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ISOTOPE SEPARATING APPARATUS

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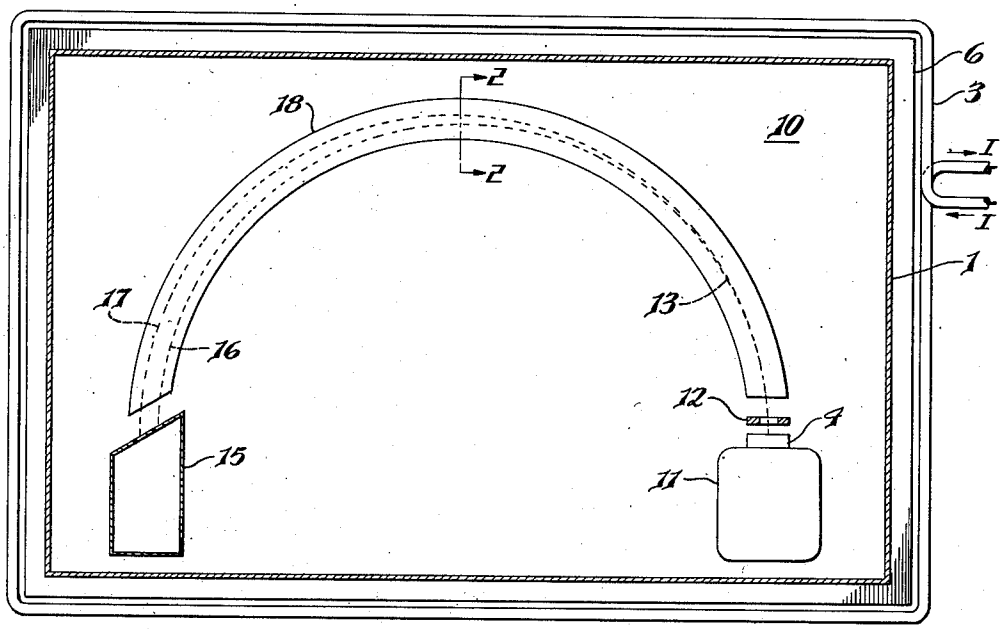


FIG. 1.

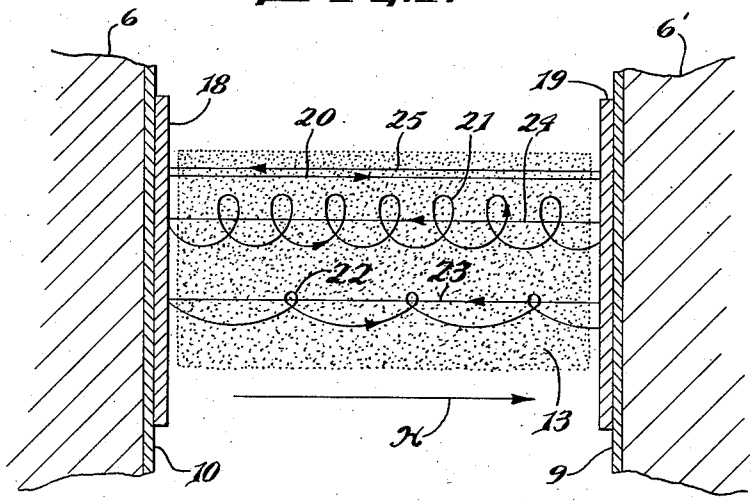


FIG. 2.

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ISOTOPE SEPARATING APPARATUS

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9 Claims. (Cl. 250—41.9)

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The Government of the United States, as represented by the U. S. Atomic Energy Commission, has a license to use and manufacture the invention covered by this patent application and any and all Letters Patent issued thereon for governmental purposes without the payment of any royalty fees to me whatsoever.

This invention relates generally to the art of isotope separation, and has particular reference to novel means whereby the employment of beams of greater ion density is made possible in mass spectrometers, and in electromagnetic apparatus for the large scale separation of isotopes commonly known as calutrons.

In the early development of mass spectrometers, it was considered most desirable to operate at as low a pressure as possible, in accordance with the accepted practice in respect to other types of electric discharge apparatus, in order to minimize interference between the electric discharge and the molecules of the medium contained within the discharge apparatus. It was also believed that there was a very definite limitation upon the intensity of the ion beams which could be attained in such spectrometers due to the defocusing action arising from the mutual repulsion of the ions forming the beam. In other words, too large a beam would blow up due to its own space charge. This limitation, while not too serious in a mass spectrometer, itself, presented a particular problem when such mass spectrometers were attempted to be modified for use as calutrons, that is, for the large scale separation and collection of the various isotopes of an element.

One method whereby this limitation was at least partly overcome and stronger ion beams were permitted to be used was conceived and developed by Ernest O. Lawrence and is described and claimed in his U. S. Patent No. 2,709,222 for Method of and Apparatus for Separation of Materials, issued May 24, 1955. His concept was to operate a calutron at a pressure substantially higher than the pressures previously employed for mass spectrometers. In his apparatus, the positive ion beam, by ionizing the residual molecules of the medium gas within the calutron, would thereby provide sufficient electrons to more or less neutralize the space charge of the beam itself, whereby substantially stronger ion beams could be employed without the undesirable defocusing action previously referred to. Increasing the operating pressure in this way, however, was accompanied by the undesirable effect of increasing interference between the ion beam and the molecules of the medium, and a compromise had to be resorted to.

The present inventor has conceived that the ion beam space charge may be neutralized without the disadvantages realized when the pressure is increased, by providing an auxiliary source of electrons adjacent to and contiguous with the ion beam and adapted to project electrons into the beam, thereby neutralizing the same and inhibiting its tendencies to defocus or blow up.

Accordingly, the principal object of the present invention is to provide means whereby the space charge of an ion beam within a calutron or within a mass spectrometer may be neutralized.

Another object of the present invention is to provide means whereby a calutron or a mass spectrometer may be operated with a stronger ion beam.

Still another object of the present invention is to provide means whereby calutrons and mass spectrometers may be operated with strong ion beams and at extremely low pressures.

Other objects and advantages of the present invention will become apparent from the specification taken in connection with the accompanying drawings wherein one embodiment of the invention is illustrated.

In the drawings, Fig. 1 is a schematic side elevation view, partially in section, of the improved electromagnetic isotope separating apparatus of the present invention.

Fig. 2 is an enlarged sectional view taken along lines 2—2 of Fig. 1 showing the details of the means for introducing the neutralizing electrons into the ion beam, and helpful in explaining the theory involved.

Referring now to the drawings, reference numeral 1 represents an evacuated vessel or tank which is traversed by a substantially uniform magnetic field, indicated at H in Fig. 2, which field is produced by an electromagnet having pole pieces 6 and 6'. Reference numeral 3 indicates a magnetizing winding for the electromagnet, which it will be understood is energized from a suitable source of magnetizing current I.

Reference numeral 11 indicates a source of positive ions which may be of a type more completely described in U. S. Patent No. 2,712,073, entitled "Temperature Control," issued June 28, 1955 in the name of Emmett V. Martin. As described in that application, there is included within the ion source 11 a container of charge material, that is, the material the isotopes of which it is desired to separately receive and collect. Suitable heating means are also included within the ion source 11 and associated with the container for vaporizing the charge material contained therein. After vaporization, the vapor of the charge material is channeled through a suitable passageway to the constricted top portion 4 of the ion source which forms an ionization chamber. There is maintained within this ionization chamber 4 an electric discharge or arc which serves the purpose of disassociating and ionizing the vapor of the charge material contained therein.

After ionization, the positive ions of the vapor of the charge material are withdrawn in the form of a beam 13 by an accelerating potential which is connected to a slotted accelerating electrode 12 and maintains it at a high negative potential with respect to the source 11. An elongated slot is formed along the top of the ionization chamber 4 adjacent to and coextensive with the elongated slot in the accelerating electrode 12 to allow the positive ions to escape from the chamber.

As is well known, the ion beam 13 thus formed is coerced through the influence of the magnetic field H to follow a circular path the radius of which is dependent upon the mass of the ions forming the beam. In this manner, the original single beam 13 is split into more or less distinct component beams 16 and 17 corresponding to the component isotopes of the charge material. The separated isotopes may then be individually collected in respective receiving pockets in the receiver or collector 15.

In accordance with the principles of the present invention, there is attached to the backside wall 10 of the evacuated tank 1 a strip 18 of radioactive material, such as phosphorous. Preferably, the strip 18 of radioactive material follows the contour of the ion beam for substantially the whole distance from the ion source 11 to the receiver 15. Opposite to strip 18, and positioned on the front side wall 9 of the tank 1, is an identically

shaped strip **19** which is of a material having a high secondary electron emission characteristic, such as cesium.

In operation the radioactive strip **18** emits high energy Beta rays, that is, electrons, along the entire length of the ion beam along one side thereof, and these electrons are constrained by the influence of the magnetic field H to move parallel to the field and therefore through and across the ion beam. These electrons, having crossed the ion beam strike the secondary electron emissive strip **19** with sufficient energy to eject therefrom a large number of low energy secondary electrons. These secondary electrons are also constrained to move parallel to the magnetic field H but at a much lower velocity than the original Beta rays emitted by the strip **18**. By virtue of this lower velocity, they are maintained within the ion beam for a much greater length of time and are therefore much more highly effective in neutralizing the space charge of the ion beam.

Referring now more particularly to Fig. 2, reference numerals **20**, **21**, and **22** indicate typical paths which may be taken by electrons emitted from the radioactive strip **18**, and reference numerals **23**, **24**, and **25** indicate typical paths which may be taken by secondary electrons ejected from the strip **19**. It will be apparent that electrons ejected from either strip come off in random initial directions relative to the magnetic field H. Due to the action of the magnetic field, however, they will all be constrained to progress generally parallel to the magnetic field. As is well known, the component of the initial velocity perpendicular to the field tends to cause the electrons to describe circular paths of a radius corresponding to this component, whereas the component of initial velocity parallel to the field serves to move the center of the circles in that direction. In this manner, it will be apparent that spirals **21** and **22** will be formed by electrons which are ejected with a component of velocity perpendicular to the magnetic field, spiral **21** indicating the path taken by an electron which comes off with a relatively high component of velocity perpendicular to the magnetic field. Reference numeral **20** indicates the path formed by an electron which is ejected with zero component of velocity perpendicular to the magnetic field, and of course, its path will be perfectly straight and along the magnetic field, as shown.

Similar theory is applicable in determining the paths followed by the secondary electrons emitted by the strip **19**. However, the energies with which such secondary electrons are emitted are of a very low order of magnitude. Accordingly, the component of velocity perpendicular to the magnetic field is so small that the radius of the circular path described as a result thereof would be negligible, and all the secondary electrons would move in a substantially straight line parallel to the magnetic field and across the ion beam, as indicated at **23**, **24**, and **25**. As previously stated, because of the fact that the secondary electrons are emitted with such a low energy content their velocity across the beam is also exceedingly slow, and therefore they are extremely effective as neutralizing agents for the space charge of the ion beam.

It is obvious that many modifications of the preferred structure illustrated may be made. For instance, the radioactive strip **18** alone would be helpful in neutralizing the beam without the necessity of employing any secondary electron effect. Accordingly, strip **19** could be replaced by a second radioactive strip, and the Beta rays produced by the radioactive material on both sides of the beam could be relied on alone to neutralize the ion beam space charge. Another obvious modification would be to form both strips of a material which had both the characteristics of Beta radioactivity and secondary electron emission. Also, the strips could be formed of a mixture of two materials, one of which is radioactive, and the other of which has a high secondary electron emission characteristic. Also, instead of providing the radioactive material and secondary electron emissive material in the form of strips **18** and **19**, these materials might simply be provided as a thin film or layer on the surface of the walls **10** and **9** of the evacuated tank **1**.

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.

I claim:

1. Electromagnetic isotope separating apparatus comprising an evacuated tank, magnetizing means associated with said tank for producing a unidirectional magnetic field traversing said tank, a source of positive ions, accelerating electrode means associated with said ion source for withdrawing a beam of positive ions therefrom and projecting said beam within said tank in a direction perpendicular to said magnetic field, receiving means disposed in the path of said beam for intercepting said ions, and a source of electrons positioned in said tank along the side of said beam for projecting electrons into said beam in a direction perpendicular to the plane of movement of the ions of said beam and parallel to said magnetic field, whereby the defocusing tendency of said beam resulting from the mutual repulsion of the positive ions forming said beam is minimized.

2. Electromagnetic isotope separating apparatus comprising an evacuated tank, magnetizing means associated with said tank for producing a unidirectional magnetic field traversing said tank, a source of positive ions, accelerating electrode means associated with said ion source for withdrawing a beam of positive ions therefrom and projecting said beam within said tank in a direction perpendicular to said magnetic field, receiving means disposed in the path of said beam for intercepting said ions, and an arcuate shaped radioactive source of Beta rays positioned in said tank along one side of said beam and facing said beam, whereby the defocusing tendency of said beam resulting from its own space charge is minimized.

3. Electromagnetic isotope separating apparatus comprising an evacuated tank, magnetizing means associated with said tank for producing a unidirectional magnetic field traversing said tank, a source of positive ions, accelerating electrode means associated with said ion source for withdrawing a beam of positive ions therefrom and projecting said beam within said tank in a direction perpendicular to said magnetic field, receiving means disposed in the path of said beam for intercepting said ions, and an arcuate shaped source of electrons disposed adjacent, along at least a portion of the length of, and facing said beam.

4. Electromagnetic isotope separating apparatus comprising an evacuated tank, magnetizing means associated with said tank for producing a unidirectional magnetic field traversing said tank, a source of positive ions, accelerating electrode means associated with said ion source for withdrawing a beam of positive ions therefrom and projecting said beam within said tank in a direction perpendicular to said magnetic field, receiving means disposed in the path of said beam for intercepting said ions, and an arcuate strip of Beta emissive radioactive material contiguous with and at one side of said beam for providing neutralizing electrons for said beam.

5. Electromagnetic isotope separating apparatus comprising an evacuated tank, magnetizing means associated with said tank for producing a unidirectional magnetic field traversing said tank, a source of positive ions, accelerating electrode means associated with said ion source for withdrawing a beam of positive ions therefrom and projecting said beam within said tank in a direction perpendicular to said magnetic field, receiving means disposed in the path of said beam for intercepting said ions,

a strip of secondary electron emissive material contiguous with, at one side of, and facing said beam, and means for bombarding with primary electrons that side of said strip which is adjacent said beam, whereby secondary electrons emitted from said strip are constrained through the influence of the magnetic field to progress across said beam to thereby neutralize the space charge of said beam.

6. Electromagnetic isotope separating apparatus comprising an evacuated tank, magnetizing means associated with said tank for producing a unidirectional magnetic field traversing said tank, a source of positive ions, accelerating electrode means associated with said ion source for withdrawing a beam of positive ions therefrom and projecting said beam within said tank in a direction perpendicular to said magnetic field, receiving means disposed in the path of said beam for intercepting said ions, a strip of secondary electron emissive material contiguous with and at one side of said beam, and a source of primary electrons having a shape similar to that of said strip and disposed on the opposite side of said beam for bombarding said strip with primary electrons, whereby the primary electrons emitted by said source and the secondary electrons ejected from said strip by said primary electrons are constrained by said magnetic field to progress across said beam to thereby minimize the defocusing tendency of said beam resulting from the mutual repulsion of the positive ions forming said beam.

7. Electromagnetic isotope separating apparatus comprising an evacuated tank, magnetizing means associated with said tank for producing a unidirectional magnetic field traversing said tank, a source of positive ions, accelerating electrode means associated with said ion source for withdrawing a beam of positive ions threfrom and projecting said beam within said tank in a direction perpendicular to said magnetic field, receiving means disposed in the path of said beam for intercepting said ions, and inwardly facing strip of secondary electron emissive material contiguous with and at one side of said beam, and a similarly shaped inwardly facing strip of Beta emitting radioactive material at the opposite side of said beam, whereby the primary electrons emitted by said radioactive strip and the secondary electrons ejected from said secondary electron emissive strip by said primary

electrons are constrained to progress along said magnetic field and across said beam to thereby tend to neutralize the space charge of said beam.

8. Electromagnetic isotope separating apparatus comprising an evacuated tank, magnetizing means associated with said tank for producing a undirectional magnetic field traversing said tank, a source of positive ions, accelerating electrode means associated with said ion source for withdrawing a beam of positive ions therefrom and projecting said beam within said tank in a direction perpendicular to said magnetic field, receiving means disposed in the path of said beam for intercepting said ions, and two similarly shaped inwardly facing strips of material positioned on opposing sides of said beam and contiguous therewith, said material being Beta ray radioactive and also secondary electron emissive, whereby the Beta ray electrons and the secondary electrons from both of said strips serve to neutralize the space charge of said beam.

9. Electromagnetic isotope separating apparatus comprising an evacuated tank, magnetizing means associated with said tank for producing a unidirectional magnetic field traversing said tank, a source of positive ions, accelerating electrode means associated with said ion source for withdrawing a beam of positive ions therefrom and projecting said beam within said tank in a direction perpendicular to said magnetic field, receiving means disposed in the path of said beam for intercepting said ions, and two similarly shaped inwardly facing strips of material positioned on opposing sides of said beam and contiguous therewith, said material being composed of a mixture of a radioactive substance and a secondary electron emissive substance, whereby the Beta ray electrons and the secondary electrons from both of said strips serve to neutralize the space charge of said beam.

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