

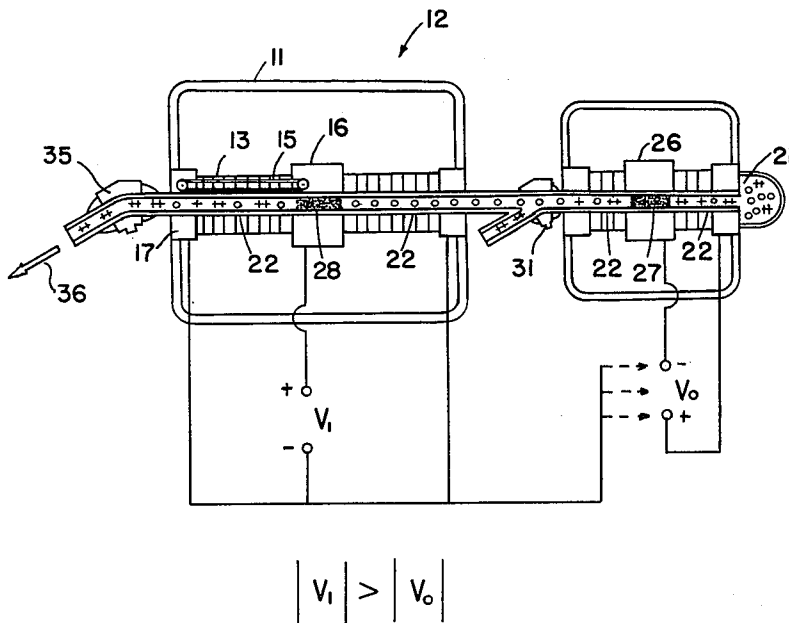
June 9, 1964

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3,136,908

PLURALLY CHARGED ION BEAM GENERATION METHOD

Filed July 28, 1960,



KEY

- O NEUTRAL ATOMS
- ++ MULTIPLY CHARGED POSITIVE IONS
- + SINGLY CHARGED POSITIVE IONS

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3,136,908

PLURALLY CHARGED ION BEAM GENERATION METHOD

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Filed July 28, 1960, Ser. No. 45,983

5 Claims. (Cl. 313-63)

This invention relates to nuclear accelerators, and more particularly relates to a machine and a method for providing a high intensity beam of plurally charged ions of atomic number of from 2 to approximately 20 available for acceleration at a high voltage terminal of an accelerator.

The D.C. acceleration of plurally charged positive ions has conventionally required that an ion source, ion focusing equipment and other supplementary ion beam generation equipment be installed within a high voltage terminal contained within a sealed and pressurized electrostatic or Cockroft Walton accelerator enclosure. The presence of such equipment within an enclosed high voltage terminal complicates the construction of an accelerator and renders maintenance of the ion source difficult. It also limits the type of ions to be accelerated to those which are readily produced by a compact source.

A source of positive ions such as is usually installed in the high voltage terminal of an electrostatic accelerator provides positive ions from an electric discharge in a tenuous atomic gas, the ions of which one wishes to accelerate. The gas used to obtain plurally charged particles may most conveniently be helium, but one is not restricted to the use of this gas. Design of such sources are manifold and are well known to those concerned with the art (D. Kamke Encyclopedia of Physics, vol. 33, 1956, p. 36, et seq.). This invention is not restricted to use of any particular design of positive ion source or D.C. accelerator, but proposes to place a source at a location remote from an electrostatic accelerator high voltage terminal.

This invention provides a method and a machine for generating a positive ion beam of plurally charged particles at an accelerator terminal from a beam of fast (non-thermal) neutral atoms produced at a source outside the accelerator enclosure. Generating the neutral particle beam outside the terminal enclosure greatly facilitates the adjustment and operation of the source mechanism and makes possible the production of ion beams which could not readily be produced subject to the space and power restrictions within an accelerator terminal.

It is an object of this invention to provide a high intensity beam of plurally charged ions of elemental gases having atomic numbers of from 2 to approximately 20.

Other objects will become apparent from the drawings and from the following detailed description in which it is intended to illustrate the applicability of the invention without thereby limiting its scope to less than that of all equivalents which will be apparent to one skilled in the art. In the drawings like reference numerals refer to like parts and:

The single figure is a schematic elevation of an electrostatic accelerator of this invention.

In the figure is shown electrostatic accelerator 12. Accelerator 12 comprises pressurized enclosure 11 containing positively charged high voltage terminal charging belt 15, equi-potential rings 13, and evacuated tube 22 disposed axially therewithin. Terminal 16 may be charged to a positive potential of several million volts with respect to terminal 17 by electrostatic charge transfer from belt 15, and may be electrically insulated from enclosure 11, of which terminal 17 is a portion, by insulators between equi-potential rings 13 in a manner conventional to elec-

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trostatic accelerators. Another method of achieving the high voltage on the terminal is by an electronic voltage multiplying circuit first applied to this use by Cockroft and Walton. The construction of a high voltage terminal and the means for charging and insulating the terminal form no part of this invention.

Ion source 21 is shown schematically and may include a source of suitable gas and a gas purifying device. Purification may be accomplished in conventional fashion by passing the gas through a liquid air trap to remove contaminants before it is introduced into accelerator 12.

Purified molecular gas of atomic number 2 or greater may be singly or multiply ionized in an electrical discharge of appropriate design. Means for producing positive ions are well known to those versed in the art and any suitable such means may be utilized.

Singly and multiply charged positive ions may be extracted from ion source 21 of FIGURE 1 by electrode 26. Electrode 26 may be negatively charged to between 100 and 2000 kilovolts and preferably to between 500 to 1000 kilovolts with respect to ion source 21, if positive helium ions are to be used. Voltage of this magnitude can readily be obtained either by an electrostatic generator, or by a voltage multiplying electronic circuit. The positive ions (multiply and singly charged) from source 21 are then passed through evacuated tube 22. Either the positive ion source 21 may be at ground potential and target 27 be negatively biased with respect thereto, or target 27 may be at ground potential and the ion source 21 be positively biased with respect to target 27 (not illustrated for simplicity), or the two components may be biased to opposite polarities with equal effect to provide a suitable potential between the two (also not illustrated for simplicity). It may be desirable to provide between ion source 21 and electrode 26 a suitable means for focusing the ion beam such as an electrostatic lens (not shown).

Within electrode 26 is charge exchange target 27. Target 27 is preferably a canal in which a quantity of gaseous matter (e.g. hydrogen, nitrogen, argon, or oxygen) is disposed in the path of travel of the particle beam, such matter having a concentration substantially greater than matter in adjacent areas through which the beam passes. It may also consist of a thin metal or carbon foil disposed across the path of the beam. Both gaseous and foil charge exchange targets are known in the art and form no part of this invention. The ions, upon passing through target 27 pick up electrons and emerge therefrom as neutral particles, i.e. a beam of fast (non-thermal) atoms. The charged particles (both multiply and singly charged) that then remain in the beam may then, if desired, be deflected by charged collector ring or magnet 31 and be removed from the beam. The uncharged atoms which comprise the operable portion of the beam can then drift with the energy previously given herein, i.e. (in the case of helium isotopes, for example) from 100 to 2000 kilo electron volts, and preferably from 500 to 1000 kilo electron volts, into the electric field of terminal 16 which is maintained at a high positive potential, e.g. several million volts, without being repelled. Thereupon the atoms can pass through target 28.

Target 28 may be a quantity of matter similar to target 27, e.g. a metal or carbon foil or a gas filled duct. Gas is the preferred target material and can most conveniently be oxygen or nitrogen, although other gas might also be used. Some of the atoms in the beam upon passing through target 28 in terminal 16 are ionized by collisions with the matter of target 28 and consequently lose their electrons. Some may lose one electron to form singly charged ions and some lose two or more electrons to form multiply charged ions. The ions that are formed may then be accelerated to ground potential at terminal

17 in a single main stage of acceleration in conventional manner. The ions emerge with an energy proportional to the product of their positive charge and the voltage on terminal 16.

The present invention relates particularly to providing such emergent ions which are multiply charged; since their charge will be twice as great or more than twice as great as the charge of singly charged ions, their energy on emergence will be at least twice as great. Usually the beam of multiply charged ions which emerges from terminal 17 will also contain singly charged ions and neutral atoms. It is desirable, for the purposes of the invention, that a significant fraction of the atoms which pass through terminal 16 are stripped of two or more electrons so that the emergent beam at 17 contains a significant fraction of multiply charged ions. Useful and valuable results are obtained if at least .002% of the particles which emerge at 17 are multiply charged ions so that a significant fraction or portion is to be considered to be .002% in the case of this invention.

A beam which contains substantially only multiply charged ions may then be provided by passing the beam through a magnetic field, which may be created in any suitable manner, such as by magnet 35, whereupon the beam of multiply charged ions is bent so that it emerges as indicated by arrow 36; the paths of singly charged ions are bent less with the result that they strike the wall of the tube; the paths of neutral atoms are of course not changed by the magnetic field and they of course likewise strike the wall of the tube at 35.

The term "thermal velocity" as it is used herein denotes velocities not greater than 2×10^6 cm./sec. "Fast" (non-thermal) atoms or ions are those having a velocity of 5×10^7 cm./sec. or greater.

The following chart shows, as an example, the relationship between some energies and velocities for two isotopes of helium for use in the accelerator of this invention. The superscripts denote the atomic weight of the positive ion.

Cm./sec.	100 kev.	1000 kev.	2000 kev.
He ³ -----	2.6×10^8	8.1×10^8	1.1×10^9
He ⁴ -----	2.2×10^8	6.9×10^8	9.7×10^8

It is to be understood that all isotopes of atoms having an atomic number of 2 or more and not greater than approximately 20 are included in the scope of this invention. Thus, for example, a beam of multiply charged ions of neon, argon or nitrogen might suitably be provided in accordance with the invention. In beams in which mixed isotopes of a particular element are present, a proportion of approximately 0.5 percent of a particular isotope is significant for operable use of the isotope in an ion beam accelerated toward a target.

While certain modifications and embodiments of the invention have been described, it is of course to be understood that there are a great number of variations which will suggest themselves to anyone familiar with the subject matter thereof and it is to be distinctly understood that this invention should not be limited except by such limitations as are clearly imposed in the appended claims.

I claim:

1. The method of providing a high energy high in-

tensity beam of multiply charged positive ions having an atomic number of from 2 to 20, comprising the steps of providing a quantity of thermal neutral atoms having an atomic number of from 2 to 20, ionizing said atoms to positive ions, accelerating said ions across a first voltage differential to provide a beam of fast (non-thermal) ions, then adding electrons to said ions to provide a beam of fast (non-thermal) neutral atoms drifting toward a first terminal having a higher positive potential of several million volts with respect to a second terminal than the potential difference across said first voltage differential, then removing more than one electron from a significant fraction of each of said atoms at said first terminal to form multiply charged positive ions, then only once accelerating said ions toward and through said second terminal with respect to which said first terminal has said high positive potential to provide a high energy and high intensity beam of multiply charged positive ions emerging from said second terminal.

2. The method of claim 1 further characterized by passing said beam of fast (non-thermal) positive ions through a quantity of matter present in greater concentration than in adjacent portions of the path of said beam to add said electrons thereto and passing said beam of drifting fast (non-thermal) neutral atoms through a quantity of matter present at said first terminal in greater concentration than in adjacent portions of said path of said beam to remove more than one electron from a significant fraction of each of said atoms.

3. The method of providing a high energy and high intensity beam of multiply charged positive ions having an atomic number of from 2 to 20, comprising the steps of first providing a beam of fast (non-thermal) neutral atoms having an atomic number of from 2 to 20 drifting toward a terminal having a high positive potential of several million volts with respect to a second terminal, then removing electrons from said neutral atoms at said first terminal to form multiply charged positive ions, then accelerating said ions toward and through said second terminal with respect to which said first terminal has said positive potential to provide a high energy and high intensity beam of multiply charged positive ions emerging from said second terminal, said potential of several million volts adding more energy to said ions than added to provide said fast neutral atoms.

4. The method of claim 3 further characterized by passing said beam of drifting fast (non-thermal) neutral atoms through a quantity of matter present at said first terminal in greater concentration than in adjacent portions of said path of said beam to remove more than one electron from a significant fraction of each of said neutral atoms.

5. The method of claim 3 characterized by at least a significantly large proportion of said positive ions emerging from said second terminal being doubly charged helium ions.

References Cited in the file of this patent

UNITED STATES PATENTS

2,206,558 Bennett _____ July 2, 1940
2,219,033 Kuhn et al. _____ Oct. 22, 1940

OTHER REFERENCES

Madansky: Physical Review Letter, volume 2, page 209, received January 23, 1959.