Jan. 28, 1958 W. A. BELL, JR., ET AL 2,821,662

ION SOURCE

Filed July 29, 1955 2 Sheets-Sheet 1

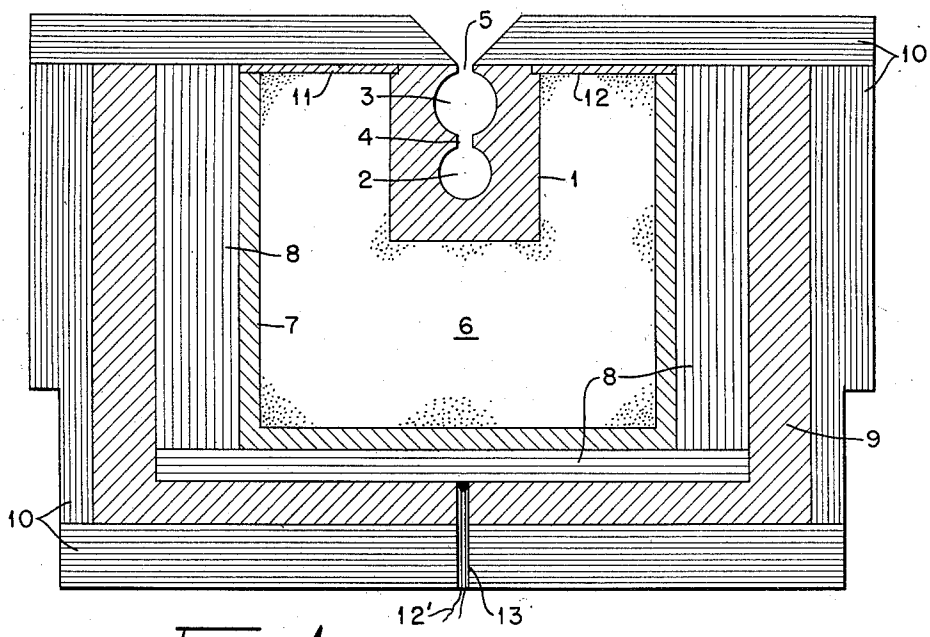


FIG. 1.

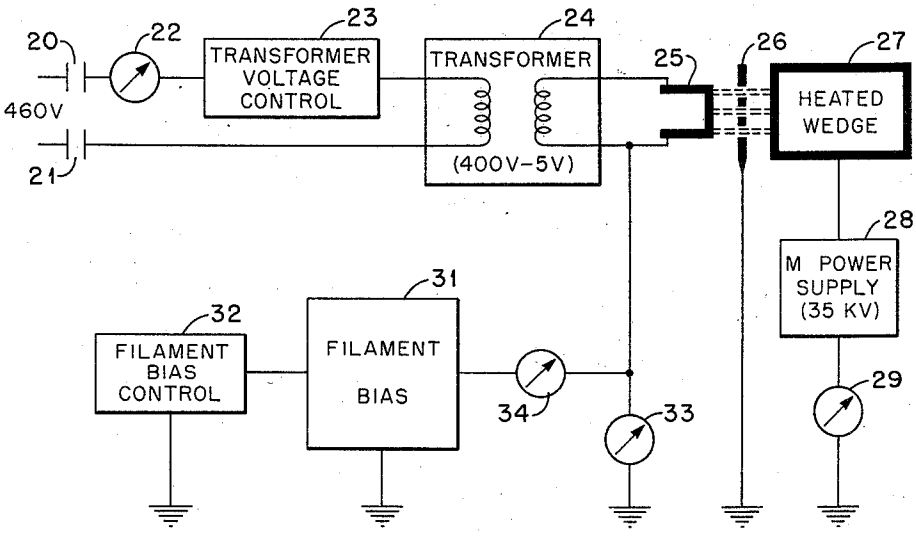


FIG. 2.

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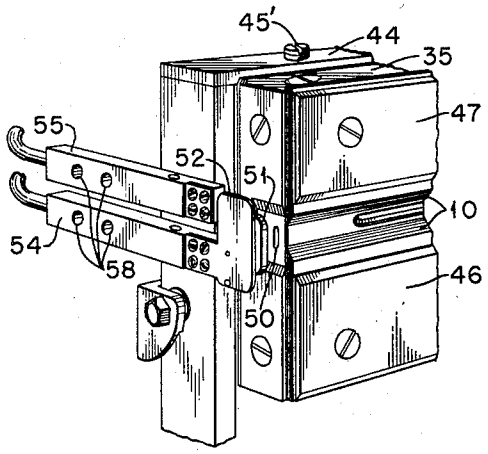


FIG. 4.

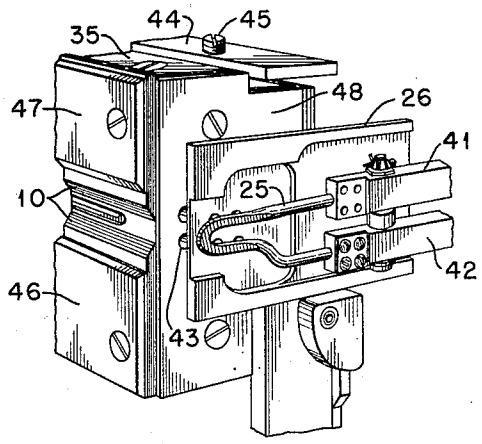


FIG. 3.

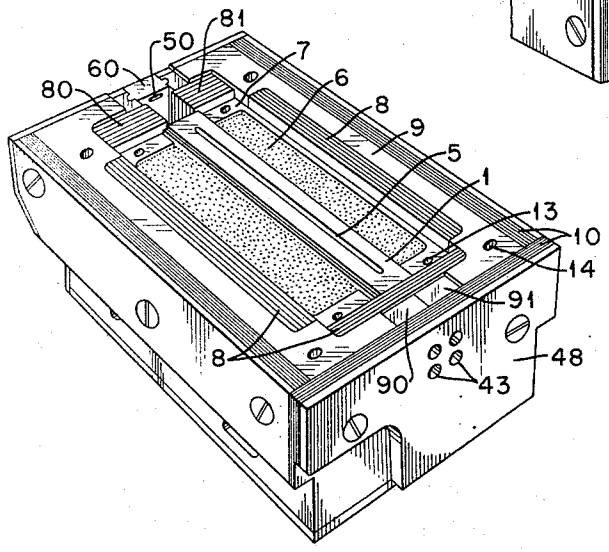


FIG. 5.

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United States Patent Office 2,821,662 Patented Jan. 28, 1958

2,821,662

ION SOURCE

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Application July 29, 1955, Serial No. 525,413

5 Claims. (Cl. 315—111)

The present invention relates to the separation of isotopes in a calutron, and more especially to a novel ion source capable of producing ions of elements which vaporize only at exceedingly high temperatures, i. e. —1500° to 3000° C.

It has been demonstrated that isotopes of many chemical elements can be separated and the desired elements enriched in the magnetic mass spectrometer known as the calutron, described in the E. O. Lawrence Patent #2,709,222. In the calutron as described in the patent, there is provided a vaporizer or furnace formed from a block of metal which contains a pocket adapted to receive a charge to be vaporized. An electrical coil heater is provided adjacent the pocket in a recess in the furnace to heat the contents of the pocket. Vapor from the furnace passes to an adjacent ion source member, and is ionized therein. These sources are eminently satisfactory for materials having relatively low vaporizing temperatures—say up to 1000° C.—but they could not be used with elements having vaporizing temperatures in the higher ranges. Such metals as platinum, palladium, ruthenium and iridium could not be satisfactorily separated into their various isotopes in the calutron.

Various methods for reaching high temperatures have been attempted including heating the furnace with a large beam of electrons, but without success. In some systems of the prior art, the charge material simply did not get hot enough to vaporize. In others, the amount of material vaporized was a function of arc conditions, and the ion output was low and unstable. In addition, the temperature of the furnace could not be controlled well enough to give stable operation. The calutron sources were too large to handle the small available samples of precious metals well, and too much power was required to heat them. Moreover, the vapor produced in the furnace tended to condense upon contact with the cooler walls of the separate ion source.

With a knowledge of these and many other problems of the separation of high temperature charge materials in a calutron, applicants have as a primary object of their invention provision of a novel ion source capable of heating a charge material up to substantially 3000° C. to vaporize the charge while at the same time establishing a stable ionizing arc through the container holding the charge to ionize the vapor. Another object of the invention is to provide means for heating a calutron charge to a very high temperature and for regulating the temperature to a substantially stable value. Yet another object of the invention is to provide maximum temperature and arc stability with minimum required power input. Another important object of the invention is to provide an ion source capable of operating satisfactorily with a very small charge, so that the relatively precious metals or very minute quantities of other materials may be used as the charge. Other objects and advantages of the invention will become apparent from the following detailed description of a preferred embodiment thereof, when read in connection with the appended drawings, in which

Figure 1 is a sectional view of one configuration of the source block, forming a vital element of our invention;

Figure 2 shows in block form typical electrical connections for heating the source block;

Figure 3 shows the means provided for heating the source block by electron bombardment;

Figure 4 illustrates the cathode, collimating slit, and source block for ionizing the charged vapor; and

Figure 5 is a perspective top view of the novel source having certain covers removed for clarity.

In accordance with the invention, a small unitary source block is provided with a filament disposed adjacent thereto for heating the block by direct electron bombardment. The block contains preferably two separate cavities, an inner cavity for containing the charge and an outer cavity forming the arc chamber. The charge is vaporized by the high temperature of the container resulting from the bombardment and passes through a connecting passageway to the arc chamber, where it is fed electrons from a cathode, the vapor is ionized, and a stable arc is created. Ions are taken from an exit slit and accelerated through the magnetic field of a calutron to a receiver where they are collected. Means are provided for separating the electrons from the filament into a plurality of discrete, very intense beams and for directing these beams closely adjacent the walls of the cavities. Special heat shielding means is provided around the source block to retain the heat generated therein by the bombardment. A second filamentary cathode is disposed at the opposite end from the first filament and aligned with the arc chamber so as to establish a stable arc between the filament and opposite chamber wall to ionize the vapor from the charge in the container.

It has been found that intense, localized heating of the charge can be attained by focusing the electrons emitted into separate, discrete beams, directed closely adjacent the walls of the inner cavity. The arc chamber can be heated at the same time to prevent vapor condensation on the chamber walls and vapor entry slit by forming the arc chamber and charge oven from a single small block, the cavities being roughly in the shape of the numeral "8" in cross-section. With such configuration, intense electron beams may be directed on either side of the central portion joining the cavities, so that both cavities and the vapor entry slit are heated effectively thereby.

One embodiment of a heat shielded source assembly is shown in Figure 1. The source block 1 is a rectangular graphite block in which are machined two cavities extending longitudinally of the block, and connected longitudinally with a slot 4. The inner cavity 2 serves as a charge container while the outer cavity 3 serves as an arc chamber for the ion source. The ion exit slot 5 is an integral part of the source block and extends parallel to slot 4. The block 1 is embedded in a carbon dust 6 for thermal insulation, the dust being surrounded by a graphite box 7. The box is in turn surrounded by multiple layers of thin graphite sheets 8 forming a heat shield. A second graphite box 9 surrounds the heat shielding layers 8 and is in turn surrounded by additional thin graphite sheets 10. The central portion of the sheets 10 are machined into a converging aperture registering with the ion exit slit 5 of the source block. A pair of thin graphite sheets 11, 12 contact shoulders on the block 1 and are fastened with screws, not shown to the box 7, to seal the dust in the source assembly. A thermocouple 12' may be provided in well 13.

In a typical source assembly, cavity 2 may be 5/16" in diameter, cavity 3 may be 3/8" in diameter, slot 4 may be 1/16" in thickness, and the lips of ion exit slit 5 may be

.032" thick. The slit may be 3/32" wide and 4½" long. The block itself may be ¾" wide, 1" high, and 5½" long. The box **7** may be ⅛" thick, 2⅝" wide and 2 3/16" deep. The dust **6** may be carbon dust #80 mesh. The shielding sheets **8** may be arranged from 0.03" carbon sheets stacked in a layer 7/16" on the sides and 3/16" on the bottom. The graphite box **9** may be ⅜" on the side and ¼" thick on the bottom surface. The outer layer of shielding **10** may be 5/16" thick on the top and sides and bottom, cut away to 3/16" thick, ¾" above the bottom surface. These outermost sheets may be of .015" carbon. The plates **11** may be ⅛" graphite.

Referring now to Figure 2, electrical heating current may be supplied from a suitable source of 460 volts through suitable contacts **20, 21**, a filament current meter **22** and a voltage control device **23** to a transformer **24**, which may be a 400 volt-5 volt step-down transformer. The filament **25** is connected to the secondary of the transformer. A carbon grid structure **26** having a plurality of apertures therein is disposed between the filament and the source block **27** and connected to ground. A high voltage source **28** of substantially 35 kilovolts is connected through the drain meter **29** to ground and has its positive terminal connected to the source block. To regulate the emission of the filament, a power supply **31** provides filament bias and is controlled by the filament bias control **32**. The bias voltage is indicated on meter **33**, while the emission current is indicated on meter **34**. Normally the filament may be operated at 400 volts positive to ground, and emission currents from 50 to 300 milliamperes may be adequately controlled by adjusting the filament-to-grid bias.

Referring now to Figure 3, a 170-mil tantalum filament **25** may be clamped in water-cooled bus bars **41, 42** fed from filament leads to a source of filament current. The bus bars are mounted on an insulator, which is in turn mounted on a grounded bracket, which may be mounted on the conventional source frame. The grid **26** may be formed from a single piece of graphite having preferably four apertures therein registering with apertures **43** drilled in plate **48** at one end of the source, and may also be supported from the same bracket as the bus bars. The grid may be spaced ⅝ in. from the plate **48** and be very close (.005 in.) to the filament. The source block may be supported and positioned in the source assembly by any suitable means and carefully insulated from grounds, since it must operate at 35 kilovolts positive. A mounting frame member **44** shown better in Fig. 4, may be mounted to the calutron source frame, not shown, and receive screws **45** which fasten it to the rear of source assembly **35**. Plates **47, 48** hold stacked plates **10** in position.

Referring now to Figure 4, the cathode end of the source block includes a collimating slit **50** registering with the outer cavity in the source block to allow electrons from the filament **51** to enter therethrough and set up an arc through the cavity. A shield **52** is provided behind the filament to reflect the electrons into the source. Electrons are accelerated from the filament into the arc chamber by maintaining the filament slightly negative with respect to the source block, say from 100 to 200 volts negative. The filament may be mounted on water-cooled bus bars **54, 55**, supported on an insulator, not shown, and the calutron source frame through screws entering holes **58**.

Referring now to Figure 5, the source is shown with the dust cover plates **11, 12** and the top shielding plates **10** removed. The block **1** provided with slit **5** is surrounded by carbon dust **6**, contained in box **7**. Holes **13** are provided to receive the screws holding plates **11, 12**, while holes **14** receive the screws holding down stacked plates **10**. Plates **8** are stacked on both sides, at both ends, and under box **7**, but the end of block **1** nearest slit **50** is left clear by provision of plates **80, 81**. Slot **50** is milled in a keyed portion **60** which fits in the end of box **9**. The opposite ends of box **9** are plugged with graphite blocks **90, 91**.

In operation of the novel source described above, the charge material is placed in the charge cavity **2**, either through a hole at one end, which is then plugged, or through slits **5, 4**, the source is assembled in its heat shielding protective covering, and then is mounted to the calutron source frame. The calutron is operated in essentially the standard manner as described in the Lawrence patent. First an arc is struck through the arc chamber from the filament to the opposite wall, using nitrogen as a support gas for the arc, and then the bombardment filament is heated to vaporize the charge material. The arc is maintained by the charge vapor emerging from the cavity **2** through slot **4** into the cavity **3** where it is ionized.

Well over 400 isotope separation runs have been performed with the elements palladium, platinum, ruthenium, and iridium with the novel high temperature sources of the character described, at temperatures from 1750° C. to well above 2800° C. and satisfactory electromagnetic enrichment of the isotopes of these elements has thus been achieved for the first time. Therefore, it will be apparent to those familiar with the art that a novel ion source has been provided which enables enrichment of certain materials not heretofore possible.

Having described our invention, what is claimed as novel is:

1. In an ion source, a container provided with walls defining a chamber for receiving a charge of material to be vaporized, a thermionic filament disposed adjacent to said container, a grid structure disposed between said filament and said container, and provided with a plurality of apertures arranged to form discrete beams of electrons directed towards said walls adjacent said chamber, means for heating said filament to cause it to emit electrons, and an adjustable potential source connected between said grid and filament for accelerating said electrons from said filament through said grid to strike said container walls, thereby heating said chamber to vaporize said material.

2. An ion source comprising a source block provided with a pair of interconnected longitudinal chambers therewithin and further provided with a longitudinal slit in one surface thereof connected with one of said chambers, a thermionic filament mounted adjacent one end of said block, a grid structure disposed between said filament and said block and provided with a plurality of spaced apertures longitudinally aligned with portions of said block surrounding said chambers, means for heating said filament to cause it to emit electrons, means for accelerating electrons from said filament to said block through said grid in a plurality of discrete, intense beams, and heat shielding means surrounding said block for retaining the heat generated in said block by said electrons.

3. An ion source comprising a source block provided with first and second longitudinal, interconnected chambers therewithin and further provided with a slit in one surface thereof connected to a first of said chambers, means for disposing a substance to be vaporized in the second of said chambers, a first thermionic filament mounted adjacent to said source block in alignment with said second chamber, a grid structure disposed adjacent said filament and provided with a plurality of apertures therein, means for heating said filament to cause it to emit electrons, means for accelerating electrons from said filament to said block through said grid, a second filament mounted at the opposite end of said block from said first filament and disposed in alignment with said first chamber, the adjacent end of said block being provided with a collimating slit aligned with said second filament and communicating with said first chamber, and means for accelerating electrons therefrom across said first chamber to strike an ionizing arc between said filament and the walls of said chamber.

4. In a source of the character described, an inner graphite block provided with a central cavity extending longitudinally thereof and a slot in one wall communicating with said cavity, an outer graphite box surrounding said block on the ends, sides and the bottom surface thereof, an inner graphite box disposed within said outer box, a thermal insulating layer comprising stacked carbon sheets disposed between said inner and outer graphite boxes, carbon dust filling the interior of said inner box and surrounding said source block on said two sides and bottom surface, and an outer shielding layer comprising thin carbon sheets stacked to form a rectangular member surrounding said outer graphite box on two sides, top and bottom, the top section of said outer shield member being provided with a tapered groove forming at its inter extremity a slit registering with the slit in said source block to allow ion escape from the interior of said source block, and means for heating said source block to vaporize a sample of charge material inserted in said chamber.

5. In an ion source, a first graphite block provided with a charge oven, an arc chamber provided with an exit slit for ions, an entrance slit for electrons and an entrance slit for vapor; a first filament disposed adjacent said electron entry slit, means for energizing said filament, means for accelerating electrons through said entry slit against the walls of said arc chamber to form with said vapor a stable arc; a second filament disposed at the opposite end of said arc chamber, means to energize said filament to emit electrons, means for focusing said electrons into a plurality of discrete intense beams, and means for directing said beams to strike said opposite end of said block in a plurality of points adjacent said vapor entrance slit and said charge oven and substantially symmetrical about said oven.

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