

May 16, 1950

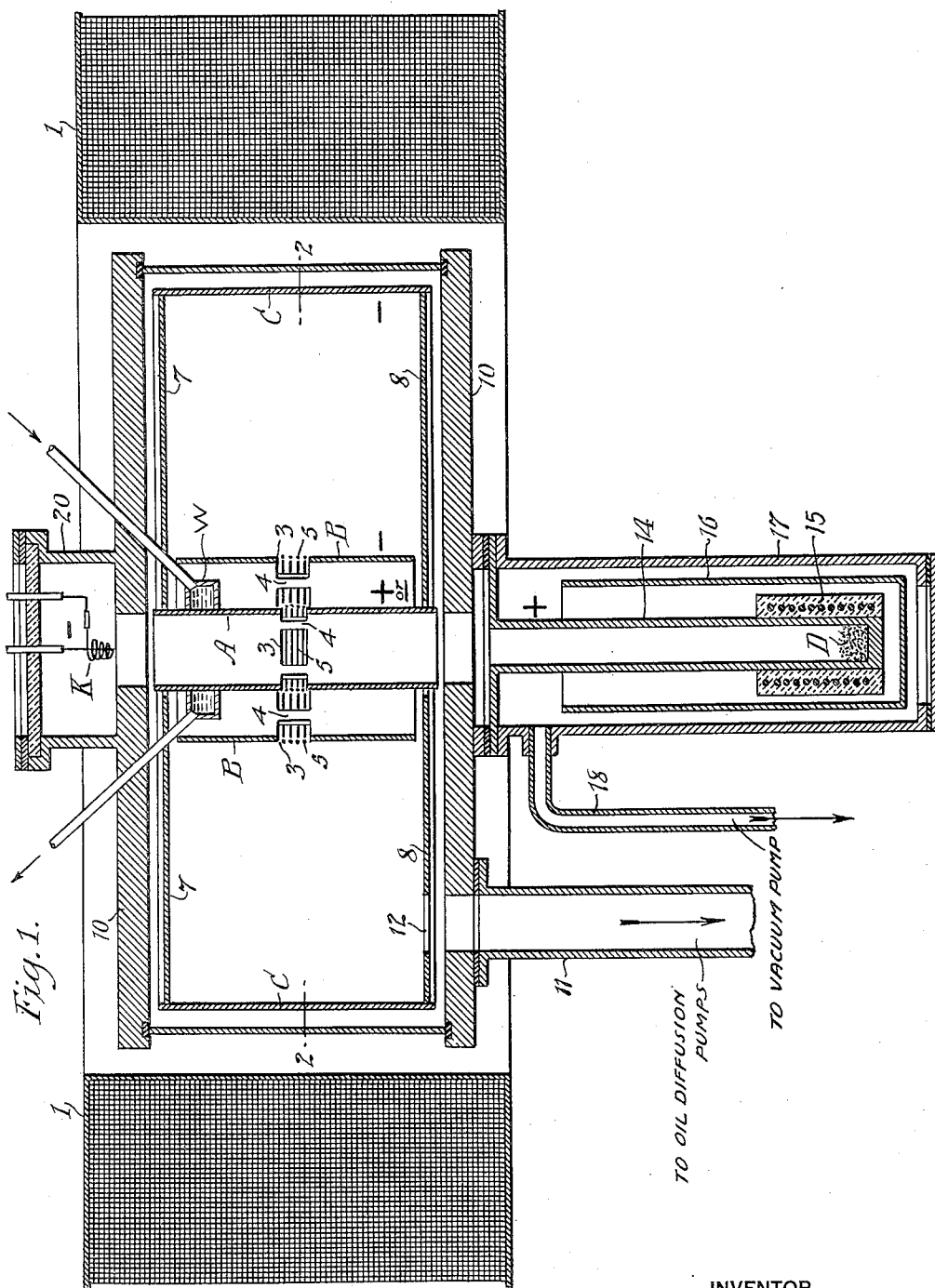
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2,507,653

IONIZED PARTICLE SEPARATOR

Filed Feb. 28, 1942

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 2.

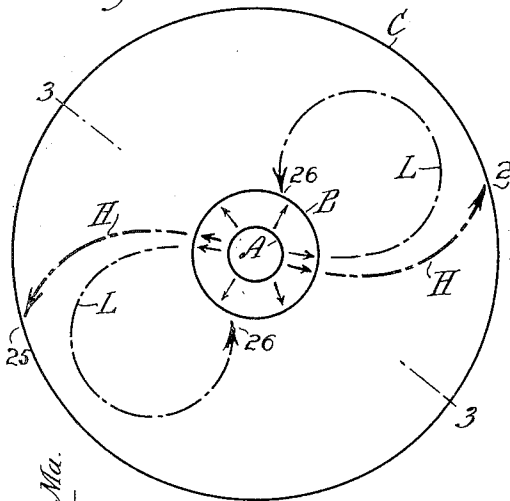
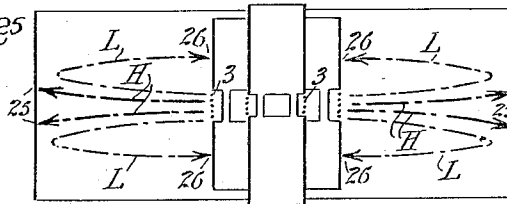


Fig. 3.



Current to third cylinder C in Ma.

Fig. 4.

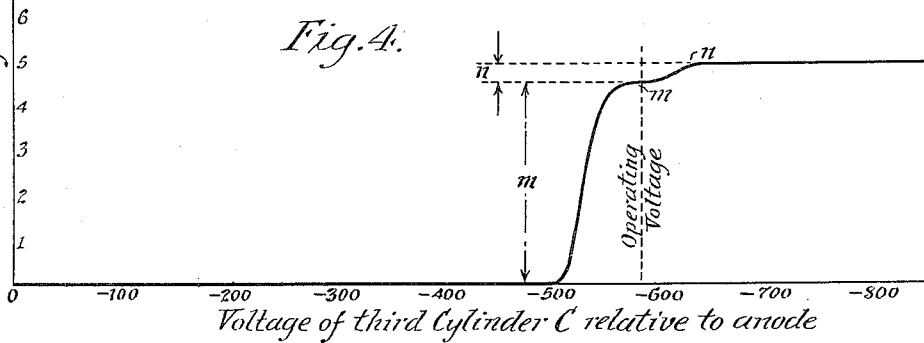
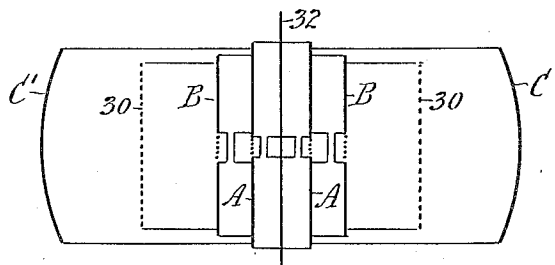


Fig. 5.



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IONIZED PARTICLE SEPARATOR

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5 Claims. (Cl. 250—41.9)

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This invention relates to separators such as are used to sort out or separate mixed materials, one from another, and is particularly useful in obtaining quantities of certain rare and rather elusive substances, such as the isotopes. These are atoms of unequal atomic weight but of the same nuclear charge (atomic number). The chemical properties of isotopes are similar but not identical, the slight difference in properties being accounted for by the difference in mass. The isotopes of a given chemical element are normally found mixed together in nature, the more rare isotopes being but a small fraction of the atoms of the common chemical element; and the segregation of certain isotopes in a pure form has been a laborious and expensive process.

The principal object of the present invention is to provide a method and apparatus suitable for the separation or production of isotopes and similar materials on a relatively large scale. Other particular objects are to reduce the cost, simplify the construction, so arrange the units of production that they may be readily multiplied or expanded for greater quantities, and to handle various types of materials. Further objects are to provide a simple method for determining the proper operating voltage; to reduce the effect of the space charge which has been a limiting factor in the past; to improve the furnace so as to reflux the material not immediately used; and various other objects as will become apparent as the description proceeds.

This device, through a combination of static electric and magnetic fields, separates part of a sample of some substance into two fractions, one fraction having an increased percentage of the heavy isotopes (over the percentage present in the original sample), and the other having an increased percentage of the light isotopes. The separation has been found to be of a relatively high order, and controllable by a simple voltage adjustment.

Referring now to the drawings forming part of this specification, Fig. 1 is a vertical cross-sectional view, partly in elevation, showing a typical embodiment of the invention.

Fig. 2 is a transverse cross-section approximately on the line 2—2 of Fig. 1, in somewhat diagrammatic form, to illustrate the principle of operation including the orbits of the heavy and light isotopes.

Fig. 3 is a diagrammatic vertical cross-section on the line 3—3 of Fig. 2 (or in general on a plane similar to Fig. 1), further illustrating the principles of operation by which the materials are separated.

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Fig. 4 is a current-voltage curve showing how the device may be set and regulated to produce the desired separation.

Fig. 5 illustrates a modification in which the collecting element is somewhat barrel shaped, instead of cylindrical, and it also shows a supplementary grid between the inner and outer collecting cylinders, to further control the electric field in that region, with any shape collecting shell.

Similar reference numerals refer to similar parts thruout the various views.

Referring now to Fig. 1, being a cross-section in which most parts are cylindrical or circular about a vertical central axis, the apparatus is surrounded by electro-magnetic coils 1 which produce an axial or vertical magnetic field in which the active parts of the apparatus is principally located. Within this field are placed three concentric conductive cylinders A, B and C, preferably made of copper or other suitable metal, the inner cylinders A and B having circumferential slits 3 extending all around them in approximately their middle portion, except for a few bridge pieces 4 on which are helically wound some grid wires 5 to assist in maintaining the electric field radial in direction. This radial electric field, which is at right angles to the vertical magnetic field, is produced by suitable potentials maintained on the cylinders A, B, and C. The grid wires 5 have somewhat the effect of dividing the wide slits 3 into a number of narrower slits, thus avoiding the divergence of field otherwise associated with a wide opening. Since the wires 5 are narrow and obstruct but a small portion of the opening, they offer little impediment to the flow of ions to be described. The potential of the grid wires 5 is the same as the cylinders on which they are wound, they being in effect part of the cylinders, since there is no insulation. The outer cylinder C, which surrounds the cylinders A and B, is a simple unbroken sheet without slots, and is used to collect the heavier isotopes, while the cylinder B collects the lighter isotopes, as will be explained later. Flat circular sheets 7 and 8, at the top and bottom, substantially close the annular chamber formed by the cylinders above described, and these parts are all enclosed in an air-tight case or envelope 10, preferably made of brass or glass. This enclosure 10 is connected by the pipe 11 to a suitable secondary vacuum pump, and an opening 12 in the lower plate 8 facilitates the withdrawal of the gases.

The supply of material D from which the different isotopes are to be separated is placed in

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the furnace 14, preferably made of stainless steel or other suitable material, which is heated by the tungsten heating coil 15. This is surrounded by the heat shield 16, and all enclosed in an air-tight shell 17 which is connected by the pipe 18 to a suitable vacuum pump, not shown, which together with the vacuum pump previously mentioned maintain suitable degrees of exhaustion. As the material D is volatilized by the heat it rises up the tube 14 and into the cylinder A, where it is acted upon and expelled by the electrical forces to be described. Such volatilized material as is not immediately affected may condense on the upper or cooler part of the furnace tube 14 and run down the walls to the hotter part to be re-volatilized, so that it is not lost.

The volatilized material D which flows into the cylinder A is met by a stream of electrons emitted by the cathode K, which may be a simple tungsten filament type or other suitable source, enclosed in the hermetically sealed upper casing 20. The furnace 14 is made positive with respect to the cathode K so that the electrons leaving the hot filament K are accelerated downward. The vertical magnetic field in which the apparatus lies serves to hold the electrons together in a beam and consequently ionization takes place mainly in a cylindrical region down the axis of the system from the cathode K to the furnace 14. The arc formed in that region serves as a powerful source of positive ions. These positive ions are then impelled out toward the negative cylindrical shell C, due to the latter being maintained at the proper negative potential, as will be described. The cylinder A is water-cooled as indicated at W in Fig. 1 so that the heat from the arc will not prevent condensation of the material on any of the cylinders.

The envelope 10-20 and the first cylinder A can be run at the potential of the anode (furnace) 14, although it is usually desirable to make at least the first cylinder A somewhat negative with respect to the anode. The other two cylinders B and C and the circular end plates 7 and 8 may all be run at the same negative potential, which is below the anode potential by an amount determined by the masses of the ions to be separated and the intensity of the magnetic field. The grid wires 5 on the first two cylinders A and B serve to keep the applied electric field mainly radial in direction. The ions pass from the ionization region in the cylinder A out thru the grids 5 and move in the region between the cylinders B and C. When the electric and magnetic fields are correctly adjusted the ions of the heavier isotope collect on the inside of the third cylinder C, and the ions of the lighter isotope collect on the outside of the second cylinder B. This is accomplished in the following manner.

Referring now to Fig. 2, which is a horizontal transverse cross-section of the three cylinders A, B, and C, taken approximately on the plane 2-2 of Fig. 1, the positive ions, flying out substantially radially from the cylinder A, under the influence of their space charge field and the applied electric field (as indicated by the arrows close to A), would continue in a radial direction to the inner wall of the cylinder C were it not for the axial magnetic field caused by the magnetic coils 1 of Fig. 1, into which the ions emerge. This magnetic field diverts the ions sideways to a degree depending on their mass and charge, and the strength of the field; and they would naturally fall into circular orbits, with the orbits of the heavier particles being

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somewhat greater in diameter than those of the lighter particles, since the heavier particles are less deflected. This is illustrated in Fig. 2 by two sets of typical orbits, marked H for the heavier and L for the lighter. The degree of deflection or curvature of the orbits can be controlled by varying the strength of the electric or magnetic fields, and so it is feasible to so set the apparatus that the outer or heavier orbits strike the outer cylinder C, as at 25, while the smaller or lighter orbits L do not reach the cylinder C but continue to curve around inward to strike the outside of the cylinder B at 26. It will be understood that the two sets of orbits shown are merely illustrative of what also occurs with the orbits of all the ions going out in all radial directions, so that at all points around the cylinders similar movements take place.

If the ions kept exactly the same horizontal plane, the lighter particles L which have emerged from the circumferential slot in the wall of the cylinder B would return to that slot and so not be collected. However, it will be seen by referring now to Fig. 3, which is a vertical cross-section thru the axis on the line 3-3 of Fig. 2, that due to the effect of space charge between the particles, they tend to diverge, and as they spread out vertically they generally return at points above or below the slot 3. Their paths are therefore somewhat helical, as indicated by the arrows H and L in Fig. 3; and while the heavier ions impinge on the inner side of the cylinder C, the lighter ones continue around and back to impinge on the outer side of the cylinder B. The atoms of the heavier isotopes are thus collected on the cylinder C and the atoms of the lighter isotopes are collected on the cylinder B. Since the orbits of the two materials are fairly distinct, there being a considerable space between them, and since their orbital diameters can be simultaneously adjusted by the electrical and magnetic means above mentioned, a nice separation of the materials is obtained.

In order to accomplish the desired separation it is of course necessary that the electrical settings be such that the heavier orbits impinge on the cylinder C while the lighter orbits do not. To properly accomplish this critical regulation, the following method is employed. The negative voltage of the third cylinder C relative to the anode is varied while the current flow to that cylinder is also read. As indicated in Fig. 4, when the resolution is sufficiently great to give complete separation, two distinct plateaus are present. The height of each rise is proportional to the abundance of the particular isotope causing it. From such a characteristic the best operating voltage for the cylinder C is easily found; and the potential of this cylinder is the only critical one in the entire system, provided the magnetic field is reasonably constant.

Typical readings are shown in the curve of Fig. 4, in this case for the element lithium, which has two isotopes of the relative mass seven and six. It will there be seen that as the voltage of the cylinder C became more negative a point was reached (at about minus 500 volts), where current began to flow. This indicated that the ions moving in the heavier or outer orbits had begun to strike the inside of the cylinder C. The belt of heavier ions has some finite thickness, due to slight variations in their initial positions and energies and to irregularities in the field. As the voltage is further reduced, the current is seen to increase rather rapidly until at some

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point indicated on the curve as m the current steadies down to a plateau, indicating that the entire width of the outer or heavier orbit is engaging the cylinder C. At this point small variations in the voltage applied do not appreciably affect the amount of current, as the heavy orbits are in full contact and the lighter orbits have not as yet reached the cylinder C. This is the proper setting for good separation, and as a matter of interest it can be readily checked by continuing to reduce the voltage further until the current goes up to the point n , indicating that the inner or lighter orbits are also engaging the outer cylinder C. After this, further reductions in the voltage do not result in any considerable increase in current, since both belts of orbits are already engaging the cylinder C. This shows that we have overstepped the proper value, as we do not want the lighter orbits to strike the cylinder C, and we consequently reduce the negative potential, that is, increase it positively, until we reach the condition m indicated by the step described. This shows the ability of the apparatus to separate the isotopes.

The orbits of course will vary with different fields and materials, but as the potential control is the only critical one required, the apparatus can be constructed in a variety of forms and sizes, and then brought into proper operation by means of the control method indicated. The device is thus adapted to a wide variety of uses. It need not necessarily be placed in a vertical position. For greater production, multiple units can be constructed one above or beyond the other, while their diameter may be varied to accord with the size of the orbits to be handled. The inherent principles of the device permit such expansion without introducing serious technological difficulties. In an initial device, in which the isotopes of lithium have been satisfactorily separated, the diameter of the cylinder C was about one foot; but of course the invention is not limited to any particular size, nor its use to any particular materials, so long as their ions have differing orbits as described.

It is not necessary that the collectors B and C, nor the inner chamber A, be strictly cylindrical. Indeed, improved results may follow in some cases by modifications in their shape, though simple cylinders are easier to construct and appear satisfactory. Fig. 5 illustrates a barrel shaped shell C', in place of a true cylinder; and also shows a cylindrical grid 33 in the region between the inner and outer collecting cylinders, which may be used with any shape collectors to further control the electric field in the same manner as the grid 5, where such additional control is desired. If an applied radial field is desired directly in the region where the ions are produced, an electrode may be placed along the axis of the system and maintained at a suitable potential. This is also shown in Fig. 5, where the electrode is indicated by the reference numeral 32.

The most important considerations in any device to separate isotopes are: (1) Rate of separation; (2) purity of separated materials; (3) expense involved. Examination of the features of the apparatus above described with respect to these three points illustrates the advantages of the radial magnetic separator method. Because of the large surface on which the ions are collected, space charge forces which are the limiting factor in other electromagnetic separators are much reduced. Furthermore, these space charge forces become important only when

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they cause sufficient divergence in the axial direction so that most of the returning light particles strike the top and bottom plates 7 and 8. Except as a second order effect, they cannot cause a mixture of isotopes to arrive at the outer or inner cylinders, so long as the potential on the outer cylinder is adjusted to the correct value. Thus in the apparatus described here larger currents can be used and therefore a greater separation rate obtained than has been feasible heretofore. As for the second consideration, resolution by this method can closely approach 100 percent separation. Finally, the expenses of operation are moderate, since no high voltage or high power equipment is necessary and most of the material consumed is separated.

While I have in the foregoing described certain particular embodiments of the invention, it will be understood that they are merely for purposes of illustration to make clear the principles thereof, and that the invention is not limited to the particular forms described, but is subject to various modifications and adaptations in different installations as will be apparent to those skilled in the art, without departing from the scope of the invention as stated in the following claims.

I claim:

1. In a separator, the combination of means for supplying a flow of a mixture of atoms of different weights to be separated, a cathode directing a stream of electrons on said atoms to ionize them, a chamber surrounding the ionization region and having an opening thru which the ions can escape, a field structure producing a magnetic field in the direction of the stream of electrons, electrostatic means for producing an electric field transverse to the magnetic field in such a direction as to accelerate the ions outwardly, said electrostatic means comprising negatively charged inner and outer plates having surfaces of revolution about the axis of symmetry of the magnetic field, the inner plate having an opening opposite the opening of the ionization chamber thru which the ions can pass toward the outer plate under the influence of the negative electric field, means for adjusting the strength of the electric field relative to the magnetic field so that the heavier ions will impinge on the inner side of the outer plate while the lighter ions impinge on the outer side of the inner plate, whereby the materials of different atomic weights are separated and collected on the two plates respectively.

2. In a separator, the combination of an ionization chamber into which materials of different weights are introduced for separation, said chamber having an opening thru which ionized atoms can emerge, a cathode supplying electrons for ionizing the atoms of said materials, a magnetic field structure maintaining a magnetic field transverse to the direction of the ionized atoms emerging from the opening of the ionization chamber, a negatively charged plate having an opening in line with the opening of the ionization chamber whereby the emerging ionized atoms describe orbits according to their mass so that the lighter ions return and also diverge by reason of their space charge from the plane of their exit, and a second negatively charged plate placed beyond the orbits of the lighter ions but within the orbits of the heavier ions, said plates having surfaces of revolution about the axis of symmetry of the magnetic field whereby the lighter ions may pass thru the opening of the first negatively charged plate and under the influence of the magnetic and electrical fields return to the back of

said plate to be collected, while the heavier ions impinge on the second negatively charged plate to be collected.

3. In a separator, the combination of an ionization chamber into which are fed materials of different atomic weights, said chamber having an opening thru which the ionized material can emerge, a cathode supplying electrons for ionizing the materials, a field structure creating a magnetic field, two negatively charged plates creating an electric field to draw the ions out of the chamber opening, said plates having surfaces of revolution about the axis of symmetry of the magnetic field, said electric field being transverse to the magnetic field so that the ions follow orbits curved in greater or less degree according to their mass, the negatively charged plate nearest the ionization chamber being used to collect the lighter ionized material and the other negatively charged plate being spaced beyond the orbits of the lighter ionized material but within the orbits of the heavier ionized material so that the latter material is collected thereon.

4. In a separator, the combination of an ionization chamber into which materials of different atomic weights are introduced for separation, said chamber having an opening thru which ionized atoms can emerge, a cathode supplying electrons for ionizing the atoms of said materials, a magnetic field structure maintaining a magnetic field transverse to the direction of the ionized atoms emerging from the opening of the ionization chamber, a negatively charged plate having an opening in line with the opening of the ionization chamber whereby the emerging ionized atoms describe orbits according to their mass so that the lighter ions return and also diverge by reason of their space charge from the plane of their exit, the opening in said plate being relatively narrow with respect to the width of the plate, so that the majority of the returning diverging ions will strike the plate rather than the opening, and a second negatively charged plate placed beyond the orbits of the lighter ions but within the orbits of the heavier ions, whereby the lighter ions may pass thru the opening of the first mentioned negatively charged plate and under the influence of the magnetic and elec-

trical fields return to the back of said plate to be collected, while the heavier ions impinge on the second negatively charged plate to be collected, said plates having surfaces of revolution about the axis of symmetry of the magnetic field.

5. In a separator, the combination of an ionization chamber into which materials of different atomic weights are introduced for separation, said chamber having a substantially circumferential opening thru which ionized atoms can emerge, a cathode directing a stream of electrons on said atoms to ionize them, a field structure producing a magnetic field in the direction of the stream of electrons, a negatively charged annular shell around said chamber, said shell having a substantially circumferential opening in line with the discharge opening of the ionization chamber, a second negatively charged annular shell spaced from and surrounding the first mentioned annular shell, said shells creating an electric field transverse to the magnetic field in such a direction as to accelerate the ions outwardly, whereby the lighter ions entering the space between the shells and following helical paths are returned to the outside of the inner shell to be collected while the heavier ions impinge on the inside of the outer shell.

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