

Oct. 20, 1959

R. BERNAS ET AL

2,909,697

APPARATUS FOR PRODUCING IONS OF A GIVEN ELEMENT

Filed March 23, 1956

2 Sheets-Sheet 1

Fig. 1.

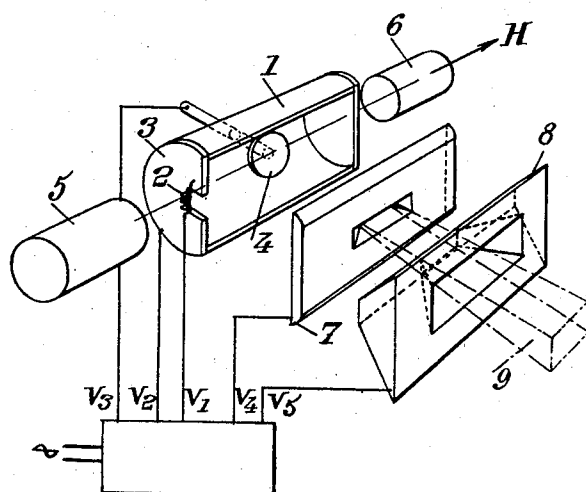
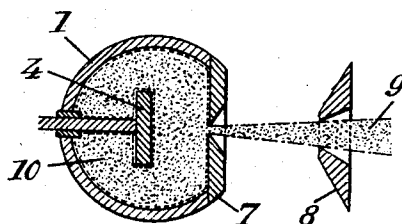


Fig. 2.



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Fig. 3.

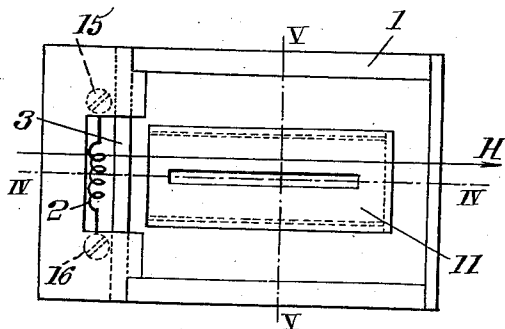


Fig. 5.

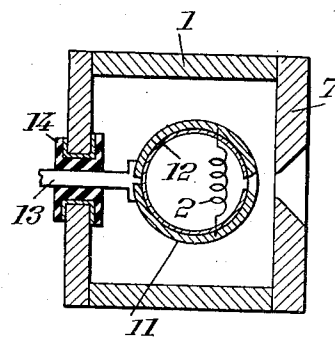


Fig. 4.

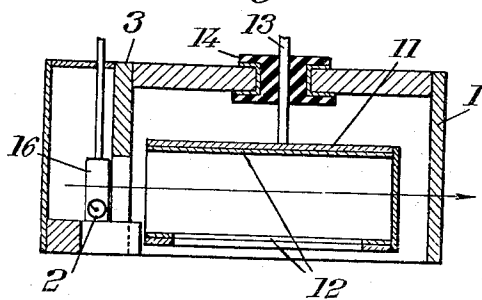
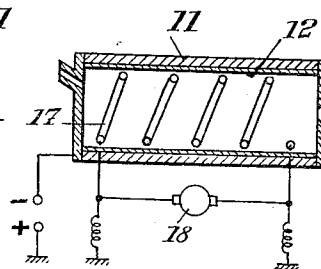


Fig. 6.



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APPARATUS FOR PRODUCING IONS OF A GIVEN ELEMENT

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9 Claims. (Cl. 313—63)

The present invention relates to apparatus for producing ions of a given element, either refractory or not. Its chief object is to permit the obtaining of ions from elements which may be in the solid state, without requiring a high temperature.

A number of apparatus make use of ion beams, in particular ion accelerators and, more especially, electromagnetic isotope separators. In such apparatus it is necessary to produce intensive beams of ionized particles of a given element.

It is therefore necessary to bring the bodies to be ionized into a state of atomic division.

Up to the present time, the most commonly used solutions for obtaining this result and forming sources of ions consisted in raising the temperature of the element to be ionized or of one of its compounds, such as a halide, in order to obtain a vapor tension.

The means for obtaining this result vary with the order of magnitude of the temperature necessary for obtaining this vapor tension (which may range from 20 to 3000° C.).

For instance, use is made of resistance furnaces in order to vaporize elements having a vapor tension of moderate value and stable compounds of elements having a low vapor tension, whereas use is made of electronic bombardment furnaces to vaporize refractory elements the compounds of which, such as halides, having a high vapor tension, are unstable at the temperature necessary for the operation of said ion sources.

These known solutions are complicated and they are not of a general application. Furthermore, in most cases, the use of a compound instead of the element itself reduces the yield of the ion stream extracted from the element, due to the dissociation of the molecules by electronic impact in such ion sources.

On the other hand, there is a phenomenon known as "cathode disintegration" which is well known and which consists in the bombardment of a cathode by positive ions of some elements or compounds of these elements accelerated up to speeds higher than one hundred electron-volts, so as to knock out the atoms of said cathode and thus to release particles of the element of which said cathode is made, whatever be the temperature.

Our invention consists essentially in subjecting a probe electrode made of the element of which a beam of ions is to be produced by ions according to the above stated cathode disintegration process, the particles thus knocked out from this probe electrode whatever be its temperature being ionized in an electric discharge of any suitable type, then extracted by means of an accelerator electric field in the form of an intensive ion beam which contains an important amount of the element of which the probe electrode is made.

Preferably, the same means are used for producing the ions which are to bombard the probe electrode and for ionizing the particles emitted from said electrode,

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which means may be an electronic discharge from a cathode produced in a magnetic field or a high frequency discharge.

Preferred embodiments of the present invention will be hereinafter described with reference to the accompanying drawings given merely by way of example and in which:

Fig. 1 is a perspective view of an apparatus according to our invention, this view being an exploded one so as to show the elements of the apparatus at a distance from one another.

Fig. 2 shows on an enlarged scale and in sectional view the main portion of the apparatus of Fig. 1.

Fig. 3 is a front view of another embodiment of our invention to be applied with an electro-magnetic isotope separator.

Fig. 4 is a sectional view on the line IV—IV of Fig. 3.

Fig. 5 is a sectional view on the line V—V of Fig. 3, said Fig. 5 further showing one of the elements of the device for extracting the ion beam.

Fig. 6 is a diagrammatical view relative to another embodiment.

In an apparatus as illustrated by Fig. 1, the parts are enclosed in a common envelope (not shown on the drawings) containing an atmosphere of a rare gas or of a vapor (chlorine, nitrogen, etc., or even the vapor of the element of which the probe electrode is made) under a pressure varying, according to the nature of said gas or vapor, from an approximate vacuum to some hundreds of atmospheres.

These parts include a casing 1, a hot cathode 2 at a potential V_1 (or any other suitable means for emitting electrons), an anode 3 at a potential V_2 , a probe electrode 4 at a potential V_3 , constituted by the element of which is to be made the ion beam to be obtained. A magnetic field illustrated by arrow H is produced along the axis of casing 1, for instance by an electro-magnet only the poles 5 and 6 of which are shown. Two electrodes 7 and 8 at respective potentials equal to V_4 and V_5 are placed, the first one 7 in the immediate vicinity of the source of ions and the second one 8 at some distance from the first one. The ion beam that is obtained is shown at 9.

In the case of a high frequency discharge, cathode 2 is no longer necessary, nor the magnetic field H.

The operation of this apparatus is as follows:

Cathode 2 produces electrons which are accelerated by anode 3 and focalized along lines of force of the axial magnetic field H so as to intensify their action.

An electric discharge can then be produced in the gas or vapor contained inside casing 1. In these conditions there is produced a plasma 10 (Fig. 2) characterized by a statistic equality of the positive and negative space charge density in each of its volume elements and by the fact that the constant potential of this plasma is always close to that of the most positive electrode.

On the other hand, the plasma 10 is limited, in the vicinity of any electrode present therein, by a region of very small size called "sheath" in which there is a potential gradient between the electrode and the plasma, so that the potential of a probe electrode has no material influence, except in the region corresponding to this sheath.

If there is then introduced into the discharge a probe electrode which is negatively biased with respect to the plasma so that the positive ions of the plasma which pass through the sheath then reach said probe electrode with a predetermined energy, the impact of these ions on the probe electrode will release atoms of the element of which said electrode is made.

According to our invention, a portion of the atoms knocked out from the probe electrode as a consequence

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of this bombardment is ionized in an electric discharge, which is advantageously the same as that which has produced the plasma but which might be different without departing from the principle of this invention. These ionized particles are then extracted in the form of an ion beam 9 by a suitable device constituted by electrode 7, placed at a potential V_4 close to that of plasma 10, and by electrode 8 at a negative potential V_5 .

Merely by way of example, we give hereinafter some values of potentials which may be used in a source of ions according to the present invention.

Potential V_1 of the cathode: about -100 volts;

Potential V_2 of the anode, the most positive potential, is taken as origin of the potentials: it is therefore $V_2=0$; it is the potential of the plasma;

Potential V_3 of the probe electrode: from -200 to -1000 volts (current from 1 to 2 amperes);

Potential V_4 of electrode 7: equal to V_2 , i.e. equal to 0; and

Potential V_5 of electrode 8: from -10,000 to -50,000 volts.

The probe electrode 4 may be in the solid or liquid state, and it may be a conductor or semi-conductor; it may even be made of an insulating material.

It should be well understood that the primary ions, that is to say the ions which serve to bombard the probe electrode, might be obtained in any other way, without departing from the principle of our invention. For instance, we might form plasma 10 by means of a high frequency discharge, or make use, in order to disintegrate the probe electrode, of a beam of primary ions of any origin whatever.

Figs. 3, 4 and 5 relate to a preferred embodiment of our invention, applicable in particular as a source of ions for an electrode-magnetic isotope separator. Of course, this apparatus is not limited to said application.

In this construction, the electrons are emitted by a hot filament 2 carried by two supports 15 and 16. Anode 3, which serves to accelerate these electrons, is of cooled copper and it is biased to some hundreds of volts with respect to filament 2. The axial magnetic field H is of some hundreds or some thousands of Gauss; the electro-magnet which produces this field is not shown. The discharge is maintained either by the element itself which emits a vapor, or by an inert or chemically active gas, or again by a vapor.

In this construction, the probe electrode is constituted by a sheet 12 of the element to be ionized or of a compound or alloy thereof, supported inside a hollow cylinder 11 made of graphite. The form of the raw material that is used is not critical, which greatly facilitates construction of the apparatus. This probe electrode is fixed in casing 1 by a support 13 secured in an insulator 14.

Due to this arrangement and to the distribution of potential imposed by the probe electrode, the plasma of the discharge is concentrated inside cylinder 11 and the probe electrode is disintegrated by the impact of the positive ions on its inner face.

A portion of the atoms knocked out from the probe electrode, after having been ionized in the discharge, is accelerated by a suitable device including the electrode 7 shown on Fig. 5 and extracted from the source in the form of an ion beam toward the electro-magnetic separator. Another portion is recondensed upon the inner walls of the probe electrode, which permits its subsequent reemission by the same process.

In order to reduce to a minimum the losses of disintegrated material, the open surface of the cylinder is limited to the slot for the outflow of the ions and to the side aperture on the side of the hot cathode 2 necessary for the inflow of the electrons into the discharge. This arrangement has the advantage of increasing the efficiency of ionization of the element that is considered, and to protect the insulator 14 of the probe electrode against metallizing.

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Fig. 6 illustrates the case of high frequency being used, as above stated, for producing the discharge. A hollow cylinder 11 contains a sheet 12 of the element to be ionized and the plasma is created inside this cylinder by a high frequency discharge taking place in a winding 17 fed from a source 18. This discharge may take place with or without an axial magnetic field H and the frequency may average 100 megacycles.

The ion producing apparatus according to the invention work quite as well with refractory metals or with non-refractory metals.

By way of example, this apparatus has been used for extracting ion beams from elements such as molybdenum, palladium, iron and copper; these beams contained from 20 to 100% of the disintegrated element.

Comparison of the characteristics of the conventional discharge and of a discharge making use of the cathode disintegration phenomenon shows another advantage of the apparatus according to our invention. This is due to the fact that with the same element and with a constant beam of ions extracted in both cases, there is an increase of the resolution power when recording the same mass spectrum on the electro-magnetic separator.

In a general manner, while we have, in the above description, disclosed what we deem to be practical and efficient embodiments of our invention, it should be well understood that we do not wish to be limited thereto as there might be changes made in the arrangement, disposition and form of the parts without departing from the principle of the present invention as comprehended within the scope of the accompanying claims.

What we claim is:

1. An apparatus for producing ions of a given element which comprises, in combination, an envelope filled with a gaseous atmosphere, electronic means for producing a discharge in said atmosphere, an electrode in said envelope located in the portion of said discharge where a plasma is formed, said electrode being at a potential more negative than said plasma, whereby positive ions of said gaseous atmosphere are made to bombard said electrode and to knock out particles of said element from said electrode, said particles being ionized by said discharge producing means, and means for extracting a beam of said ionized particles from said envelope.

2. An apparatus according to claim 1 in which said plasma is at zero potential.

3. An apparatus for producing ions of a given element which comprises, in combination, an envelope filled with a gaseous atmosphere, a hot cathode for producing an electric discharge in said gaseous atmosphere, an anode for accelerating the flow of electrons from said cathode, means for producing in said gaseous atmosphere an axial magnetic field focalizing the electrons emitted by said cathode, an electrode made of said element located in said atmosphere, means for placing said electrode at a potential suitable to enable bombardment thereof by the positive ions of said gaseous atmosphere produced by said discharge, whereby particles of said element are knocked out from said electrode, said particles being ionized by said discharge, and means for extracting a beam of said ionized particles from said envelope.

4. An apparatus according to claim 3 in which said means for extracting the beam of ionized particles consist in two electrodes at least one of which is at a very high negative potential.

5. An apparatus according to claim 3 in which said electrode is in the solid state.

6. An apparatus according to claim 3 in which said electrode is in the liquid state.

7. An apparatus for producing ions of a given element which comprises, in combination, an envelope filled with a gaseous atmosphere, electronic discharge means for producing an electric discharge in said gaseous atmosphere, an electrode made of said element located inside said atmosphere, means for placing said electrode at a

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potential suitable to produce bombardment thereof by the positive ions of said gaseous atmosphere due to said discharge, whereby particles of said element are knocked out from said electrode, said particles being ionized by said discharge producing means, and two electrodes, at least one of which is at a very high negative potential, for extracting a beam of said ionized particles from said envelope.

8. An apparatus for producing ions of a given element which comprises, in combination, an envelope filled with a gaseous atmosphere, electronic discharge means for producing an electric discharge in said gaseous atmosphere, an electrode consisting of a cylindrical sheet at least partly constituted by the element to be ionized located inside said atmosphere, a hollow graphite cylinder disposed to contain said sheet, insulating means for supporting said cylinder, means for placing said electrode at a potential suitable to produce bombardment thereof by

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the positive ions of said gaseous atmosphere due to said discharge, whereby particles of said element are knocked out from said electrode, said particles being ionized by said discharge producing means, and means for extracting a beam of said ionized particles from said envelope.

9. An apparatus according to claim 8 in which said sheet and said cylinder are provided with a slot for the outflow of the ion beam.

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