THE TRUE CATHODE RAYS

Prof. Crookes's Celebrated Discovery as Related by Himself.

ELECTRICITY IN HIGH VACUUM

Plea for Existence of Matter in a Radiant State in Which It Differs from Its Solid, Liquid, and Gaseous Form.

The great popular interest taken in the discovery of the X rays by Prof. Röntgen, both in this country and in Europe, has brought the phrase "Crookes tube" into prominence, because it was by means of a tube of this kind that Prof. Röntgen's experiments were conducted.

The experiments made by Prof. William Crookes with discharges of high potential electricity in glass tubes of high vacuum have become classical and mark the beginning of an epoch which has been so brilliantly crowned by Röntgen's discovery. These results were first embodied in an interesting and lucid paper which Prof. Crookes read before the British Association on Aug. 22, 1879, at its annual meeting, held that year in Sheffield.

The dark space at the cathode or negative point of a glass tube exhausted to a tension of a millionth of an atmosphere was first brought under the general notice of men of science in this paper. Crookes held that the discharge of rays from the cathode represented matter in its ultra-gaseous or radiant state—a theory still held by many eminent physicists, particularly in England. The late Heinrich Hertz carried these experiments a step further by demonstrating that the cathodic "rays" which would not pass through glass, mica, or any other transparent substance would pass through metal foil. Then Philipp Lenard showed that after the cathodic "rays" were passed through an aluminium window in the high vacuum tube, they retained their property of exciting phosphorescence in substances surrounded by the ordinary atmosphere, though the "rays" themselves could not be produced in air. It was reserved for Röntgen to show that another and totally different kind of "rays," which were not the cathode "rays" of Crookes, Hertz, and Lenard, were produced at the cathode of a high vacuum tube, and had the remarkable property of penetrating opaque substances without regard to their electrical conductivity.

William Crookes was born in London in 1832. He became an assistant to Hofmann, the distinguished chemist, in the Royal College of Chemistry, when he was only eighteen years of age. He discovered the rare metal thallium in 1863, and two years later invented the soda amalgamation process of separating gold and silver from their ores. The Royal Society in 1875 awarded him a royal gold medal for chemical and physical researches. He is the author of several practical treatises on a wide range of subjects, including the manufacture of beetroot sugar, dyeing, calico and tissue printing, and select methods of chemical analysis. He founded The Chemical News in 1859, and in 1864 became the editor of The Quarterly Journal of Science. His account of electrical phenomena in high vacuum tubes, the essential parts of which are here reproduced from his famous address before the British Association in 1879, is the best and clearest extant, and the perusal of it is calculated to give the general reader a thorough grasp of the whole subject, and to lead him to appreciate more fully than before the probable nature and behavior of the X rays of Röntgen.

The title of Prof. Crookes's paper was: "On Radiant Matter," and the paper itself was substantially as follows:

"To throw light on the title of this lecture I must go back more than sixty years—to 1816. Faraday, then a mere student and ardent experimentalist, was twenty-four years old, and at this early period of his career he delivered a series of lectures on the 'General Properties of Matter,' and one of them bore the remarkable title, 'On Radiant Matter.' The great philosopher's notes of this lecture are to be found in Dr. Bence Jones's 'Life and Letters of Faraday,' and I will here quote a passage in which he first employs the expression 'radiant matter':

"'If we conceive a change as far beyond vaporization as that is above fluidity, and then take into account also the proportional increased extent of alteration as the changes rise, we shall, perhaps, if we can form any conception at all, not fall far short of radiant matter; and as in the last conversion many qualities were lost, so here also many more would disappear.'

"Faraday was evidently engrossed with this far-reaching speculation, for three years later—in 1819—we find him bringing fresh evidence and argument to strengthen his startling hypothesis. His notes are now more extended, and they show that in the intervening three years he had thought much and deeply on this higher form of matter. He first points out that matter may be divided into four states—solid, liquid, gaseous, and radiant—these modifications depending upon differences in their several essential properties. He admits that the existence of radiant matter is as yet unproved, and then proceeds, in the following series of ingenious arguments, to show the probability of its existence:

"'I may now notice a curious progression in physical properties accompanying changes of form, and which is perhaps sufficient to induce, in the inventive and sanguine philosopher a considerable degree of belief in the association of the radiant form with the others in the set of changes I have mentioned.

"'As we ascend from the solid to the fluid or gaseous states physical properties diminish in number and variety, each state losing some of those which belong to the preceding state. When solids are converted into fluids all the varieties of hardness and softness are necessarily lost. Crystalline and other shapes are destroyed. Opacity and color frequently give way to a colorless transparency, and a general mobility of particles is conferred.

"'Passing onward to the gaseous state, still more of the evident characters of bodies are annihilated. The immense differences in their weight almost disappear; the remains of difference in color that were left are lost. Transparency becomes universal, and they are all elastic. They now form but one set of substances, and the varieties of density, hardness, opacity, color, elasticity, and form, which render the number of solids and fluids almost infinite, are now supplied by a few slight variations in weight, and some unimportant shades of color.

"'To those, therefore, who admit the radiant form of matter, no difficulty exists in the simplicity of the properties it possesses, but rather an argument in their favor. These persons show you a gradual resignation of properties in the matter we can appreciate as the matter ascends in the scale of forms, and they would be surprised if that effect were to cease at the gaseous state. They point out the greater exertions which nature makes at each step of the change, and think that, consistently, it ought to be greatest in the passage from the gaseous to the radiant form.'—Life and Letters of Faraday, Vol. I., p. 308.

"If, in the beginning of this century, we had asked, What is a gas? the answer then would have been that it is matter, expanded and rarefied, to such an extent as to be impalpable, save when set in violent motion; invisible, incapable of assuming or of being reduced into any definite form like solids, or of forming drops like liquids; always ready to expand where no resistance is offered, and to contract on being subjected to pressure. Sixty years ago such were the chief attributes assigned to gases. Modern research, however, has greatly enlarged and modified our views on the constitution of these elastic fluids. Gases are now considered to be composed of an almost infinite number of small particles or molecules, which are constantly moving in every direction with velocities of all conceivable magnitudes.

"As these molecules are exceedingly numerous, it follows that no molecule can move far in any direction without coming in contact with some other molecule. But if we exhaust the air or gas contained in a closed vessel, the number of molecules becomes diminished, and the distance through which any one of them can move without coming in contact with another is increased, the length of the mean free path being inversely proportional to the number of molecules present. The further this process is carried the longer becomes the average distance a molecule can travel before entering into collision; or, in other words, the longer its mean free path, the more the physical properties of the gas or air are modified. Thus, at a certain point, the phenomena of the radiometer become possible, and on pushing the rarefaction still further, i. e., decreasing the number of molecules in a given space and lengthening their mean free path, the experimental results are obtainable to which I am now about to call your attention. So distinct are these phenomena from anything which occurs in air or gas at the ordinary tension, that we are led to assume that we are here brought face to face with matter in a fourth state or condition, a condition as far removed from the state of gas as a gas is from a liquid.

"I have long believed that a well-known appearance observed in vacuum tubes is closely related to the phenomena of the mean free path of the molecules. When the negative pole is examined while the discharge from an induction-coil is passing through an exhausted tube, a dark space is seen to surround it. This dark space is found to increase and diminish as the vacuum is varied, in the same way that the mean free path of the molecules lengthens and contracts. As the one is perceived by the mind's eye to get greater, so the other is seen by the bodily eye to increase in size; and if the vacuum is insufficient to permit such play of the molecules before they enter into collision, the passage of electricity shows that the 'dark space' has shrunk to small dimensions. We naturally infer that the dark space is the mean free path of the molecules of the residual gas, an inference confirmed by experiment.

"I will endeavor to render this 'dark space' visible to all present. Here is a tube, (Fig. 1,) having a pole in the centre in the form of a metal disk, and other poles at each end. The centre pole is made negative, and the two end poles connected together are made the positive terminal. The dark space will be in the centre. When the exhaustion is not very great, the dark space extends only a little on each side of the negative pole in the centre. When the exhaustion is good, as in the tube before you, and I turn on the coil, the dark space is seen to extend for about an inch on each side of the pole.

"Here, then, we see the induction spark actually illumniating the lines of molecular pressure caused by the excitement of the negative pole. The thickness of this dark space is the measure of the mean free path between successive collisions of the molecules of the residual gas. The extra velocity with which the negatively electrified molecules rebound from the excited pole keeps back the more slowly moving molecules which are advancing toward that pole. A conflict occurs at the boundary of the dark space, where the luminous margin bears witness to the energy of the discharge.

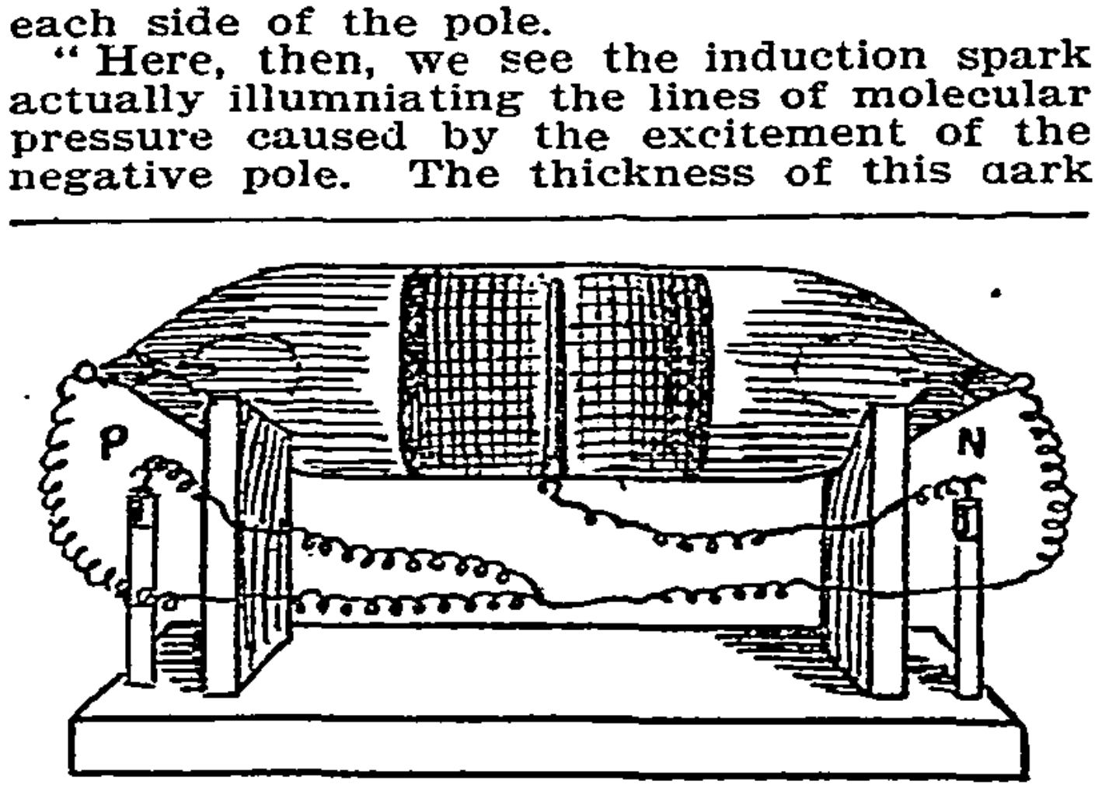

Figure 1.
High Vacuum Tube Showing Cathode "Dark Space" in the Centre.

"Therefore the residual gas—or, as I prefer to call it, the gaseous residue—within the dark space is in an entirely different state to that of the residual gas in vessels at a lower degree of exhaustion. To quote the words of our last year's President, in his address at Dublin:

"'In the exhausted column we have a vehicle for electricity not constant, like an ordinary conductor, but itself modified by the passage of the discharge, and perhaps subject to laws differing materially from those which it obeys at atmospheric pressure.'

"In the vessels with the lower degree of exhaustion, the length of the mean free path of the molecules is exceedingly small as compared with the dimensions of the bulb, and the properties belonging to the ordinary gaseous state of matter, depending upon constant collisions, can be observed. But in the phenomena now about to be examined, so high is the exhaustion carried that the dark space around the negative path has become so long that the hits in a tube. By great rarefaction, the mean free path has become so long that the hits in a given time in comparison to the misses may be disregarded, and the average molecule is now allowed to obey its own motions or laws without interference. The mean free path, in fact, is comparable to the dimensions of the vessel, and we have no longer to deal with a continuous portion of matter, as would be the case were the tubes less highly exhausted, but we must here contemplate the molecules individually. In these highly exhausted vessels the molecules of the gaseous residue are able to dart across the tube with comparatively few collisions, and radiating from the pole with enormous velocity, they assume properties so novel and so characteristic as to entirely justify the application of the term borrowed from Faraday, that of Radiant Matter.

Radiant Matter Exerts Powerful Phosphorogenic Action Where It Strikes.

"I have mentioned that the radiant matter within dark space excites luminosity where its velocity is arrested by residual gas outside the dark space. But if no residual gas is left, the molecules will have their velocity arrested by the sides of the glass; and here we come to the first and one of the most noteworthy properties of radiant matter discharged from the negative pole—its power of exciting phosphorescence when it strikes against solid matter. The number of bodies which respond luminously to this molecular bombardment is very great, and the resulting colors are of every variety. Glass, for instance, is highly phosphorescent when exposed to a stream of radiant matter. Here (Fig. 2) are three bulbs composed of different glass; one is uranium glass, (a,) which phosphoresces of a dark green color; another is English glass, (b,) which phosphoresces of a blue color; and the third (c) is soft German glass—of which most of the apparatus before you is made—which phosphoresces of a bright apple-green.

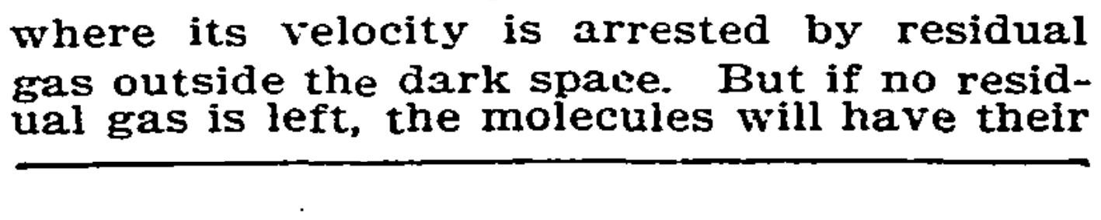

Figure 2.
Three Kinds of Glass Tubes Displaying Different Phosphorescence.

"There is one particular degree of exhaustion more favorable than any other for the development of the properties of radiant matter which are now under examination. Roughly speaking, it may be put at the millionth of an atmosphere. At this degree of exhaustion the phosphorescence is very strong, and after that it begins to diminish, until the spark refuses to pass.

Radiant Matter Proceeds in Straight Lines.

"The radiant matter, whose impact on the glass causes an evolution of light, absolutely refuses to turn a corner. Here is a V-shaped tube, (Fig. 3,) a pole being at each extremity. The pole at the right side (a) being negative, you see that the whole of the right arm is flooded with green light, but at the bottom it stops sharply, and will not turn the corner to get into the left side. When I reverse the current and make the left pole negative, the green changes to the left side, always following the negative pole and leaving the positive side with scarcely any luminosity.

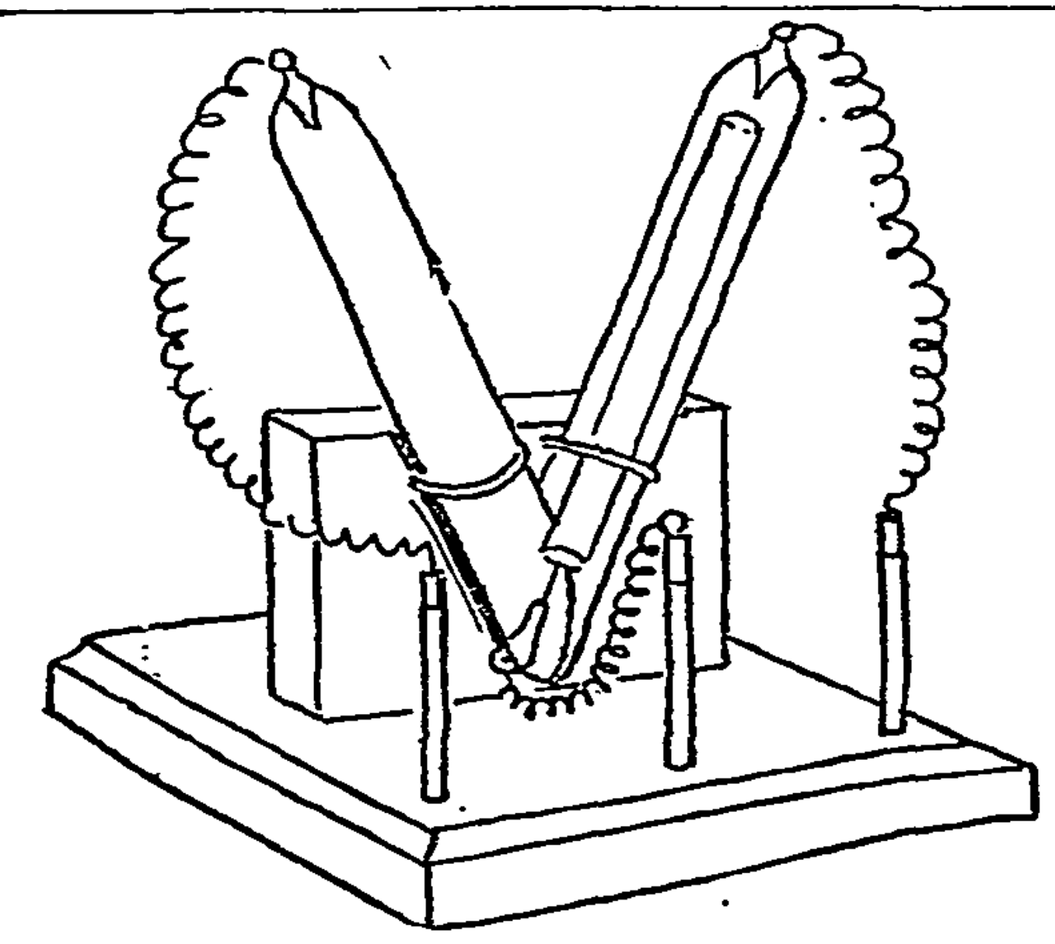

Figure 3.
V-shaped Tube to Show That Radiant Matter Will Not Turn a Corner.

"In the ordinary phenomena exhibited by vacuum tubes—phenomena with which we are all familiar—it is customary, in order to bring out the striking contrasts of color, to bend the tubes into very elaborate designs. The luminosity caused by the phosphorescence of the residual gas follows all the convolutions into which skillful glass-blowers can manage to twist the glass. The negative pole being at one end and the positive pole at the other, the luminous phenomena seem to depend more on the positive than on the negative at the ordinary exhaustion hitherto used to get the best phenomena of vacuum tubes. But at a very high exhaustion the phenomena noticed in ordinary vacuum tubes when the induction spark passes through them—an appearance of cloudy luminosity and of stratifications—disappear entirely. No cloud or fog whatever is seen in the body of the tube, and with such a vacuum as I am working with in these experiments, the only light observed is that from the phosphorescent surface of the glass. I have here two bulbs, (Fig. 4,) alike in shape and and position of poles, the only difference being that one is at an exhaustion equal to a few millimeters of mercury—such a moderate exhaustion as will give the ordinary luminous phenomena—while the other is exhausted to about the millionth of an atmosphere. I will first connect the moderately exhausted bulb (A) with the induction coil, and, retaining the pole at one side (a) always negative, I will put the positive wire successively to the other poles with which the bulb is furnished. You see that as I change the position of the positive pole, the line of violet light joining the two poles changes, the electric current always choosing the shortest path between the two poles, and moving about the bulb as I alter the position of the wires.

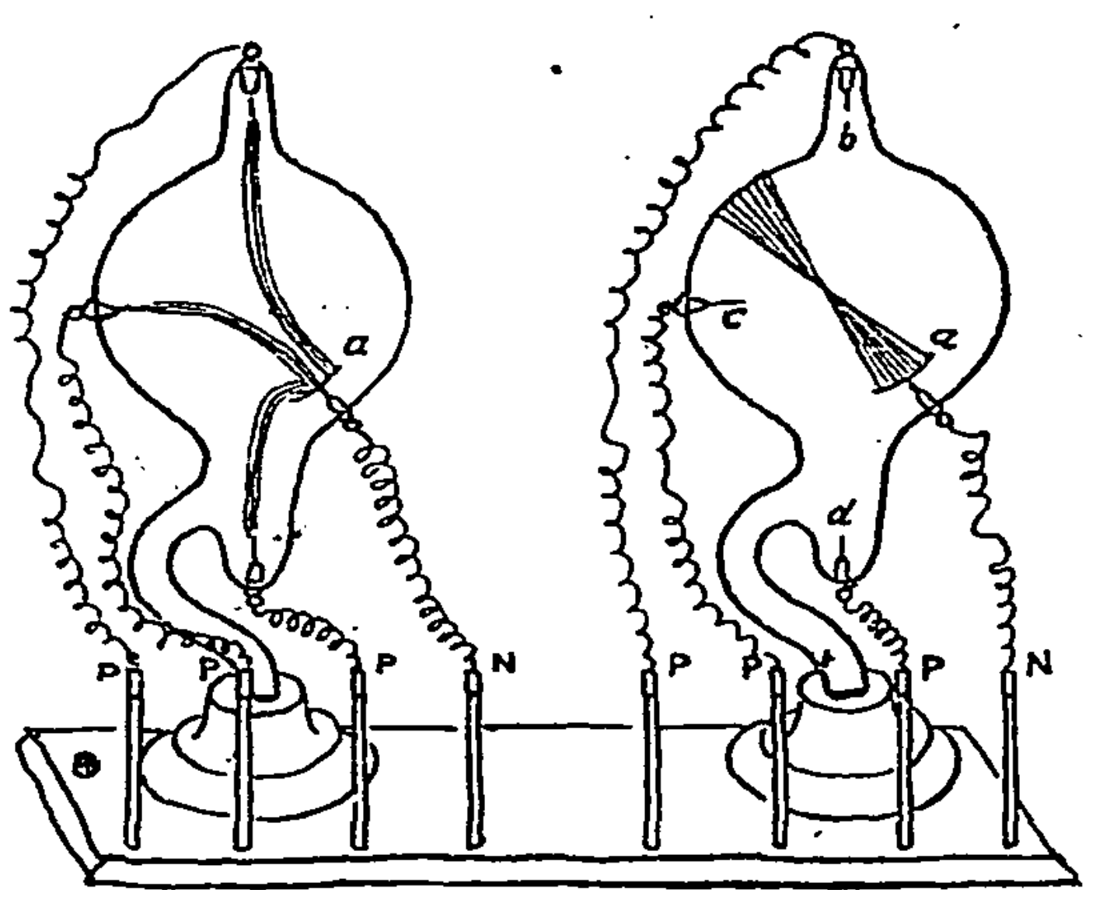

Figure 4.
Two Tubes to Show the Different Behavior of the Cathode Rays in Medium and High Vacua. The Right-Hand Tube Represents the Highest Vacuum.

"This, then, is the kind of phenomenon we get in ordinary exhaustions. I will now try the same experiment with a bulb (B) that is very highly exhausted, and, as before, will make the side pole (a) the negative, the top pole (b) being positive. Notice how widely different is the appearance from that shown by the last bulb. The negative pole is in the form of a shallow cup. The molecular rays from the cup cross in the centre of the bulb and thence diverging, fall on the opposite side and produce a circular patch of green phosphorescent light. As I turn the bulb round you will all be able to see the green patch on the glass. Now observe, I remove the positive wire from the top, and connect it with the side pole (c.) The green patch from the divergent negative focus is there still. I now make the lowest pole (d) positive, and the green patch remains where it was at first, unchanged in position or intensity.

"We have here another property of radiant matter. In the low vacuum the position of the positive pole is of every importance, while in a high vacuum the position of the positive pole scarcely matters at all; the phenomena seem to depend entirely on the negative pole. If the negative pole points in the direction of the positive, all very well, but if the negative pole is entirely in the opposite direction, it is of little consequence; the radiant matter darts all the same in a straight line from the negative.

Radiant Matter When Intercepted by Solid Matter Casts a Shadow.

"Radiant matter comes from the pole in straight lines, and does not merely permeate all parts of the tube and fill it with light, as would be the case were the exhaustion less good. Where there is nothing in the way, the rays strike the screen and produce phosphorescence, and where solid matter intervenes they are obstructed by it, and a shadow is thrown on the screen.

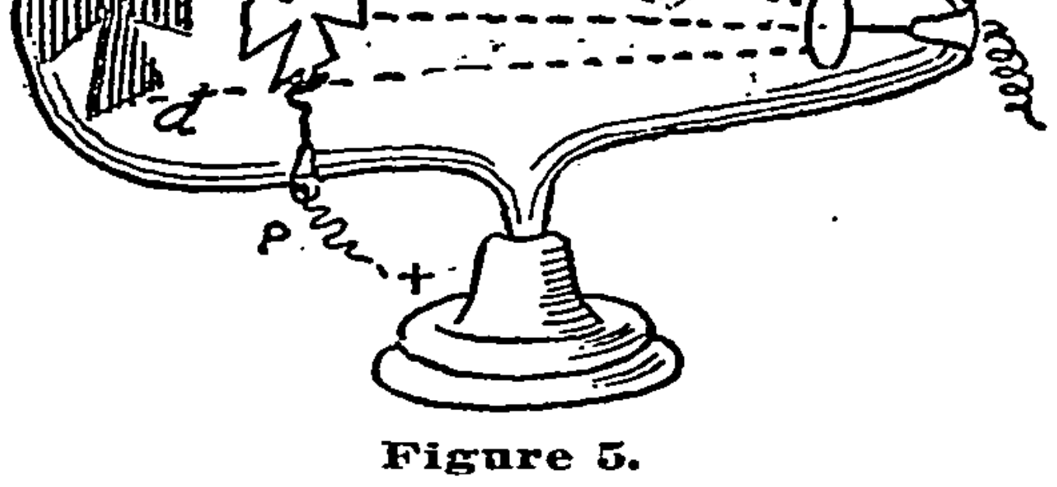

Figure 5.
Pear-Shaped Tube to Show the Shadow Cast by a Maltese Cross of Aluminium.

"In this pear-shaped bulb (Fig. 5) the negative pole (a) is at the pointed end. In the middle is a cross (b) cut out of sheet aluminium, so that the rays from the negative pole projected along the tube will be partly intercepted by the aluminium cross, and will project an image of it on the hemispherical end of the tube, which is phosphorescent. I turn on the coil, and you will all see the black shadow of the cross on the luminous end of the bulb (c, d.) Now, the radiant matter from the negative pole has been passing by the side of the aluminium cross to produce the shadow; the glass has been hammered and bombarded till it is appreciably warm, and at the same time another effect has been produced on the glass—its sensibility has been deadened. The glass has got tired, if I may use the expression, by the enforced phosphorescence. A change has been produced by this molecular bombardment, which will prevent the glass from responding easily to additional excitement: but the part that the shadow has fallen on is not tired—it has not been phosphorescing at all, and is perfectly fresh; therefore, if I throw down this cross—I can easily do so by giving the apparatus a slight jerk, for it has been most ingeniously constructed with a hinge by Mr. Gimingham—and so allow the rays from the negative pole to fall uninterruptedly on to the end of the bulb, you will suddenly see the black cross (c, d, Fig. 6,) change to a luminous one (e, f,) because the background is now only capable of faintly phosphorescing, whilst the part which had the black shadow on it retains its full phosphorescent power. The stenciled image of the luminous cross unfortunately soon dies out. After a period of rest the glass partly recovers its power of phosphorescing, but it is never so good as it was at first.

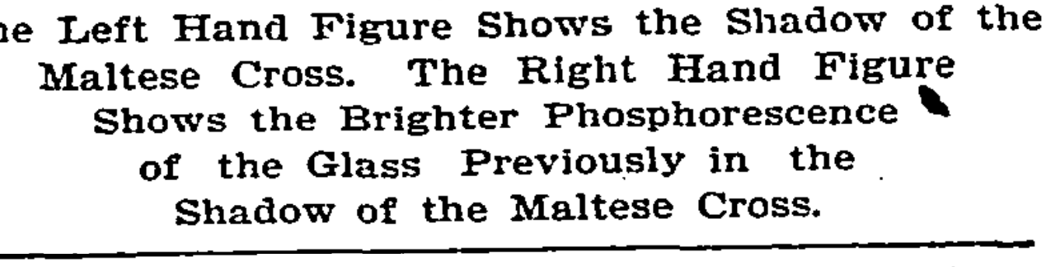

Figure 6.
The Left Hand Figure Shows the Shadow of the Maltese Cross. The Right Hand Figure Shows the Brighter Phosphorescence of the Glass Previously in the Shadow of the Maltese Cross.

Here, therefore, is another important property of radiant matter. It is projected with great velocity from the negative pole, and not only strikes the glass in such a way as to cause it to vibrate and become temporarily luminous while the discharge is going on, but the molecules hammer away with sufficient energy to produce a permanent impression upon the glass.

Radiant Matter Exerts Strong Mechanical Action Where It Strikes.

"We have seen, from the sharpness of the molecular shadows, that radiant matter is arrested by solid matter placed in its path. If this solid body is easily moved, the impact of the molecules will reveal itself in strong mechanical action. Mr. Gimingham has constructed for me an ingenious piece of apparatus, which, when placed in the electric lantern, will render this mechanical action visible to all present. It consists of a highly exhausted glass tube, (Figure 7,) having a little glass railway running along it from one end to the other. The axle of a small wheel revolves on the rails, the spokes of the wheel carrying wide mica paddles. At each end of the tube, and rather above the centre, is an aluminium pole, so that whichever pole is made negative the stream of radiant matter darts from it along the tube, and, striking the upper vanes of the little paddle wheel, causes it to turn round and travel along the railway. By reversing the poles I can arrest the wheel and send it the reverse way, and if I gently incline the tube the force of impact is observed to be sufficient even to drive the wheel up hill.

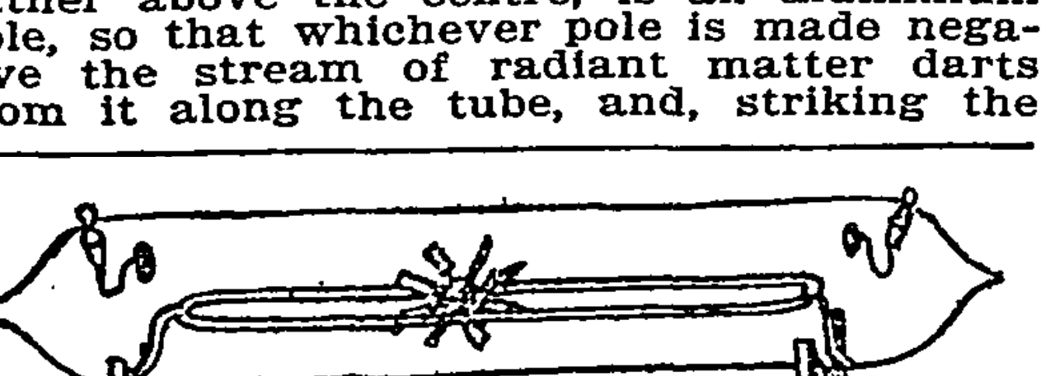

Figure 7.
Small Wheel in a Vacuum Tube to Show the Mechanical Action of the Cathode Rays.

"The experiment therefore shows that the molecular stream from the negative pole is able to move any light object in front of it.

Radiant Matter Is Deflected by a Magnet.

"I now pass to another property of radiant matter. This long glass tube (Figure 8) is very highly exhausted; it has a negative pole at one end (a) and a long phosphorescent screen (b, c) down the centre of the tube. In front of the negative pole is a plate of mica (b, d) with a hole (e) in it, and the result is, when I turn on the current, a line of phosphorescent light (e, f) is projected along the whole length of the tube. I now place beneath the tube a powerful horseshoe magnet; observe how the line of light (e, g) becomes curved under the magnetic influence, waving about like a flexible wand as I move the magnet to and fro.

"This action of the magnet is very curious, and if carefully followed up will elucidate other properties of radiant matter. Here (Fig. 9) is an exactly similar tube, but having at one end a small potash tube, which if heated will slightly injure the vacuum. I turn on the induction current, and you see the ray of radiant matter tracing its trajectory in a curved line along the screen, under the influence of the horseshoe magnet beneath. Observe the *shape of the curve*. The molecules shot from the negative pole may be likened to a discharge of iron bullets from a mitrailleuse, and the magnet beneath will represent the earth curving the trajectory of the shot by gravitation. Here on this luminous screen you see the curved trajectory of the shot accurately traced. Now suppose the deflecting force to remain constant, the curve traced by the projectile varies with the velocity. If I put more powder in the gun the velocity will be greater and the trajectory flatter, and if I interpose a denser resisting medium between the gun and the target. I diminish the velocity of the shot and thereby cause it to move in a greater curve and come to the ground sooner. I cannot well increase before you the velocity of my stream of radiant molecules by putting more powder in my battery, but I will try and make them suffer greater resistance in their flight from one end of the tube to the other. I heat the caustic potash with a spirit lamp, and so throw a trace more gas. Instantly the stream of radiant matter responds. Its velocity is impeded, the magnetism has longer time on which to act on the individual molecules, the trajectory gets more and more curved, until, instead of shooting nearly to the end of the tube, my molecular bullets fall to the bottom before they have got more than half way.

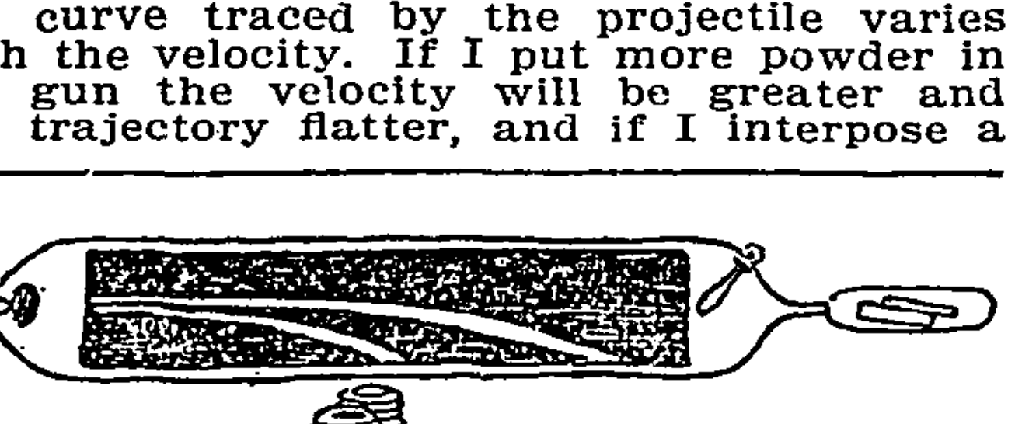

Figure 8.
To Show the Deflection of the Cathode Rays When Near a Magnet.

The Chemistry of Radiant Matter.

"As might be expected, the chemical distinctions between one kind of radiant matter and another at these high exhaustions are difficult to recognize. The physical properties I have been elucidating seem to be common to all matter at this low density. Whether the gas originally under experiment be hydrogen, carbonic acid, or atmospheric air, the phenomena of phosphorescence, shadows, magnetic deflection, &c., are identical, only they commence at different pressures. Other facts, however, show that at this low density the molecules retain their chemical characteristics. Thus, by introducing into the tubes appropriate absorbents or residual gas, I can see that chemical attraction goes on long after the attenuation has reached the best stage for showing the phenomena now under illustration, and I am able by this means to carry the exhaustion to much higher degrees than I can get by mere pumping. Working with the aqueous vapor I can use phosphoric anhydride as an absorbent; with carbonic acid, potash; with hydrogen, palladium, and with oxygen, carbon, and then potash. The highest vacuum I have yet succeeded in obtaining has been to one-twenty millionth of an atmosphere, a degree which may be better understood if I say that it corresponds to about the hundredth of an inch in a barometric column three miles high.

"It may be objected that it is hardly consistent to attach primary importance to the presence of matter, when I have taken extraordinary pains to remove as much matter as possible from these bulbs and these tubes, and have succeeded so far as to leave only about the one-millionth of an atmosphere in them. At its ordinary pressure the atmosphere is not very dense, and its recognition as a constituent of the world of matter is quite a modern notion. It would seem that when divided by a million, so little matter will necessarily be left that we may justifiably neglect the trifling residue and apply the term vacuum to space from which the air has been so nearly removed. To do so, however, would be a great error, attributable to our limited faculties being unable to grasp high numbers. It is generally taken for granted that when a number is divided by a million the quotient must necessarily be small, whereas it may happen that the original number is so large that its division by a million seems to make little impression on it. According to the best authorities, a bulb of the size of the one before you (13.5 centimeters in diameter) contains more than 1,000000,000000,000000,000000 (a quadrillion) molecules. Now, when exhausted to a millionth of an atmosphere, we still have a trillion molecules left in the bulb—a number quite sufficient to justify me in speaking of the residue as matter.

"To suggest some idea of this vast number I take the exhausted bulb, and perforate it by a spark from the induction-coil. The spark produces a hole of microscopical fineness, yet sufficient to allow molecules to penetrate and destroy the vacuum. The inrush of air impinges against the vanes and sets them rotating after the manner of a windmill. Let us suppose the molecules to be of such a size that at every second of time a hundred millions could enter, how long, think you, would it take for this small vessel to get full of air? An hour? A day? A year? A century? Nay, almost an eternity! A time so enormous that imagination itself cannot grasp the reality. Supposing that this exhausted glass bulb, indued with indestructibility, had been pierced at the birth of the solar system; supposing it to have been present when the earth was without form and void; supposing it to have borne witness to all the stupendous changes evolved during the full cycles of geologic time, to have seen the first living creature appear, and the last man disappear; supposing it to survive until the fulfillment of the mathematicians' prediction that the sun, the source of energy, four million centuries from its formation, will ultimately become a burnt-out cinder; supposing all this—at the rate of filling I have just described, 100 million molecules a second—this little bulb even then would scarcely have emitted its full quadrillion of molecules."

"But what will you say if I tell you that all these molecules, this quadrillion of molecules, will enter through the microscopical hole before you leave this room? The hole being unaltered in size, the number of molecules undiminished, this apparent parodox can only be explained by again supposing the size of the molecules to be diminished almost indefinitely—so that instead of entering at the rate of 100 millions every second, they troop in at the rate of something like 300 trillions a second. I have done teh sum, but figures, when they mount up so high cease to have any meaning, and such calculations are as futile as trying to count the drops in the ocean.

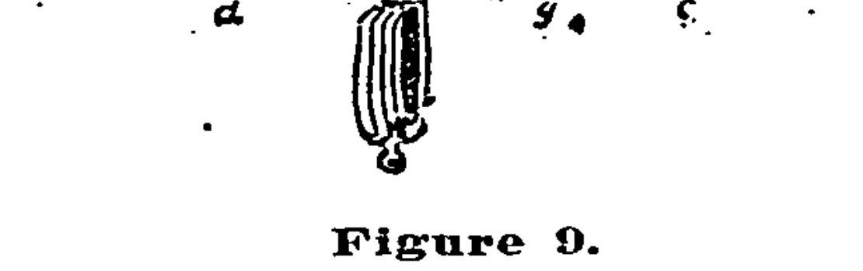

Figure 9.
To Show the Difference in the Path of the Rays When Deflected by a Magnet in High and Medium Vacua.

"In studying this fourth state of matter we seem at length to have within our grasp and obedient to our control the little indivisible particles which with good warrant are supposed to constitute the physical basis of the universe. We have seen that in some of its properties radiant matter is as material as this table, whilst in other properties it almost assumes the character of radiant energy. We have actually touched the border land where matter and force seem to merge into one another, the shadowy realm between known and unknown, which for me has always had peculiar temptations. I venture to think that the greatest scientific problems of the future will find their solution in this border land, and even beyond; here, it seems to me, lie ultimate realities, subtle, far-reaching, wonderful."

—Max Nordau has been telling an interviewer about his early life. It is no surprise to learn that Nordau was a precocious child. He could read at four, and in a stern and austere childhood this was his only amusement. The first work of fiction which came under his notice was "Midshipman Easy," which inspired him with a longing for adventure and travel, which he was afterward able to realize, and which gave him "a high opinion of British pride and British tenacity." He began to write early, and in 1863, when he was only fourteen, various poems, essays, and tales of his were published.

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