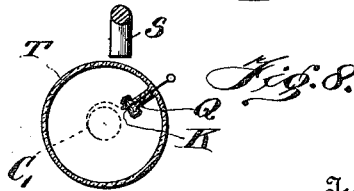
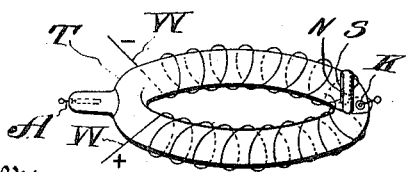
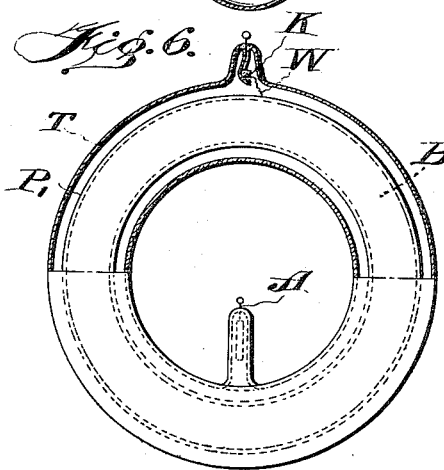
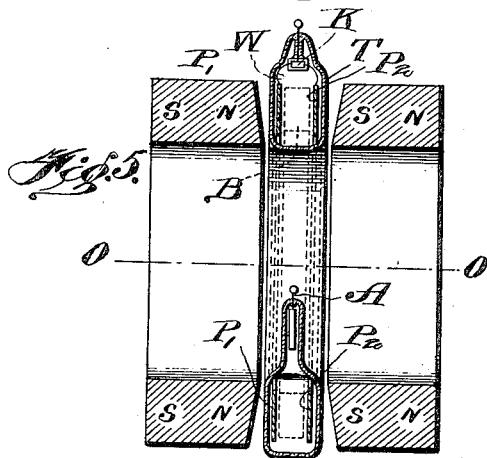
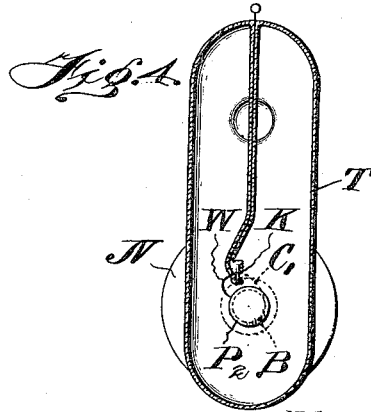
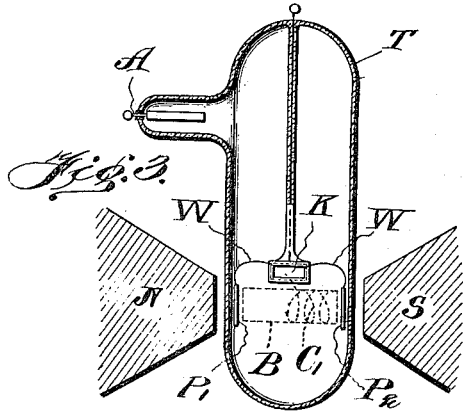
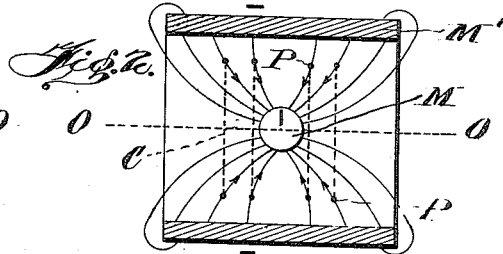
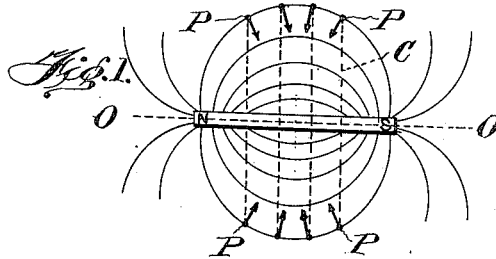


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 METHOD OF AND MEANS FOR PRODUCING ELECTRICALLY CHARGED PARTICLES.  
 APPLICATION FILED APR. 26, 1913.

1,137,964.

Patented May 4, 1915.



Witnesses  
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# UNITED STATES PATENT OFFICE.

ROBERT H. GODDARD, OF WORCESTER, MASSACHUSETTS.

METHOD OF AND MEANS FOR PRODUCING ELECTRICALLY-CHARGED PARTICLES.

1,137,964.

Specification of Letters Patent.

Patented May 4, 1915.

Application filed April 26, 1913. Serial No. 763,934.

To all whom it may concern:

Be it known that I, ROBERT H. GODDARD, a citizen of the United States, residing at Worcester, in the county of Worcester and State of Massachusetts, have invented certain new and useful Improvements in Methods of and Means for Producing Electrically-Charged Particles, of which the following is a specification.

10 The object of this invention is to produce electrically charged particles in a partial vacuum, by means of impact with particles which are themselves charged with electricity, and to employ this for useful purposes hereinafter more particularly pointed out.

I accomplish the object of my invention by causing a stream of particles which are charged with electricity to travel in a limited space by means of a suitable electrostatic or electromagnetic field, or a combination of these, and causing these charged particles to strike molecules of gas or vapor and render them charged with electricity.

25 In order to more fully describe my invention, reference will be had to the accompanying drawings in which,

Figure 1, is a diagram illustrating the method of confining the path of the charged particles by a magnetic field; Fig. 2, a semi-diagrammatic sectional view illustrating the method of confining the charged particles by an electrostatic field; Figs. 3 and 4, vertical central sections taken on planes 90° apart, of a form of apparatus embodying my invention in which both magnetic and electrostatic means are employed for confining the path of the rays of charged particles; Figs. 5 and 6, are vertical sectional views taken on planes 90° apart, of a modified form of the apparatus shown in Figs. 3 and 4; Fig. 7, a perspective view, and Fig. 8, an enlarged detail cross-section illustrating another modification of my said invention.

Referring to Fig. 1, N S represents a bar magnet symmetrical about axis O—O, and the curved lines represent the lines of force of this magnet. Now if a beam of particles charged with electricity be directed sufficiently perpendicular to a radius from the axis O—O; that is, sufficiently perpendicular to the plane of the paper, these charged particles, indicated by the letter P, will move around the axis O—O in circles indicated by the dotted lines, and the force on each of

these particles is perpendicular to the lines of magnetic force, as indicated by the arrows. This merely indicates one way of confining the path of the charged particles, which in turn affects the charging of the other particles. The same result may be effected by an electrostatic field, and one way of accomplishing this is shown in Fig. 2, where M represents a charged sphere, and M' an oppositely charged hollow cylinder. If the beam of charged particles P is sufficiently nearly perpendicular to a radius from the axis O, these charged particles will move in circles indicated by the dotted lines. The electrostatic field, however, must be symmetrical about the axis O—O. In Figs. 1 and 2 the particles are taken as charged negatively.

The beam of charged particles is most readily kept within a limited space by a combination of electrostatic and magnetic fields, and one form of apparatus embodying such an arrangement is shown in Figs. 3 and 4, to which reference will now be had. This apparatus comprises a tube T, in which is a cathode K and an anode A, the cathode being protected by glass, except at its face, as shown most clearly in Fig. 4, and magnet poles N S. The stream of electrified particles is, in this case, cathode rays. Ordinarily a stream of such rays proceeds nearly perpendicularly to the cathode, but in the present apparatus, under the influence of a strong enough magnetic field produced by poles N S, these rays are deflected and proceed in spirals, the path of one of which is indicated by the spiral dotted line C'.

In order to prevent the rays from striking the walls of the tube T, two negatively charged metal disks P<sub>1</sub> and P<sub>2</sub>, are placed near the sides of the tube as shown. A convenient way to charge disks P<sub>1</sub> and P<sub>2</sub> is to connect them by wires W, to the cathode K. When the cathode rays approach the sides of the tube they are repelled by these charged plates. The rays proceeding from the cathode K are thus kept within the space indicated by the dotted line B, being kept from moving out radially by the magnetic field, and from moving lengthwise by the charged plates P<sub>1</sub> and P<sub>2</sub>. Thus each charged cathode particle, or electron, must remain in motion within this space B, until it strikes an atom or molecule of gas which is present; and this holds true whatever the degree of exhaustion of the tube T.

A modification of the apparatus shown in Figs. 3 and 4, is shown in Figs. 5 and 6, to which reference will now be had. This apparatus also employs combined electrostatic and magnetic fields for confining the rays, and operates in the same way as the apparatus of Figs. 3 and 4, the only difference being in the modified form of the several parts.

In Figs. 5 and 6, tube T is in the form of a ring; the charged plates P and P' are also of ring form to conform to the tube T, and the magnets N S are also in the form of two rings lying on opposite sides of the tube T. The magnets in the case shown in Figs. 5 and 6, however, have their inside pole faces so shaped as to give a stronger field at the part of the gap nearest the axis O—O, this being advisable to insure the particles from the cathode K always passing below the cathode after once being sent off.

It is not necessary to produce the beam by any particular cathode. For example, a Wehnelt cathode, mercury cathode, or any other kind of cathode, or a plate caused to give off rays by being illuminated, may be used. Also, the charged particles need not necessarily be restricted to cathode rays; the so-called positive rays, for example, or any other type of charged particles may be employed.

Referring now to the form of the invention shown in Figs. 7 and 8, the tube T here is also in the form of a hollow ring, but the magnetic field is produced by a winding W W, on this ring. The rays proceed from a cathode K in this case, as in those above described, but a magnet N S is necessary to push the path of the rays upward in the immediate vicinity of the cathode, otherwise the path of the rays indicated by the dotted line in Fig. 8 would proceed in a circle directly from the cathode, and would strike the back of the cathode somewhere around the point Q.

Among the uses to which this invention may be put, may be mentioned the pumping out of a tube or other inclosed space. It is well known that when an electrical discharge takes place in a vacuum tube, gases may be absorbed by the electrodes or even by the walls of the tube itself, but in all cases the exhaustion ceases when a certain vacuum is obtained. This can be due only to the fact that the gas in the tube ceases to become ionized. In fact, it has been shown that, in very high vacua, conduction takes place entirely by the electrons or cathode ray particles. In the case described, with a Wehnelt cathode, ionization takes place within the space B at any degree of exhaustion, and the gas within this space is thus ionized and driven into an electrode, preferably charcoal, however high the vacuum may be. In this way a much higher degree of vacuum

may be obtained than by means at present employed.

Another application of the invention is the production of light at low temperatures, by the impact of charged particles traveling within a limited space with atoms and molecules in said space, thus causing light to be emitted. In this case the tube T, for example, would contain a suitable gas or vapor, the molecules of which would produce the illumination by impact with the charged particles traveling as described.

Another application of the said invention is the production of a very sensitive vacuum gage for high vacua. Owing to the impossibility of the charged particles leaving the space B, Figs. 3 to 6, for example, until they have collided with atoms or molecules of the gas, they will travel a great distance before leaving this space, if the vacuum is extremely high. Hence, if a beam of rays is allowed to enter the space B for an instant, carrying a charge of known quantity, the quantity of electricity within space B will therefore slowly diminish. If the ions escaping from space B are carried off as fast as they escape, then, after a certain time, if the magnetic field is removed, the charge appearing in the tube will give a measure of the degree of exhaustion.

I am aware that a single ion or electron could move in a circle as long as desired in a uniform magnetic field, provided it were projected exactly at right angles to the magnetic lines of force, and provided that there were no electrostatic effects present to disturb its motion. I am also aware that a single ion or electron could move in a circle as long as desired about an infinitely long electrode by applying a suitable magnetic field, provided it were projected exactly at right angles to the axis of the said electrode, and provided that there were no electrostatic effects present to disturb its motion. I am further aware that these hypothetical cases have been treated mathematically, owing to their simplicity. Nevertheless, they are not within the scope of my invention, for the reason that they are not realizable experimentally, and hence cannot be used to produce the useful results enumerated in my specification. The two said cases cannot be realized experimentally for the following reasons; first, a vacuum tube of infinite dimensions cannot be made; second, in a vacuum tube of finite dimensions there are always present electrostatic forces between the charged particles and the various electrodes, the walls of the tube, and even bodies outside the tube, each of which forces tends to change the paths of the said particles; and third, it is practically impossible to project a charged particle in a certain direction, with perfect precision. Furthermore, with a number of ions or electrons, instead of a

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single ion or electron, and with electrode surfaces of finite extent, the space in which the ions or electrons would move would not remain limited. The mutual electrostatic repulsions would spread the paths farther and farther apart, thus increasing the space containing the said particles. Therefore it is evident that charged particles can continue in motion indefinitely within a strictly limited space, or until they strike some other particle within this space, only when adequate means are employed to prevent the spreading of the group of particles, under the disturbing influences unavoidably present. In order to prevent the said spreading of the particles, the means described in this specification must be employed; namely, a magnetic field or an electrostatic field, of such a shape that the field will overcome lateral spreading, illustrated by Figs. 1 and 2, respectively; or, second, means whereby the lateral spreading is overcome by charged plates, illustrated in Figs. 3, 4, 5 and 6; or, third, means whereby the lateral spreading causes the particles to describe closed paths of finite magnitude, illustrated in Figs. 7 and 8.

Having thus described my invention, it should be understood that other modifications of the same may be made without departing from the spirit thereof.

What I claim is:—

1. The method of producing electrically charged particles by impact with other charged particles which consists in causing electrified particles to move continuously within a confined space and retaining all of them therein until they strike molecules or particles of gas or vapor.

2. Apparatus of the class described, comprising means to generate rays of charged particles and means to produce a field of energy acting on said charged particles to confine their entire movement to a limited space and a receptacle containing a gas or vapor the molecules of which are subject to impact by said charged particles.

3. Apparatus of the class described, comprising means to generate rays of electrically charged particles, combined electromagnetic and electrostatic means to produce a field of energy acting on said charged particles to confine them to a limited space, and a receptacle containing a gas or vapor the molecules of which are subject to impact by said charged particles.

4. Apparatus of the class described, comprising a receptacle containing a gas or vapor, means to generate therein electrically charged particles, and means to confine said particles to a limited space within said receptacle and prevent any of them from passing outside of said space without first striking one or more molecules of said gas or vapor.

5. Apparatus of the class described, comprising a tube containing a gas or vapor, a cathode, plates charged from the cathode, and magnet poles cooperating with said plates to confine the rays from said cathode to a limited space.

In testimony whereof I affix my signature in presence of two witnesses.

ROBERT H. GODDARD.

Witnesses:

FRANCOIS W. HIXON,  
WILLIAM C. WOOD.