W. Gibbs, G. L. Goodale, H. B. Hill, C. L. Jackson, E. C. Pickering, F. W. Putnam, C. S. Sargent, J. Trowbridge.

Chicago: The University of Chicago, (1): A. A. Michelson, C. O. Whitman.

College Hill: Tufts College, (1): A. Michael.

Hoboken: Stevens Technological Institute, (2): A. M. Mayer; H. Morton.

New Haven: Yale University, (13): W. H. Brewer, G. J. Brush, R. H. Chittenden, E. S. Dana, W. L. Elkin, J. W. Gibbs, C. S. Hastings, S. W. Johnson, O. C. Marsh, H. A. Newton, S. I. Smith, A. E. Verrill, A. W. Wright.

New York: American Museum, (1): J. A. Allen.

New York: Columbia College, (3): C. F. Chandler [G. W. Hill], R. Mayo-Smith, O. N. Rood.

New York: The Public Library (—): [J. S. Billings].

Philadelphia: University of Pennsylvania, (4): G. F. Barker [J. S. Billings], E. D. Cope, J. P. Lesley, H. C. Wood.

Princeton: College of New Jersey (1): C. A. Young.

Providence: Brown University (2): C. Barus, A. S. Packard.

Washington: U. S. Army, (5): H. L. Abbot, J. S. Billings, C. B. Comstock, E. Coues, C. E. Dutton.

Washington: American Ephemeris, (—): [G. W. Hill], [S. Newcomb].

Washington: U. S. Navy, (2): A. Hall, S. Newcomb.

Washington: U. S. Coast and Geodetic Survey, (1): C. A. Schott [H. Mitchell].

Washington: U. S. Geological Survey (5): G. F. Emmons, G. K. Gilbert, A. Hague, R. Pumpelly, C. A. White.

Washington: U. S. Weather Bureau, (1): C. Abbe.

Washington: Smithsonian Institution and National Museum and Fish Commission, (4): T. N. Gill, G. B. Goode, J. P. Langley, J. W. Powell.

Waterville: Colby University, (1): W. A. Rogers.

Worcester: Polytechnic Institute, (1): T. C. Mendenhall.

In Private Life: (15): A. G. Bell, S. C. Chandler, B. A. Gould, G. W. Hill, C. King, M. C. Lea, T. Lyman, H. Mitchell, S. W. Mitchell, E. S. Morse, C. S. Pierce, F. Rogers, S. H. Scudder, W. Sellers, J. H. Trumbull.

EDWARD S. HOLDEN.
LICK OBSERVATORY,
UNIVERSITY OF CALIFORNIA.

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*DIFFUSIVE REFLECTION OF RÖNTGEN RAYS.**

THE following communication contains a brief description of a series of experiments with Röntgen radiance which were conducted during the last six weeks. The results of these experiments seem to possess a sufficient scientific and practical importance to merit notice. The most important refer to diffuse reflection or scattering of Röntgen radiance. It seems desirable to state first, briefly, the disposition of the apparatus and the method of experimentation by means of which the Röntgen effects can be rendered sufficiently intense for the purpose described below.

Induction Coil and Interrupter. A powerful coil was found indispensable for strong effects and satisfactory work. The vibrating interrupter is too slow and otherwise unsatisfactory, and it was replaced by a rotary interrupter, consisting of a brass pulley, 6 inches in diameter and $1\frac{1}{4}$ inches in thickness. A slab of slate $\frac{3}{4}$ inch thick was inserted and the circumference was kept carefully polished. This pulley was mounted on the shaft of a Crocker-Wheeler $\frac{1}{8}$ HP motor giving 30 revolutions, and, therefore, 60 breaks per second. Two adjustable Marshall condensers of three microfarads each were connected in shunt with the break,

* Presented before the New York Academy of Sciences, April 6, 1896.

and the capacity adjusted carefully until the break-spark was a minimum and gave a sharp cracking sound. Too much capacity will not necessarily increase the sparking, but it will diminish the inductive effect which is noticed immediately in the diminished intensity of the discharge. A powerful coil with a smoothly working rotary interrupter will be found a most satisfactory apparatus in experiments with Röntgen radiance.

Edison's Fluoroscope. A fluorescent screen, made by Aylsworth & Jackson, of East Orange, N. J., according to Mr. Edison's directions, will be found an indispensable aid in these experiments. The salt employed is tungstate of calcium and it is so powerful that with a satisfactorily working tube it will show a noticeable fluorescence at a distance of *over thirty feet.* Those who have struggled with barium-platino-cyanide screens will appreciate fully Mr. Edison's improvement. This fluorescent screen was employed successfully for three distinct purposes. First, to study the operation of the vacuum tube under various conditions; secondly, to shorten the time of exposure in photography; and thirdly, to study the phenomena of diffuse reflection.

The most Efficient Working of the Tube—The Critical Temperature. The tubes employed were an old pear-shaped Crookes tube with a cross and several pear-shaped German tubes, imported sometime ago by Eimer & Amend, of New York. They all had discs at each electrode. Very satisfactory tubes are also being made now at the lamp works of the General Electric Company at Harrison, New Jersey. These were also employed in my experiments with completely satisfactory results. No fresh tube works quite satisfactorily with a powerful coil and a rapid rate of interruption; it heats too much, and the vacuum becomes thus rapidly impaired and the intensity of the Röntgen radiance is very much diminished. This is true even of larger tubes. Each new tube must undergo first an electric treatment. I have described this matter at some length at the meeting of the Academy on March 2d. Since that time I have investigated it more fully and brought it to a satisfactory termination. Mr. Tesla has also in the meantime discussed this matter, but in what appears to me to be a somewhat fanciful way. He imagines that the vacuum of a Crookes tube becomes more and more attenuated by the passage of current through it on account of the expulsion of the gas through the walls of the bulb. He maintains that he even succeeded in piercing electrically a small hole in the tube through which the gas from the vacuum was expelled with so enormous a velocity as to prevent the outside air from rushing in. This marvelous experiment does certainly support Mr. Tesla's favorite molecular bombardment theory, but it seems to leave us with the gloomy propect of having to refill our tubes from time to time with a fresh vacuum. The following experiments, however, lead to the conclusion that this necessity will probably never arise and that Mr. Tesla's interpretation of the cause of variation of the vacuum during the discharge is probably wrong. The electrical treatment of the tube is simply this: Pass a sufficiently strong current until the tube becomes so hot as to lose much of its Röntgen radiance. Stop then and let it cool. Repeat the operation and observe that after each operation the vacuum has gone up and that the Röntgen effect becomes stronger. It is not advisable to drive the vacuum much beyond the sparking distance between the electrodes on the outside. But even if this point has been reached then a judicious application of the Bunsen flame to the tube will enable the coil to force and maintain a strong enough current through the tube so as to heat it gradually, which increases the facility with which the discharge passes through the tube. The fluoroscope tells us that there is then a perfectly definite temperature at which the tube will work most efficiently and it is desirable to operate the tube at this temperature. This can be easily done by directing currents of air against those parts of the tube where it heats most, that is, against the parts opposite to the electrodes. By a suitable regulation of the air currents and a careful watching with the fluoroscope the tube can be kept steadily at the temperature of its highest efficiency for hours. A deviation above or below this point will produce a very large diminution in the Röntgen effect. This temperature of highest efficiency is so sharply defined that it looks very much like a critical point in the discharge. Below this temperature the discharge is in straight lines from the cathode and the portion of the glass opposite to the cathode fluoresces much more intensely than the rest. Above this temperature the discharge begins to spread in all directions from the cathode and the whole tube fluoresces strongly. There is then considerable flickering until the temperature is sufficiently above the critical temperature. The tube heats then rapidly and a yellowish mist begins to rise from the anode. As soon as the air blast begins to cool the tube this mist begins to clear away and the whole tube regains a clear transparency. If the tube is made too cool the discharge becomes too faint; there is very little heating because the coil fails to force a strong enough current. The Bunsen burner will assist the coil then to force a sufficiently powerful discharge again. The blackening of the tube by the disintegration of the electrodes seems to be the only thing that will determine the length of its life.

The Combination of a Fluorescent Screen with a Photographic Plate. Photography at a Long Distance from the Tube and through the Heavier Parts of the Human Body.—With an arrangement of apparatus as described above it was found possible to produce very much stronger photographic effects, but not sufficiently strong for penetration through the thigh and the trunk of the human body at reasonably short exposures and at long enough distances from the tube to obtain the desirable clearness in the pictures of these massive parts. A completely successful application of Röntgen's beautiful discovery to surgery depends for the present on a successful solution of the problem just mentioned. I have obtained one satisfactory solution with the method which I first described before the Academy on March 2d. It consists in placing in contact with the photographic plate a fluorescent screen and thus transforming most of the Röntgen radiance into visible light before it reaches the sensitive film. Photographs of the hand were thus obtained at a distance of twenty-five feet from the tube with an exposure of half an hour. At the distance of four inches the hand can be photographed by an exposure of a few seconds. It was in this manner only that I succeeded in photographing on a single plate the whole chest, shoulders and neck of my assistant, with an exposure of seventy minutes and at a distance of three feet between the plate and the tube. The collar button and the buttons and clasps of the trousers and the vest show very strongly through the ribs and the spinal column. This result seems to prove beyond all reasonable doubt the applicability of radiography to a much larger field in surgery than was expected a few weeks ago.

Diffuse Reflection of the Röntgen Radiance.—The question of reflection and refraction of the X-rays is a very important one. It was discussed by Prof. Röntgen in sections 7 and 8 of his original essay. Neither by photography nor by the fluorescent screen could he detect an appreciable refraction with certainty. A reflection from metallic surfaces in the immediate vicinity of a photographic film was detected, "but," quoting Röntgen's own words, "if we connect these facts with the observation that powders are quite as transparent as solid bodies and that, moreover, bodies with rough surfaces are in regard to the transmission of X-rays, as well as in the experiment just described, the same as polished bodies, one comes to the conclusion that regular reflection, as already stated, does not exist, but that the bodies behave to the X-rays as muddy media do to light."

In face of these observations made by Prof. Röntgen, Prof. Rood's and Mr. Tesla's experiments must be interpreted as a confirmation of Prof. Röntgen's results, and not as a demonstration of the existence of a regular reflection. If I understand Prof. Rood's words correctly, no claim is made by him of a discovery of regular reflection; for he says: "These facts and the character of the deformations point very strongly to the conclusion that in the act of reflection from metallic surface the Röntgen rays behave like ordinary light." Mr. Tesla, however, infers with much confidence regular reflection from his theory of bombardment. His experimental method is the same as that of Prof. Rood; that is, he places a reflecting plate at an angle of forty-five degrees to the direct ray and then places the photographic plate at right angles to the direction in which the reflected ray should pass if regular reflection existed. On account of the greater power of his apparatus, his time of exposure was one hour, whereas that of Prof. Rood was ten hours. It is evident, however, that an effect upon the photographic plate does not prove the existence of regular reflection, as Mr. Tesla maintains with much assurance and with much rejoicing over the realization of the prophesy which he made, inspired by his molecular bombardment theory.

In my experiments on reflection I aimed at getting rid of the photographic plate and substituting the fluorescent screen in its place. Two conditions had to be fulfilled to make this substitution possible. First, a very powerful and perfectly steady discharge had to be maintained. Secondly, a very sensitive fluoroscope had to be employed. The first was accomplished by the apparatus and the operations described above. The second was found in Mr. Edison's tungstate of calcium fluoroscope. The tube was placed between two thick planks of pine coated with sheet lead $\frac{1}{16}$ of an inch thick. This screening was found to be somewhat insufficient when the tube operated at maximum efficiency and another screen consisting of a thick copper plate had to be employed. The planks were placed so as to form a wedge around the tube. The cathode streamer was horizontal and passed through a vertical slit formed by the edges of the two screening lead-covered planks. In front of this slit was a fixed pivot on which a mirror could be rotated. The mirror consisted of a polished sheet of platinum pasted upon a rectangular piece of pine board of nearly the same area as the platinum sheet and about one inch thick. The slit was made $\frac{1}{16}$ in. wide and its image examined was by means of the fluoroscope. The tube was six inches from the slit.

a. Quite near the slit the image was sharp and intense. But as the fluoroscope was gradually moved away from the slit its image broadened out somewhat, and there was at each side of it a diffuse border. At about two inches from the slit the image of the slit looked like a wide spectral line upon the less luminous background of a wide band which shaded off gradually into the dark space of the screen. With increase of distance the relative intensities of the two grew more and more equal, and at about six inches from the slit the whole fluorescent screen (about 6 inches by 4 inches) was uniformly illuminated. There was evidently a diffuse scattering of the X-rays in their passage through the air. This inference was confirmed by other experiments which will be discussed presently. Various well-known devices were employed to concentrate the cathode rays along the axis of the tube. So, for instance, wrapping tinfoil around the tube. This, however, did not diminish the gradual diffusion of the image of the slit on the fluorescent screen when the distance between the slit and the fluoroscope was gradually increased. Up to about three inches from the slit the real image of the slit could still be distinguished easily from the diffuse background as a band of maximum intensity.

b. The platinum mirror was now placed quite near the slit and at a convenient angle to the direction of the ray, and the fluoroscope was placed quite near the mirror. There was a faint illumination of the fluorescent screen, but it was perfectly uniform. Not the slightest indication of an image of the slit could be detected, although the distance between the slit and the mirror plus the distance between the mirror and the fluorescent screen was less than the distance at which the image of the slit on the fluorescent screen appeared as a band of maximum intensity when observed directly. A change in the angle of the mirror produced but a small change in the fluorescence of the screen, and then the change seemed to be such as to approach a maximum when the mirror and the fluorescent screen were parallel to each other. The same experiment was repeated with other metals and with the same result. This experiment, therefore, does not speak in favor of regular reflection.

c. Turning the mirror completely around, so that the face of the wooden block on which the metal plate was fastened served as a mirror it was found that the fluorescent effect upon the screen was stronger than with the platinum. A pad of paper of about the same size as the wooden block acted more strongly than the platinum or any other metal. Various substances were tried, like glass, vulcanite, the hand, various metals, and they all produced a diffuse reflection of varying intensity, and at all angles of inclination. In all cases the maximum effect seemed to take place when the broadest side of the reflecting object was about parallel to the fluorescent screen. But the fluorescence was very weak as long as the slit was narrow.

d. The slit was now made wider, and the same series of experiments were repeated with various widths of the slit. The fluorescence of the exploring screen increases, of course, with the width of the slit. The observations made with the narrow slit were confirmed. In every case the maximum intensity on the exploring screen was obtained when the broadest side of the reflecting object was about parallel to the screen. Wood and transparent insulators produced a stronger effect than metals. No accurate quantitative comparisons have yet been made. Among the insulators experimented with, wood produced the strongest effect, and among the metals aluminium is the weakest for the same thickness of the plate. The thickness of the reflecting plate increases the effect; this increase will go on until the reflecting plate is several inches thick if this plate is an insulator. In the case of metals, however, like sheets of iron or copper, the change in the fluorescent effect due to the diffusely reflected radiance ceases as soon as the reflecting plate becomes thick enough to be practically opaque to the direct ray.

e. The human body when in the path of the X-rays will act as a reflector. It is quite an easy matter to detect a person walking across the room in the vicinity of the slit, for as soon as a person crosses the path of the X-rays the fluoroscope will light up. While making this particular observation I noticed that when the tube was operating especially well a faint fluorescence was still present even if no reflecting body was in front of the slit. Precautions were observed to exclude any radiance that might reach the fluoroscope directly by a sort of diffraction around the edges of the slit, but still the fluorescence in the fluoroscope persisted. There was evidently a diffuse scattering of the Röntgen radiance in the air itself. This, however, is so small that it is distinctly noticeable only when the tube operates so powerfully that a strong image of the hand on the fluorescent screen can be obtained by the radiance reflected from a pine board two inches thick and 16 inches square, placed at a distance of six inches from slit. With a good sized tube of proper vacuum and working at the temperature of highest efficiency this intensity is not at all difficult to obtain, provided, of course, that one has sufficient electric power to excite the tube.

These experiments prove beyond all reasonable doubt that the Röntgen radiance is diffusely scattered through bodies, gases not excepted. We may call it diffuse reflection, if we choose, provided that we do not imply, thereby, that we must necessarily assume an internal inter-molecular regular reflection, in order to explain the phenomenon. For if a puff of smoke be forced through a pile of wood some of it will come out pretty well scattered, although we cannot speak here of a reflection in the ordinary sense, but rather of deflection, reserving the term 'reflection' for those particular cases in which the angle of incidence is equal to the angle of deflection. It might turn out, for instance, that the X-rays are due to a circulating motion of ether and that the stream lines are deflected and diffusely scattered within the molecular interstices of ponderable substances. Appearances seem to speak more in favor of this view than in favor of a wave motion of ether.

The diffuse scattering of the Röntgen radiance by bodies placed in its path may be also described by saying that *every substance when subjected to the action of the X-rays becomes a radiator of these rays*. This statement will be more complete than the statement that a diffuse reflection takes place, if my observation should prove correct that the maximum effect in the fluoroscope is obtained when the largest surface of the body, acted upon by the Röntgen radiance, is placed parallel to the fluorescent screen. For in that case there is actually secondary radiation due to the diffuse scattering which proceeds normally to the surface of the intercepting body.

The fact that opaque bodies like metals are less effective in producing this secondary radiation leads to the conclusion that there is in these bodies an internal dissipation of the Röntgen radiance much greater than in the case of transparent dielectric substances. A properly constructed bolometer should give us much information on this point, and it is my intention to take up this subject as soon as time and facilities will permit.

These diffusion effects, which are present even in air, bring the Röntgen radiance into still closer resemblance to the principal features of the cathode rays which were studied by Professor Lenard. The difference in their behavior towards magnetic force is still to be explained. Is it not possible that this magnetic effect in air is masked by the diffuse scattering of the X-rays?

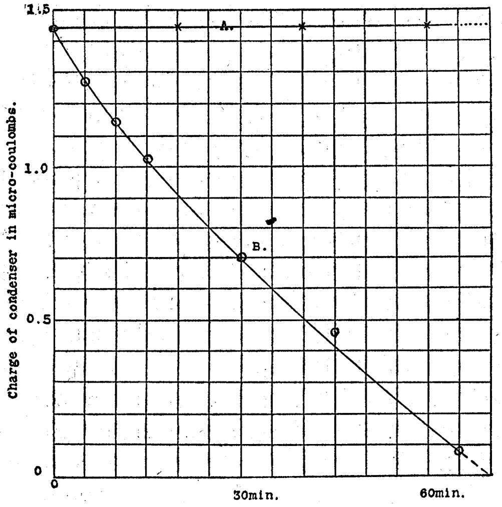
In conclusion I wish to observe that among the several theories proposed to account for the properties of the X-rays we may insert one which can be easily inferred from the somewhat neglected essay which the late Prof. v. Helmholtz wrote toward the closing days of his life. It is the essay, 'Inferences from Maxwell's theory concerning the motion of pure ether' (Wissenschaftliche Abhandl. B. III., p. 526, Wiedem. Am. Vol. LIII., p. 135–143).

M. I. Pupin.

Columbia University, April 2, 1896.

A METHOD OF DETERMINING THE RELATIVE TRANSPARENCY OF SUBSTANCES TO THE RÖNTGEN RAYS.

The fact that the Röntgen rays have the power of dissipating the charge of a perfectly insulated electrified body was established by Professor J. J. Thompson,* and furnishes us one of the simplest methods of detecting the rays. This effect is the basis of a very simple method of making quantitative measurements of the intensity of the radiation. If we take a condenser and allow the Röntgen rays to fall upon it, we shall find that there is a very considerable diminution in its insulation resistance, and that the charge of the condenser is gradually dissipated. This is illustrated by the



Time between charging and discharging condenser.

curves A and B in the accompanying figure. A was obtained under the ordinary conditions. B was obtained when the Crookes tube was in action, and placed about six inches from the wooden side of condenser. The curve A was determined before, and again immediately after the determination of B. The two determinations of A were identical, showing that the effect of the Röntgen ray on the insulation disappeared with the cessation of the ray. In making these measurements a Nalder micro-farad condenser was used, the condenser being charged with a standard Clark cell. It is evident, therefore, that it is possible to compare the transparency of different substances by allowing the rays to pass through screens made of the substances and placed between a Crookes tube and the condenser and measuring the resulting leakage of the condenser.

I am now engaged in making a series of measurements, using this method and a condenser especially constructed for the purpose, and hope to give the results in a subsequent number.

It would seem that the method is capable of giving results much more quantitative in character than any that can be obtained by photographic methods.

Wm. Lispenard Robb.

Trinity College, March 25, 1896.

*London Electrician, February 7, 1896.

AN APPARATUS FOR THE STUDY OF SOUND INTENSITIES.

The study of sound intensities presents many difficulties to the physicist as well as to the psychologist; the determination of the equality of loudness of two sounds, as well as of the law of relation between the physical cause and the sensational result is perhaps the most serious one. The facts that sounds must be estimated successively and should be of a constant intensity from beginning to end further complicate the problem. The method of the falling ball has been most frequently used; it consists in dropping a ball successively from two different heights and recording the minimum difference in height necessary to