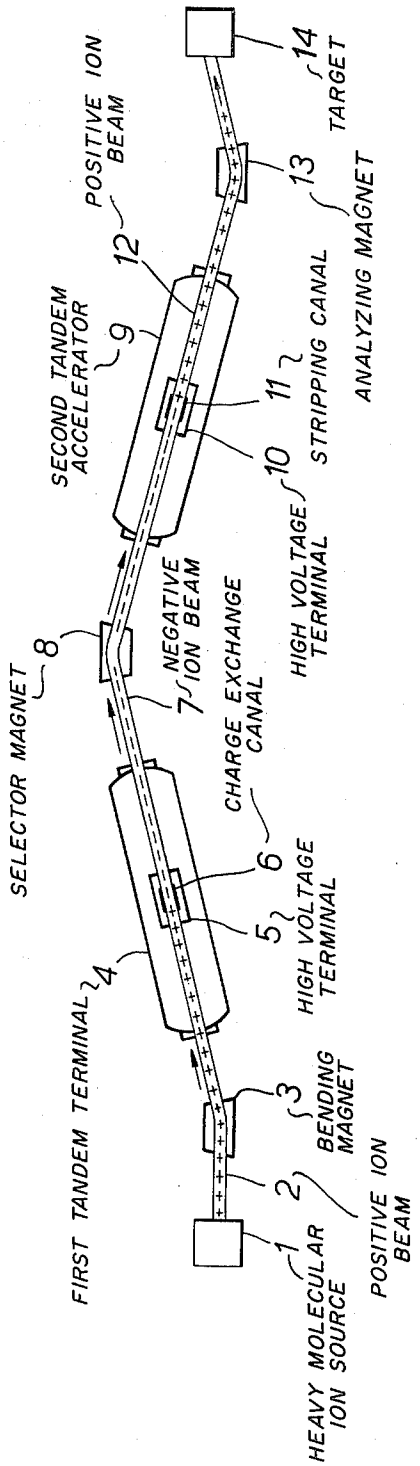
Sept. 28, 1965 F. A. JULIAN ETAL 3,209,269

LINEAR ACCELERATORS OF TANDEM TYPE

Filed June 21, 1962



United States Patent Office 3,209,269 Patented Sept. 28, 1965

3,209,269

LINEAR ACCELERATORS OF TANDEM TYPE

Frederick Arthur Julian, Arborfield, and Anthony Christopher Riviere, Earley, Reading, England, assignors to the United Kingdom Atomic Energy Authority, London, England

Filed June 21, 1962, Ser. No. 204,163
Claims priority, application Great Britain, June 27, 1961, 23,308/61
7 Claims. (Cl. 328—233)

This invention relates to electrostatic accelerators of the tandem type. Suitable electrostatic accelerators, often called Van der Graaf accelerators, are well known. Much information has been given in many publications and detailed description is not needed here. Attention is, however, directed to two publications. The 1958 Accelerator Conference, High Voltage Engineering Corp., and the Proceedings of the Second Accelerator Conference, Nuclear Instruments and Methods, vol. II, No. 1, January 1961, in which recent information is given.

In such accelerators negative ions are produced at ground potential and then accelerated to a high voltage positive terminal. Within the terminal the ions are stripped of electrons and converted to positive ions which therefore can receive further acceleration from the positive terminal to ground.

It has been proposed already that the negative ions could be given an initial acceleration before they are injected into the tandem accelerator, and it has already been suggested that this could be achieved by injecting a neutral particle beam from ground potential into a first tandem accelerator having a negative high voltage terminal at which electron addition would occur. The negative particles so produced would then receive an acceleration from the negative terminal before being injected into the tandem accelerator having a positive centre terminal.

There are, however, difficulties inherent in the system already proposed. The minimum gap between the ground potential beam inlet and the negative voltage terminal is about eight metres and no means has yet been found to prevent defocusing of the neutral beam while it drifts, across this gap. Better focusing could be achieved by injecting the neutral particles with higher energy but there is an optimum energy for highest efficiency of the process producing negative ions at the negative high voltage terminal, and variation from this optimum would reduce the efficiency.

An object of this invention is to provide an electrostatic accelerator of the tandem type having at least four acceleration stages by the first stage of which a well focused particle beam is provided at the negative high voltage terminal.

According to the invention an electrostatic accelerator has a positive ion source adapted to generate heavy molecular positive ions and to be held at ground potential, a negative high voltage terminal zone adapted to contain a gas target for the said molecular ions whereby at least a portion of the molecular ions disintegrate into fragments and the fragments pick up electrons to form negative ions, selector means for selecting any desired species from the said negative ions, and a positive high voltage terminal member adapted to accelerate the said negative ions and strip electrons from at least a portion thereof to form positive ions.

The fragmentation of the heavy ion will occur by collision with gas particles moving with thermal energy. The energy of the ion will then be divided among the fragments. By a suitable choice of variables, e.g., nature of the ion and accelerating voltage, the energy of the liberated element will be such as to optimize the production of negative ions of the said element. For a high efficiency of attachment of electrons to a particle the

velocity of the particle receiving the electron should be comparable with the orbital velocity of electrons in donor atoms, that is between 10^8 and 3×10^8 cm./sec. Thus for example in the case of hydrogen the energy should be between 5 and 40 kev. If the heavy ions are accelerated to 6 mev. the mass of the heavy ions should be about 150 a.m.u. The use of hydrocarbon molecules would enable the liberation of hydrogen and carbon, and the use of oxygen-containing organic substances would allow the liberation of hydrogen, oxygen and carbon at the negative high voltage terminal. The desired ions for final acceleration could be selected by magnetic means.

The accelerator of the invention requires a gas target thickness at the electron attachment canal which would be sufficient to achieve molecular dissociation as well as negative ion formation. The equilibrium thickness for H^- ion formation at 40 kev. is about 600μ Hg cm. and the thickneses required for one mean free path of the dissociation process is 300μ Hg cm. if a cross section of 10^{-16} cm.^{2} is assumed. From the practical viewpoint a gas target of this thickness is easily achieved. The finite aperture of such a gas target may cause a loss of about 50 percent of the negative ions due to the angular spread arising from the dissociation process. However, the problem of focusing the heavy molecular ion beam would be no more difficult than the injection of H^- ions into a conventional tandem, since the molecular ions would be accelerated to a high energy in the first stage.

In a test of the basis of the invention a 3 mev. Van der Graaf single stage accelerator was used. The radio frequency ion source of this machine was supplied with hydrogen iodide (molecular weight 128 a.m.u.) and the accelerator was operated at 1 mv. The total ion beam was passed through a hydrogen gas target between accelerator and analysing magnet, and the gas pressure adjusted for maximum negative ion yield. Both positive and negative hydrogen ions were observed whose momenta corresponded to 7.8 kev., which would be expected from the break up of accelerated HI^+ ions. The negative ion current was about 10^{11} A. and the ratio of positive to negative ion currents was 7 to 1, in reasonable agreement with the equilibrium value of this ratio of 5.7 to 1. The small value of the negative ion current was almost certainly due to the low yield of HI^+ ions from the ion source, and could be raised by the use of a more efficient source for positive ions. The actual current of HI^+ ions accelerated was not known but if complete dissociation occurred then the negative ion current would be 2 percent of the incident molecular ion current. The choice of an ion containing several hydrogen atoms would increase the number of negative ions available by the same ratio.

An embodiment of the invention is illustrated on the accompanying drawing which is a diagrammatic layout.

In the drawing a heavy molecular ion source 1 produces a positive ion beam 2 which is filtered by a bending magnet 3 and passed into a first tandem accelerator 4 having a negative high voltage terminal 5 within which is a dissociation and charge exchange canal 6. The negative ion beam 7 produced therein is passed through a selector magnet 8 and into a second tandem accelerator 9 having a positive high voltage terminal 10 within which is a stripping canal 11. The positive ion beam 12 produced therein is passed through an analyzing magnet 13 and from thence to a target 14.

We claim:

1. A method of producing a high-energy beam of positive ions of a given element comprising forming positive molecular ions of a compound of the given element with at least one further element, said compound having a molecular weight which is large compared with the atomic weight of said given element; accelerating said molecular ions towards a negatively polarized terminal zone contain-

ing a gas target adapted to cause at least a portion of the molecular ions to disintegrate into fragments and the fragments to pick up electrons to form negative ions, accelerating said negative ions beyond said negatively polarized terminal zone, selecting ions of the given element from said accelerated negative ions, accelerating said selected negative ions towards a positively polarized terminal zone containing means for stripping electrons from at least a portion of said selected ions to form positive ions of the given element, and accelerating said positive ions beyond said positively polarized terminal zone.

2. A method of producing a high-energy beam of positive hydrogen ions comprising forming positive molecular ions of a compound of hydrogen with at least one further element, said compound having a molecular weight which is large compared with the atomic weight of hydrogen, accelerating said molecular ions towards a negatively polarized terminal zone containing a gas target adapted to cause at least a portion of the molecular ions to disintegrate into fragments and the fragments to pick up electrons to form negative ions, accelerating said negative ions beyond said negatively polarized terminal zone, selecting hydrogen ions from said accelerated negative ions, accelerating the selected hydrogen ions towards a positively polarized terminal zone containing means for stripping electrons from at least a portion of the hydrogen ions to form positive hydrogen ions, and accelerating the positive hydrogen ions beyond said positively polarized terminal zone.

3. A method as claimed in claim 2 wherein said compound is hydrogen iodide.

4. An electrostatic accelerator comprising a positive ion source, said source generating an ion beam of positive molecular ions of at least one desired element, the molecular weight of said positive molecular ions being large compared with the atomic weight of said desired element, a negatively polarized zone for accelerating said positive molecular ions away from said source and toward the negative zone, duct means providing an uninterrupted path for said heavy positive molecular ions from said source to said zone, dissociation and charge exchange means within said negative zone, said dissociation and

charge exchange means comprising a target of gas particles for collision with said positive molecular ions for liberating positive atomic ions of the elements of said positive molecular ions and for imparting thereto electrons to form negative atomic ions, the velocity of said positive molecular ions being sufficiently low at the point of collision with said gas particles to be comparable to the velocity of the electron donor atoms of said gas particles, thereby achieving optimum efficiency in the formation of negative atomic ions, selector means for selecting the negative atomic ions of said desired element, and positive high voltage terminal means for accelerating the negative atomic ions of said desired element and means for stripping electrons from said negative atomic ions to form positive atomic ions.

5. An accelerator according to claim 4 wherein said positive molecular ions containing said desired element are of a chemical compound.

6. An accelerator according to claim 4 wherein said selector means comprises a selector magnet of sufficient field strength to bend the negative ions of said desired element along a predetermined path.

7. An electrostatic accelerator as claimed in claim 4 in which the negative high potential terminal zone is within a first pressure vessel adapted to be held at earth potential and the positive high voltage terminal is within a second pressure vessel adapted to be held at earth potential.

References Cited by the Examiner

"Neutralization and Ionization etc." by Batho, December 15, 1932, Physical Review, vol. 42, page 755.

"Negative Hydrogen Ion Source" by Weinman and Cameron, May 1956, Review of Scientific Instruments, vol. 27, No. 5, pages 288–293.

"Nuclear Instruments and Methods," vol. 11, No. 1, January 1961, page 109.

Zhurnal Eksperimental 'noi iTeoreticheskoi Fiziki V 34n6, June 1958, pp. 1398–1405.

GEORGE N. WESTBY, *Primary Examiner.*

DAVID J. GALVIN, *Examiner.*