United States Patent

[11] 3,617,789

[72] Inventors **Roy Middleton**
Moylan;
Charles T. Adams, Wallingford, both of Pa.

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[73] Assignee **University of Pennsylvania**
Philadelphia, Pa.

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[54] **PROCESS FOR PRODUCTION OF NEGATIVE HELIUM IONS AND OTHER NEGATIVE IONS**
6 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **313/63,** 250/84, 313/230
[51] **Int. Cl.** **H05h 5/00**
[50] **Field of Search** 313/63, 230; 250/43, 84

[56] **References Cited**

UNITED STATES PATENTS

3,374,384 3/1968 Donnally 313/230
3,424,905 1/1969 Donnally ..... 313/63 X

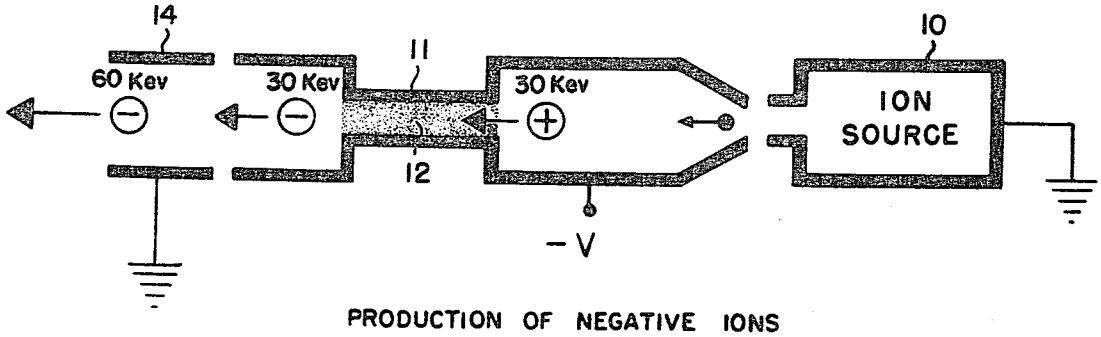
OTHER REFERENCES

" Negative Hydrogen Ion Source" by J. A. Weinman and J. R. Cameron, The Review of Scientific Instruments, Vol. 27, No. 5, May 1956, pp. 288–293, Class 313–63.

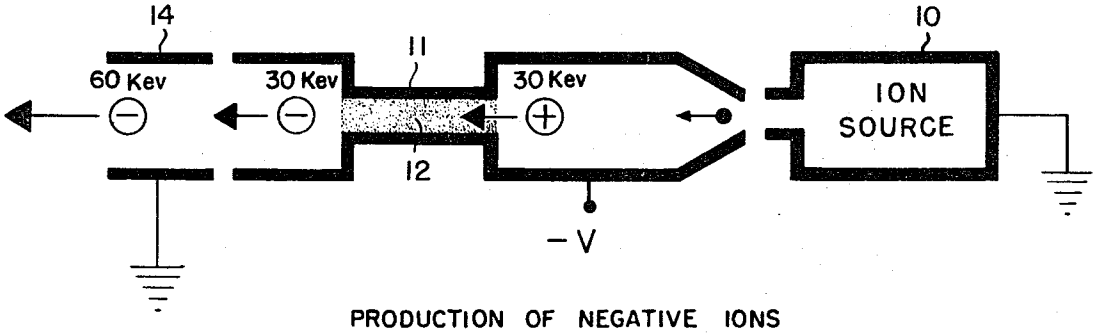
" Modification of An Ion Source for the Production of Microampere $^4H_e^-$ Beams" by John et al., IEEE Transactions on Nuclear Science, June 1967, Volume NS–14, Number 3, pp. 82–86.

Primary Examiner—Raymond F. Hossfeld
Attorney—Paul & Paul

ABSTRACT: A method is disclosed for producing negative ions by passing energetic positive ions through a charge exchange medium consisting of metallic vapors of low ionization potential. This process, in which all low ionization potential metallic vapors can be utilized, enables the production of a large species of negative ions at more copious rates than hitherto possible by charge exchange.

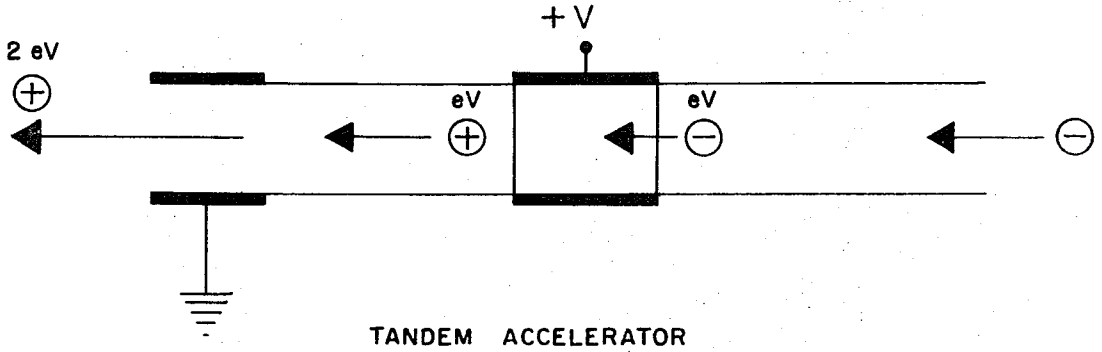


PRODUCTION OF NEGATIVE IONS



PRODUCTION OF NEGATIVE IONS

FIG. 1.



TANDEM ACCELERATOR

FIG. 2.

INVENTORS
ROY MIDDLETON &
CHARLES T. ADAMS
BY
Paul & Paul
ATTORNEYS

PROCESS FOR PRODUCTION OF NEGATIVE HELIUM IONS AND OTHER NEGATIVE IONS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention lies in the field of processes for the production of negative ions and, more particularly to a process for production of negative ions utilizing metallic vapors of low ionization potential.

2. Description of the Prior Art

The production of negative helium ions is conventionally accomplished by passing positive helium ions through a gaseous charge exchange medium, wherein a small fraction of such positive ions is converted into negative helium ions. The commonly used medium for such charge exchange has been hydrogen. In this standard process, the positive ions are produced by a commercially available ion source and are accelerated to an optimum energy for passage through the charge exchange medium. The voltage to which the ions are accelerated is determinative of the energy of the resulting negative ions.

Relatively recently Donally has disclosed that a greater rate of production of negative helium ions can be produced by injecting low energy positive helium ions through a charge exchange medium consisting of the vapor of an alkali atom, Group I, Periodic Table. See U.S. Pat. No. 3,374,384, issued Mar. 19, 1968. In particular, Donally utilized cesium and potassium for the charge exchange medium. Further, he employed relatively low energies of "up to several kilo-electron volts, the optimum energies being said to lie in the range of up to about 3,000 electron volts."

Although the process of Donally constituted an improvement over the prior art, it was limited to the vapors of the alkali atoms, and to the production of negative helium ions. More particularly, the resulting negative helium ions carried relatively low energies corresponding to the optimum energies for producing such negative helium ions. The low energy yield has a distinct drawback in that it is generally desirable to have high energy negative ions, as for example, for introduction into a tandem accelerator.

SUMMARY OF THE INVENTION

The primary object of our invention is to provide a process for producing a large species of negative ions.

Another object of our invention is to provide a process for production of negative ions utilizing metallic vapors of low ionization potential.

It is a further object of our invention to provide a process for producing negative ions at energies of up to several tens of Kev., and to produce them more copiously than is possible by any prior process, utilizing charge exchange.

Accordingly, this invention provides a process for producing the negative ions of a plurality of atoms which comprises the introduction of positive ions at relatively high energies into a charge exchange region. The medium of such region may be the vapor of any metallic atom, preferably of atoms having low ionization potentials. Upon charge exchange wherein a fraction of the positive ions introduced into the medium are converted to negative ions, such negative ions are filtered out by conventional electric or magnetic field means. The negative ions of a plurality of elements, including helium, lithium, boron, carbon, nitrogen, and oxygen, as well as certain radicals, e.g., NH^1, can be produced by this process.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows the process of this invention in schematic form.

FIG. 2 shows a schematic representation of a tandem accelerator.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, FIG. 1 shows a conventional ion source **10** which provides a beam of positively charged ions. The positively charged ion beam is accelerated by a negative voltage V, whereby each positive ion acquires an energy of V electron volts (assuming that it carries only a single positive charge). V is termed the charge exchange voltage, said voltage numerically also representing the energy of the ions in electron-volts as they pass through the charge exchange region **11**. Typical energy values as used in this invention lie in the range of 5 to 50 kev. The charge exchange region **11** is filled with the vapor of a metallic, low ionization metal, at a pressure optimized for maximum rate of production of negative ions. Said pressure is a variable, which, along with the length of the charge exchange region **11**, can be adjusted for maximum results corresponding to the vapor used and the atoms being ionized. Upon emergence from charge exchange region **11**, the negative ions will be further accelerated due to the potential field effects of ground electrode **14**, whereby the energy of each negative helium atom will be doubled. Consequently, if V is made 30 kv., the negative atoms will emerge at the end of the process with 60 kev. energy. The negative ions which have thus been produced can be conveniently separated from the remainder of the positive ions by conventional electric or magnetic field techniques.

Experiments performed utilizing the process of this invention have determined that high energy beams of negative helium ions can be produced by charge exchange in a wide variety of vapors in addition to those of the alkali metals, Group I, Periodic Table. In particular, the vapors of the alkaline earth metals, Group II, Periodic Table, are very effective. The vapor properties which appear to be most determinative of the efficiency of the production of beams of negative helium and other ions are that the vapor be metallic and have a low ionization potential. In general, the lower the ionization potential the greater is the yield of negative ions. In addition, it is desirable that the vapor should be constituted of atoms having a low atomic number, in order to minimize the multiple scattering of the ion beam which results from collisions with the vapor atoms. In this respect, for example, magnesium is preferable to barium.

While the process has been described in terms of vapors comprised of metallic atoms, beams of negative ions can be produced at desirable energies by charge exchange in the vapors of other low ionization potential elements, as well as compound vapors. It is anticipated that any compound having a low ionization potential, or containing atoms having a low ionization potential which would be released upon collision, would be a suitable vapor medium.

The use of high voltages, and correspondingly high charge exchange energies, plays a dual role in the process of this invention. First, the higher energies are required to effect charge exchange. In using the vapor of lithium, a Group I atom, for the charge exchange medium, intense beams of negative $^3He^1$ ions were produced at an exchange energy of approximately 20 kev., and a slightly higher yield of $^4He^1$ at an exchange energy of approximately 26 kev. Similarly, positive lithium ions with exchange energies in the range of 30 to 40 kev., when passed through lithium vapor, produced a yield of negative lithium ions about an order of magnitude more efficient than that possible with the standard hydrogen process.

The second beneficial role played by using high exchange energies is that the resulting negative ions are produced at higher energies. This is of critical importance in the operation of a tandem accelerator, where the negative ions must be introduced at high energy in order to avoid beam scattering, preferably approaching 100 kev. In a typical application of this invention, the negative ion which has been produced, carrying, for example, 60 kev., as noted in FIG. 1, is introduced directly into the tandem accelerator shown in FIG. 2. If such negative ion carries a low energy of only several kev., it becomes necessary to pass it through a separate preaccelera-

tion stage prior to introduction to the tandem accelerator. The subject process yields negative ions having twice the charge exchange energy, typically 50 to 80 kev., a range which is acceptable for tandem accelerator operation.

The process of this invention is general in that it is not restricted to the production of negative helium ions. Rather, a wide range of negative ions can be produced by charge exchange in a vapor medium possessing a low ionization potential. It was stated above that positive lithium ions of energy in the range of 30 to 40 kev., when passed through lithium vapor, yield a beam of negative ions approximately one order of magnitude greater than that produced by using hydrogen as the charge exchange medium. Similarly, positive boron ions and carbon ions, when passed through lithium vapor have yielded large negative ion currents. Our investigations also have shown that such other negative ions can be produced copiously by charge exchange in other than vapors of the alkaline metals, Group I, Periodic Table. Indeed, the vapors of the alkaline earth metals, Group II, Periodic Table, and other low ionization potential metallic elements and compounds, are almost as effective. All such negative ions, produced by the process of this invention, possess the additional advantage of carrying higher energies.

The following table summarizes the results obtained using the process of this invention. Current figures indicate relative negative ion yields with respect to a reference source of positive ion current.

Ion	Vapor element	Group	Z	Ionization potential	Charge exchange energy, kev.	Ion current, micro-amps
$^3He^-$	Mg	II	12	7.61	26	7
$^3He^-$	Ca	II	20	6.09	10–35	6–7
$^3He^-$	Li	I	3	5.36	20	9
$^4He^-$	Li	I	3	5.36	26	>9
$^3He^-$	S	VI	16	10.30	20	.05
					25	.09
					30	.12
					35	.15
					40	.16
					45	.22
$^3He^-$	Zn	IIb*	30	9.36	50	.24
					20	.60
					25	1.2
					30	1.6
					35	1.7
					40	1.85
					45	1.95
					50	2.0
Li^-	Li	I	3	5.36	20–40	3–5
B^-	Li	I	3	5.36	20–40	3–4
C^-	Li	I	3	5.36	30–40	5–10
NH^-	Li	I	3	5.36	40	7
O^- or OH^-	Li	I	3	5.36	40	>100

* Transition element.

The comparison between Zinc and sulfur confirms that the yield is optimized for a metallic exchange medium having a low ionization potential. The vapors of Group II elements are appreciably as effective as Group I elements, the effectiveness dropping off with increasing ionization potential.

In general, any low ionization potential metal which can be vaporized can be used in this process, for the production of any negative ion. Although charge exchange energies in the range of 10 to 50 kev. have been used in experiments to date, higher energies should provide greater yields of certain negative ions, particularly heavier ions, when interacting with certain metallic vapors. Further, charge exchange energies in the range of 5 to 10 kev. should be effective in producing certain negative ions, particularly lighter ions. Although the process of this invention has been described with reference to specific ions, vapors and energies, modifications can be made within the spirit and scope of this invention.

We claim:

1. A process for producing negative helium ions, comprising:
   a. accelerating a beam of positive helium ions through a negative potential in the range of 5 to 50 kv., thereby raising the energies of said ions to 5 to 50 kev.; and
   b. passing said beam of positive helium ions through a vapor, said vapor comprising atoms selected from the group consisting of the alkaline earth metals, Group II, Periodic Table, said energized positive helium ions interacting with said vapor whereby some of said positive helium ions undergo charge exchange and are converted to negative helium ions.

2. The process as defined in claim 1 wherein said negative helium ions are attracted to ground potential, thereby raising the energies of said negative helium ions to the range of 10 to 100 kev.

3. A process for producing negative helium ions comprising:
   a. accelerating a beam of positive helium ions through a negative potential in the range of 5 to 50 kv., thereby raising the energies of said positive ions to the range of 5 to 50 kev.;
   b. passing said beam of energized positive ions through a vapor, said vapor comprising atoms selected from the group consisting of magnesium, calcium, sulfur and zinc, said energized positive helium ions interacting with said vapor such that some of said positive helium ions undergo charge exchange and are converted to negative helium ions.

4. A process for producing negative ions selected from the group consisting of Li^1, B^1, C^1, O^1, NH^1, and OH^1, comprising:
   a. accelerating a beam of positive ions through a negative potential in the range of 5 to 50 kv., said positive ions being selected from the group consisting of Li^+, B^+, C^+, O^+, NH^+, and OH^+; and
   b. passing said beam of positive ions through a vapor, said vapor comprising atoms selected from the group consisting of the alkali metals, Group I, Periodic Table, said accelerated positive ions interacting with said vapor whereby some of said positive ions undergo charge exchange and are converted to negative ions.

5. The process as described in claim 4 wherein said vapor comprises atoms of lithium.

6. A process for producing negative ions selected from the group consisting of Li^1, B^1, C^1, O^1, NH^1 and OH^1, comprising:
   a. accelerating a beam of positive ions through a negative potential in the range of 5 to 50 kv., said positive ions being selected from the group consisting of Li^+, B^+, C^+, O^+, NH^+, and OH^+; and
   b. passing said beam of positive ions through a vapor, said vapor comprising atoms selected from the group consisting of the alkaline earth metals, Group II, Periodic Table, said energized positive ions interacting with said vapor whereby some of said positive ions undergo charge exchange and are converted to negative ions.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,617,789 Dated November 2, 1971

Inventor(s) Roy Middleton et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 68, "NH^1" should read -- NH^- --. Column 2, line 57, "$^3He^1$" should read -- $^3He^-$ --; line 58, "$^4He^1$" should read -- $^4He^-$--. Column 4, line 38, "Li^1, B^1, C^1, O^1, NH^1, and OH^1" should read -- Li^-, B^-, C^-, O^-, NH^-, and OH^- --; line 52, "Li^1, B^1, C^1, O^1, NH^1, and OH^1" should read -- Li^-, B^-, C^-, O^-, NH^-, and OH^- --.

Signed and sealed this 9th day of May 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

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