced by the retarding field produced by the high negative potential of the electrodes **30** and **31** to cause the electrons to flow in a path substantially as indicated in broken lines in Figure 2. In order that these electrons may take a path as indicated, the electrodes **30** and **31** are positioned so that the field produced by their high negative potential will extend into the slot to cause the electrons flowing in the direction of the magnetic field H to slow down, stop, and reverse in direction to travel back toward the filament.

To place apparatus of the type described in operation, it is first necessary to remove one of the walls or a portion of a wall forming the chamber **10** to gain access to the interior thereof. A supply of the ionizable material to be vaporized is then placed upon the filaments **23** and **24** by coating or otherwise, for example, by removing, coating and replacing the said filaments. The chamber **10** is then closed and evacuated to the desired vacuum, and the heater voltage **28** is impressed across the filaments **23** and **24** by means of the sealed leads **26**. The heat of the filaments vaporizes the material to produce within the slot region a vapor of the material to be ionized. The tungsten wire filament **11** is heated to an electron emission temperature by connecting the sealed leads **15** to a source of potential **17**.

An electron current controlled arc is then struck between the filament **11** and the electrodes **12** and **13** by connecting the electron accelerating potential **22** to the filament and electrodes. As is apparent from the drawings, the electrodes **30** and **31** are at a high negative potential relative to the anode forming electrodes by being connected through the sealed leads **32** and **33** to the grounded side of the source of direct current potential **35**. The high negative potential of these electrodes serves two important functions in my apparatus. First, this potential serves to withdraw from the region of the slot formed by electrodes **12** and **13** the ions formed by the bombardment of the electrons influenced by the electric field established between the electrodes **30** and **31** and the electrodes **12** and **13**.

In serving its second function this field retards the flow of electrons within the vicinity of the front slot edge, stops these electrons, and reverses their direction to increase their ionizing power and to form a space charge which produces an electric field extending into the slot and in turn serves to augment the withdrawal of the ions produced in this region. Furthermore, many of the electrons emitted from the filament **11** will initially collide with the vapor molecules and produce ions in close proximity to the filament. These ions will be influenced by the arc voltage field between the filament and anodes **12** and **13**, and will migrate toward the filament to neutralize the space charge of the emitter.

It will now be appreciated that a preferred embodiment of my invention has been diagrammatically illustrated so that others may likewise most conveniently obtain the good results and objects of this invention.

It should be apparent that I am not limited specifically to the structure disclosed in the drawings. For example, rather than utilize the slot forming electrodes **12** and **13**,

a series of capillary tubes could be provided with the retarding field produced by the ion accelerating electrodes supported in close vicinity to the capillary openings of the tubes. Likewise the cathode of the source may be indirectly heated or otherwise rendered electron emissive, and the material to be ionized might be vaporized by the heat of the arc, or previously vaporized and introduced into the arc region. Furthermore, I am not liimted to the number of slot forming electrodes illustrated—in fact, many slots could be built up one above the other. Grid electrodes could also be provided with a plane ion source.

While it is not involved in this invention, it should be understood that facilities may also be provided whereby pieces of the metal or metal compounds may be mechanically fed on to the filaments **23** and **24** to avoid the necessity of opening the chamber of envelope **10** to replenish the source of vapor of the material to be ionized. Thus, many modifications may be made both in the apparatus and methods described without departing from the spirit and scope of this invention as defined in the appended claims.

I claim:

1. An apparatus for producing ions including in combination a sealed envelope, electrodes supported within said envelope defining therebetween an ionizing space, means within the said space for vaporizing the material to be ionized, means supported within said envelope at one side of said electrodes for emitting a copious supply of electrons, means for applying a potential to said electrodes to produce an electric field for accelerating the electrons within the space to ionize the vapor between said electrodes therein, means to produce a magnetic field in a direction transverse to said electric field, and negatively charged means supported within said envelope at the side of said electrodes opposite said emitting means to withdraw the ions formed by bombardment of electrons within the region of the space defined by said electrodes and influenced by said negatively charged means and to retard the electron flow within this region to increase the ionizing capabilities thereof and to establish a space charge extending into said region for augmenting the withdrawal of ions therefrom.

2. An ion source comprising a pair of flat conductive members superposed in spaced relationship to form a slot, means for producing within said slot a vapor of a material the ions of which are desired, an electron source at one side of said slot at the entrance thereof and substantially midway between said members, means for applying a positive potential to each of said members for accelerating the electrons from said source, means for directing at least a portion of said accelerated electrons through the vapor within said slot, an electrode positioned on the side of said slot opposite said electron source, and means for maintaining said electrode at a negative potential relative to said source whereby the direction of flow of the electrons within said slot is reversed through the vapor within the slot to produce further ions, the potential of said electrode also serving to withdraw ions from said slot region.

3. An ion source comprising a pair of flat conductive members superposed in spaced relationship, means for producing within the space between said conductive members a vapor of the material to be ionized, an extended filament of an electron emitting material at one side of said space, means for producing an electron controlled arc between said filament and conductive members, means for causing at least a portion of the electrons of said arc to be directed through the vapor within said space for forming ions of said vapor, ion accelerating means comprising a magnetic field having a direction between said conductive members and normal to said filament comprising spaced parallel equipotential conductive surfaces positioned adjacent said space at the side opposite said filament, means for charging said surfaces negatively with respect to said filament to direct the electrons back through the vapor in a reverse direction to produce further ions in said space.

4. An ion source comprising a pair of conductive members having their greater length in a direction transverse of a predetermined ion path, said members being superposed in spaced relationship to form a slot, means for supplying within said slot a vapor of the material to be ionized, an arc electron source at one side of said slot, and means providing a magnetic field having a direction through said slot for collimating a flow of electrons from said source whereby the electrons will flow through the slot in the direction of the magnetic field, an electrode positioned at the edge of the slot opposite said arc electron source, means for applying a negative potential to said electrode to cause the electrons flowing through the slot to be slowed down, stopped and reversed in direction to produce further ions of the vapor in their return path toward their source.

5. An apparatus for producing ions from a solid material including in combination a sealed envelope, a pair of flat electrodes supported within said envelope in parallel relation and spaced to provide an ionizing region therebetween, an electron emitter supported at one side of said electrodes substantially midway between the surfaces thereof, and heater means supported within the space between the electrodes for producing within said region a vapor of the material to be ionized, means providing a magnetic field parallel to said electrodes and means for applying an electron accelerating potential to said electrodes whereby to ionize by electron bombardment the vapor in this said region.

6. An apparatus for producing ions including in combination a sealed envelope, an electron emitter supported within the interior of said envelope, said emitter comprising a long straight wire filament, means for conducting a current through said filament to heat the filament to an electron emitting temperature, first electrode means supported within said envelope at one side of said filament and extending lengthwise thereof to define an ionizing space, means providing a magnetic field along said space, means for supplying within the space defined by said electrode means a vapor of the material to be ionized, and means for applying an electron accelerating potential to said electrode means for accelerating the electrons emitted from said filament and second electrode means adjacent said first electrode means on the side away from said filament for directing the electrons in a return path through the vapor in the space defined by said means to ionize said vapor.

No references cited.