MINOR CONTRIBUTION.

A Résumé of the Experiments Dealing with the Properties of Becquerel Rays.

By Oscar M. Stewart.

The literature on Becquerel rays is quite scattered, consisting of a large number of articles, only a few of which are in English. Knowing this and believing the subject deserving of more attention than it has received, it has been thought advisable to give here a summary of the present state of our knowledge of the subject, together with its bearing on the subject of X-rays.¹

The discovery of X-rays and the use of fluorescent screens with them aroused a greater interest in fluorescence and phosphorescence. This increased interest and the use of fluorescent and phosphorescent screens with photographic plates led to the discovery that some of these chemicals emitted a sort of invisible radiation. An effect from several different chemicals was noticed, but the radiation from uranium and its salts differs from the rest, as will presently be seen. Becquerel rays, or uranium rays, as Becquerel himself called them, are the rays given off from metallic uranium or any of its salts. This radiation at first appears to be a phosphorescence. Sylvanus Thompson² has suggested the name of 'hyper-phosphorescence' for it and allied phenomena.

Becquerel rays occupy a unique position, inasmuch as far more is definitely known about them than any of the other 'new' 'rays.' With X-rays nothing has been proven one way or the other about their character, save that if they are ultra-violet rays their wave-length must be extremely small, so small that the refractive index for nearly all bodies is practically unity. With the rays of Becquerel there can be no reasonable doubt that they are short transverse ether waves.

A great deal of the work that has been done with the radiation from fluorescent salts has been done with the aid of photography. It is well to state at the outset that, as is now rather well known, photographic results are often misleading. Many cases where a radiation was thought

² Philosophical Magazine, s. 5, 42, p. 103.
to exist can be explained by a chemical effect, either direct or resulting
from the vapors given off by the salt when laid on or near the pho­
tographic plate. Much interest was excited but a short time ago over a
supposed invisible radiation from glow worms. The discoverer\(^1\) has lately
announced that the effect was in some way due to moisture, it being
necessary to keep the glow worms wet. Moistened paper gave the
same effect that the glow worms had. In this last article the authors call
attention to some similar but anomalous phenomena of pseudo-radiation
from cadmium oxide, which can not be entirely explained by the chemical
action of a vapor. It has been announced in several places that freshly
cleaned zinc gives a radiation which will affect photographic plates.
M. Colson\(^2\) has shown that magnesium and cadmium give the same
effect, and that the action is due to a vapor given off by the freshly
cleaned surfaces. In some cases cited in this paper where a radiation
from some chemical is said to have been found, no detailed statement
has been made of the experiment so that it is not possible to draw any
conclusion in regard to their reliability.

In the early part of February, 1896, Charles Henry\(^3\) published the
statement that sulphide of zinc augmented the photographic effect of light
and X-rays. He claimed to have found that if he covered an object
with this sulphide the photographic effect of X-rays was increased,
showing that bodies partially opaque to X-rays became less so when
covered with this zinc sulphide. This he regarded as a "new proof of
the complexity of the radiations emitted from a Crookes' tube." He
found that this sulphide when exposed to magnesium light or daylight
acted photographically through black cardboard and aluminum. For
diffused daylight the exposure was from three to five hours. A week
later Niewenglowski\(^4\) published the statement that commercial sulphide
of calcium emitted radiations which traversed opaque bodies. Becquerel,\(^5\)
two weeks later than Henry, announced that this statement might be ex­
tended to other phosphorescent bodies, in particular to the salts of uranium,
in which the phosphorescence is very short. He wrapped a photographic
plate with two thicknesses of heavy black paper such that the plate was
not fogged by an exposure to the sun for a day. He placed on the sheet
of paper the phosphorescent material, double sulphate of uranium and
potassium, and exposed it to sunlight for some hours. On developing
the plate a silhouette of the substance appeared in black on the negative.
When a coin or any metallic screen was interposed, shadows of these ap­
peared on the plate. The effect was still obtained when a piece of glass
was interposed, which prevented a direct chemical action.

\(^1\) Muraoka and Kasuya, Wiedmann's Annalen, 64, p. 186, 1898.
In his next article he states more about this compound. The visible phosphorescence is very bright, but its duration is less than one one-hundredth of a second. Continuing the experiments first described he placed a plate in a frame wrapped in black cloth and closed on one side by a plate of aluminum. When exposed to full sunlight for a day the plate was not fogged, but when some of the uranium salt was placed on the aluminum plate and exposed to the sun for some hours, the photographic action was marked. If the aluminum plate was a little thick, the action was less than across two sheets of black paper. Between the salt and the aluminum plate was placed a screen of copper, 0.1 mm. thick, in the form of a cross. This gave a distinct shadow, but showed that the copper plate was partially transparent.

One day he had prepared several plates in this way, with a screen and some of the crystals on it, but as the day was cloudy and the sun appeared only occasionally, he put the plates away in a drawer all prepared. Unfortunately, as he then thought, it remained cloudy. After waiting for several days he developed the plates, expecting to find perhaps a feeble image, but was surprised to find that the images appeared with great intensity. He found in this accidental way that it was not necessary to expose the crystals to sunlight or daylight. Crystals laid on plates affected the plates when they were left in a dark room. It must be remembered that these phenomena could not be attributed to the visible phosphorescence, as the latter lasted only about 0.01 sec.

Becquerel at first said that he thought that these invisible radiations were due to a phosphorescence, the persistence of which was much greater than the duration of the visible phosphorescence. If the radiation is a phosphorescence, it ought to be stimulated by exposure to light. This was found to be true for daylight and the light from an arc lamp, but magnesium light and X-rays produced no increase. On the other hand he obtained radiations from uranium salts which were neither fluorescent nor phosphorescent so far as is known.

Nitrate of uranium ceases to phosphoresce or fluoresce when dissolved. To further test the relation between these invisible radiations and the phosphorescence, Becquerel took a crystal of this salt and placed it in a tube. It was warmed in the dark, being carefully protected from the radiation from the alcohol lamp. After the salt had dissolved, he permitted it to crystallize, still keeping it in darkness. When placed on a photographic plate covered with black paper it acted strongly on the plate. The solution of uranium nitrate although not fluorescent, also emitted these invisible radiations.

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1 C. R., 122, p. 501.  
2 C. R., 122, p. 691.  
3 C. R., 122, p. 766.  
4 C. R., 122, p. 691.  
5 C. R., 122, p. 691.  
6 C. R., 122, p. 765.
As the rays were given off by the salts of uranium whether they were fluorescent or not, he was led to the conclusion that it must be a property of the metal. He found, on testing, that metallic uranium gave the effect with about four times the intensity obtained from any of the salts he had used.

Although this seems to be a phenomenon of invisible phosphorescence, it is evidently not intimately connected with visible fluorescence or phosphorescence. Further, if it is a phosphorescence, uranium is then the only metal known to give it.

Using the double sulphate of uranium and potassium and metallic uranium, Miethe confirmed Becquerel's observations showing that the rays would transverse aluminum.

**Duration of the Radiation.**

When Becquerel discovered that the uranium salts did not need to be exposed to light to give off this radiation, he put some samples away in the dark and tested them from time to time. The results were announced in the Comptes Rendus in his various articles. But it is only the later ones that interest us. Salts which had been kept in darkness for six and some for eight months showed no sensible diminution of their emissive properties. Some of these salts had been sealed in glass tubes and kept in boxes of lead, where all known radiation, except from the sides of the box, was excluded. Still later he announced that the salts which he had kept in darkness for more than a year, all known radiation being excluded, continued to give these rays with an intensity scarcely decreasing (à peine décroissante).

The emission of some of the salts which had been kept in obscurity for two months, when exposed to the sun, or better, to the light from an arc lamp or electric spark, was slightly increased, but in a few hours it was back to its normal state.

The source of the energy radiated from uranium kept in darkness is at present unknown.

Elster and Geitel have confirmed Becquerel's work on the duration of the emission of the radiation from uranium.

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1 C. R., 122, p. 1086.
2 These comparisons were made with an electroscope. The method is here described later. The uranium used was chemically pure having been prepared by M. Moissan.
4 C. R., 123, p. 856.
5 C. R., 124, p. 803.
6 C. R., 122, p. 1086.
Reflection and Refraction.

To test the character of these rays Becquerel began a series of experiments which were quite successful. He was eventually able to show reflection, refraction, and polarization. Owing to the extreme feebleness of these rays it was entirely out of the question to show diffraction.

On a plate was placed a layer of the double sulphate of uranium and potassium, and placed over the top of half of this was a polished steel mirror with its face down. The plate, when developed after an exposure of fifty-five hours, showed a difference between the two halves indicating that the steel mirror had reflected the rays. A hemispherical mirror was polished from a block of tin and regular reflection was obtained with exposures of forty-six hours.

Owing to the feeble intensity of the radiation, he was at first unable to detect refraction, but later experiments were successful. On one face of a prism of crown glass was fastened, parallel to the refracting edge, a glass tube of about 1 mm. diameter. This tube was filled with nitrate of uranium and formed a linear source. The prism was laid with the other face on a photographic plate. After an exposure of three days the plate showed a refraction of about the same magnitude as that obtained with ordinary light. No determination could be made of the refractive index of the prism for these rays.

To protect it from moisture some nitrate of uranium had been put in a bell-shaped glass tube one end of which had been sealed with paraffin to a thin glass plate. This was placed in an upright position on a photographic plate. The negative showed plainly that the rays had been refracted and totally reflected in the glass tube in the same way that light follows a liquid vein of water. This effect was also obtained from calcium sulphide. Becquerel said: "If the phenomena of reflection and refraction had not been shown in any other way it was clearly shown by this proof alone."

The fact that pulverized glass seemed transparent was apparently contradictory. In fact, the photographic plate was affected more under the pulverized glass than elsewhere. Becquerel made no attempt, so far as we are aware, to explain this anomaly. If this particular quality of glass with respect to air had a refractive index of about unity for Becquerel rays, when pulverized it should appear transparent. It may be noted that pulverized glass is transparent for X-rays.

Polarization.

Becquerel found that the rays could be polarized and that tourmalin showed dichroism. A piece of tourmalin, 0.5 mm. thick and with its faces

1 C. R., 122, p. 561.
2 C. R., 122, p. 693.
3 C. R., 122, p. 562.
4 C. R., 122, p. 766.
parallel to the optic axis, was cut in two, and the two pieces were laid on a photographic plate with their optic axes at right angles. A third piece of tourmalin, 0.88 mm. thick and also cut parallel to the optic axis, was laid on top of the first two in such a way that its axis was parallel to the axis of one of the pieces and perpendicular to that of the other. The photographic plate showed clearly the existence of dichroism, that is, the crossed tourmalins were opaque, while the part where the axes were parallel was transparent. This experiment showed double refraction, polarization, and the dichroism of tourmalin.

With X-rays the same tourmalins gave a negative result. This did not prove that the X-rays could not be polarized; it only showed that there was no unequal absorption of the two rays by tourmalin.

Discharge of an Electrified Body.

Becquerel found that, like X-rays and ultra-violet light, these radiations would discharge an electrically charged body. He used the electroscope of M. Hurmuzescu, which was surrounded by a metallic sheath for guarding against electrostatic action and had windows of yellow glass to keep out ultra-violet light. This electroscope would hold its charge for a long time, a month it is said. He replaced one of the yellow glass windows with aluminum, against the outside of which was placed the uranium salt. A slow discharge was then detected. A plate of the double sulphate of uranium and ammonium, 45 mm. by 25 mm., which had been kept in the darkness for five days, was placed under the gold leaves, the latter having been given a charge sufficient to cause a divergence of 12°. By watching the rate of discharge quantitative results could be obtained. Under these conditions it took from 21 to 25 minutes to completely discharge either a positive or negative charge.

Absorption.

Becquerel found that he could use the electroscope of Hurmuzescu to determine the absorption of different substances. Double sulphate of uranium and potassium dissipated a charge with a velocity 4.15 times as fast as when a plate of quartz, 5 mm. thick and cut perpendicular to the optic axis, was interposed. X-rays gave the ratio 15.7, showing that quartz was more transparent to Becquerel rays.

Two methods were thus available for testing absorption, namely, photography and the electrical discharging action. It was found by Becquerel that the following substances were rather transparent to the radiation from the salts of uranium: water; most solutions, even of metallic salts
such as copper nitrate, chloride of gold, and nitrate of uranium; an alcoholic solution of chlorophyl; paraffin; quartz; Iceland spar; and sulphur. Quartz is more opaque than Iceland spar. Uranium glass, a red glass, and a blue cobalt glass were more opaque. Copper was nearly as transparent as aluminum. Platinum of about one-third the thickness of a sheet of aluminum was about as transparent. Air was found to slightly absorb the radiation.

The absorption of these rays was compared to the absorption of X-rays and he found that most substances, particularly the metals, were more transparent to uranium rays than to X-rays.

Becquerel found with the electroscope that the absorption of these rays by two metals, platinum and aluminum, superimposed was less than the sum of the effects taken separately. This shows that the rays are not homogeneous. The heterogeneity of X-rays has been shown in the same way.

**Conductivity of Gases.**

In November, 1896, Becquerel added another important fact to our knowledge of uranium rays, viz., that they, like X-rays, impart to gases the property of discharging electrified bodies. His experiments were made with air and carbon dioxide. As has been already stated he had found that these rays discharged an electrified body. But now he found, as had been found with X-rays, that the rays seem to make the gas through which they pass a conductor and that this gas after being acted upon by the rays from metallic uranium would discharge an electrically charged body when brought in contact with it. Rays from the double sulphate of uranium and potassium gave the same result.

Becquerel found that metallic uranium, although conventionally insulated, would not hold a charge unless it was kept in a vacuum. He made some measurements to find the dependence of the rate of discharge of the uranium on the density of the surrounding gas. It was found to be for potentials of 15 volts proportional to the square root of the density. This should not be accepted as final, as the law probably depends a great deal on the potential. This is the law which Benoist and Hermuzescu proposed for the case of X-rays. But wide deviations from this law have since been found at lower voltages.

The analogy of the discharge of electricity from uranium to the discharge of negative electricity from metals by ultra-violet light is at once suggested. Elster and Geitel tested zinc, aluminum, and other substances

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1 C. R., 122, p. 693.  
2 C. R., 123, p. 857.  
3 C. R., 122, p. 763.  
4 C. R., 124, p. 438.  
5 C. R., 122, p. 705.  
6 C. R., 122, p. 926 and 123, p. 1265.  
which present photo-electric effects, i.e., a discharge of negative electricity by ultra-violet light, and found that they gave no radiation similar to Becquerel rays. Hence they conclude that photo-electric phenomena cannot be explained by a hyper-phosphorescence of the charged metals.

Becquerel’s last two papers deal chiefly with the dependence of the rate of discharge on the potential, the density being kept constant. For low potentials the law of discharge is identical with the law of cooling, that is the rate of fall of potential, \( \frac{dV}{dt} \), is proportional to the potential \( V \).

But for larger potentials the value of \( \frac{dV}{dt} \) increases very slowly with potential and tends toward a constant. This he finds can be expressed by the equation

\[
\frac{dV}{dt} \left( a + \frac{b}{V} \right) = -1
\]

where \( a \) and \( b \) are constants and proportional to the capacity of the discharging bodies. In different experiments \( a \) varied from 4.1 to 4.5 and \( b \) from 20 to 31.

It will be noticed that, although the gas seems to act as a conductor, for higher potentials it does not obey Ohm’s law. So far as any comparison can be made, all these results agree with the results which have been obtained with X-rays.

Beattie and de Smolan tested the rate of discharge of electricity by uranium and compared it with the discharge by ultra-violet light and X-rays. They also tested the rate of discharge from uranium in different gases and at different pressures. They found that the discharge by uranium, as with X-rays, was not proportional to the potential. Their results for this agree with those of Becquerel. They, like Becquerel, found that positive and negative charges were dissipated at the same rate and that the rate of discharge by uranium was not perceptibly increased when it was heated or exposed to the sun. It may be stated in this connection that they found that ultra-violet light discharged positive and negative charges at the same rate, “the positive or negative charge being reckoned from the steady electrometer reading which is obtained when the two quadrants of the electrometer are insulated and the ultra-violet light shining.” This result agrees with that obtained by Branly, but it has been contradicted by others.

They tested the rate of discharge for different potentials of an insulated piece of uranium in hydrogen, oxygen, carbon dioxide as well as in

1 C. R., 124, p. 444.
2 C. R., 124, p. 800.
4 See article by Merritt, “The Influence of Light upon the Discharge of Electrified Bodies,” Science, 4, pp. 853 and 890.
air. For all potentials the rate in air was less than in oxygen, and in hydrogen it was less than in air. The rate of discharge in carbon dioxide is greater than in hydrogen, but as its rate increases more rapidly with potential than air and oxygen, for high potentials the rate becomes larger than that for air or oxygen. In air for potentials of four and ninety-six volts the rate of discharge was nearly proportional to the atmospheric pressure. With hydrogen the rate of discharge was "at higher pressures somewhat approximately proportional to the pressure, at lower ones to the square root of the pressure." With oxygen the rate was approximately proportional to the square root of the pressure.

J. C. Beattie showed that the gas itself if near an electrified body became electrified when exposed to uranium rays. He placed an insulated piece of uranium inside of a metallic cylinder. The air from around the uranium could be drawn through an electric filter, an insulated tube of block tin filled with brass filings connected to an electrometer. When the cylinder and uranium were both grounded, the air acquired a slight positive charge. When the uranium was kept positively charged the air became positive even when the uranium was wrapped in aluminum foil or surrounded by paraffin and tin foil. When negatively charged the air became negative. The results clearly indicated a slight difference between the amount of negative and positive electricity given to the air, the positive being the larger, but the difference was of about the same magnitude as the charge obtained when both the cylinder and uranium were grounded. Uranium acetate and uranium nitrate were tested with the same results although the action was not so great. No increase in the electrification of the air was observed when ultra-violet light was allowed to fall on the acetate. When a piece of lead was substituted for the uranium no effect was obtained.

It had been shown that when X-rays passed between two insulated metals, these metals took on final charges equal to those they would have if connected by a drop of water. Beattie and de Smolan found the same effect with Becquerel rays. Righi in his earlier experiments found a similar effect with ultra-violet light. However, Beattie and de Smolan continued the study of this effect, using X-rays, ultra-violet light, and Becquerel rays. They found as Righi had in his later work that the potential difference of two metallic plates when exposed to ultra-violet light depended upon the distance between the plates. Hence the potential difference found could not be the contact electromotive force. With

X-rays and rays from uranium no change was detected when the distance between the plates was varied. The potential difference between two metals depended on the nature of the surface of the metals, that is, whether polished or not.

The difference of potential between two plates due to uranium rays when gases at different pressures were between the plates was tried by them. For hydrogen, oxygen, and air the potential difference at different pressures was approximately the same. They state that we are not warranted in saying that the difference of potential developed by X-rays and Becquerel rays is the volta difference between the electrically effective surfaces of the two metals. In the case of Becquerel rays the potential difference observed was in the same direction but larger than the potential difference obtained when the plates were connected by a drop of water.

The various phenomena connected with the action of X-rays on gases can be explained on the hypothesis given by J. J. Thomson and Rutherford\textsuperscript{1} and the same explanation holds for Becquerel rays. This theory assumes that the gas is in some way broken up into ions which can carry electric charges. In other words the gas becomes a sort of electrolyte.

**Formation of Fog.**

It has been shown by Wilson\textsuperscript{2} and Richardz\textsuperscript{3} that X-rays will cause a condensation of water in supersaturated dust-free air. Wilson\textsuperscript{4} has shown that the rays from the double sulphate of uranium and potassium produce the same effect. Sometimes only a light fog can be seen, while at other times a dense shower is visible. The effect of the gas will persist for some seconds after the radiation has been cut off. The same thing has been observed with ultra-violet light, but Lenard and Wolf found that there was no fog formation unless the action takes place in the neighborhood of a charged body so that there may be fine particles driven off from it to form the nuclei for the drops of water. Wilson, following the explanation of Thomson, thought that the ions in the dissociated gas form the nuclei for the formation of the drops of water.

**Thermo-luminescence.**

Hoffman\textsuperscript{5} found that Wiedemann's discharge rays would excite thermo-luminescence, that is, certain substances after an exposure to these rays would become luminous when heated. Borgman\textsuperscript{6} found that this thermo-
luminescence was excited also by X-rays and Becquerel rays. He used
a mixture of calcium sulphate and manganese sulphate. This mixture
gave no phosphorescence or thermo-luminescence after a long exposure
to an arc light. But the effect was very marked under the action of
the discharge rays coming from a spark of a Voss machine. For
Becquerel rays it took long exposures. When exposed for six days the
action was quite strong.

Excitation of Fluorescence.

P. Spies found that with the rays of Becquerel he could produce no
visible fluorescence, but that a fluorescence could be detected photographically. A sheet of bromide of silver paper was laid on a piece of fluor-
spar. This was then wrapped in black paper and exposed to the
radiation from uranium. The paper next to the fluor spar was very
strongly blackened. A lead plate placed between the bromide of silver
paper and the uranium would act as a screen.

F. Maack found that uranium rays which had gone through pulver-
ized resin (Kolophonium) acted more strongly on a photographic plate
than when the resin was not present. He thought that the uranium rays
were changed into less refrangible but more actinic rays. The latter he
found to penetrate cardboard with more difficulty than the former.

Radiation from Other Salts.

As has been stated Henry found that zinc sulphide, and Niewenglowski
found that sulphide of calcium, emitted rays which traversed opaque
bodies. Troost also published a note saying that he had obtained
shadowgraphs of metallic objects with a radiation from hexagonal blende
(zinc sulphide) rendered phosphorescent by magnesium light, and recom-
mended its use in the place of Crookes' tubes. Arnold found that Bec-
querei rays are emitted by zinc sulphide, fluor spar, mixtures of various
sulphides, and retene, but that many strongly luminescent solid solutions
send out no Becquerel rays. Steffani found that certain phosphorescent
substances give rays of short wave-length which pass through opaque
substances.

From a sulphide of calcium that luminesces blue and from another that
luminesces a greenish blue Becquerel obtained through glass and 2 mm.
of aluminum the strongest effects he had obtained up to that time. The

3 C. R., 122, p. 564.
5 Beibl., p. 916, 1896.
6 C. R., 122, p. 563.
rays were also shown to be capable of reflection. Hexagonal blende gave no effect. Later these sulphides failed to work and could not be revived by heating or cooling, or by exposing to daylight, magnesium light, or X-rays. Finally he excited the sulphides and hexagonal blende by sparks until they were strongly phosphorescent and still they failed to work. Troost had a similar experience with the hexagonal blende, finding that although new crystals were effective the old ones failed. No explanation has been given of this curious phenomenon.

McKissick obtained photographic effects through black paper from lithium chloride in solution, barium sulphide, calcium sulphate, quinine chloride, quinine sulphate, sugar, chalk, glucose, sodium, tungstate, sterein, uranium acetate, and ammonium phospho-molybdate. These substances were exposed to the sun for two hours and then put in the dark. The time of exposure of the plates varied from 48 to 72 hours. It has been found that black paper is not a sufficient protection against chemical action; whether any further precautions were taken is not stated by the writer.

The radiation from uranium and its salts differs from the radiation from other salts in the persistence of the emission of the rays when the substances are kept in darkness. On the other hand, the radiation from the sulphides of calcium resembles the uranium radiation in the fact that they can both be reflected and will both penetrate aluminum and glass. Further than this the relation between the two classes of radiation has not yet been determined.

Conclusions.

As these rays can be reflected, refracted and polarized there can be no reasonable doubt that they are transverse ether waves. Interference alone is left to be established to confirm this, but owing to the extreme feebleness and short wave-length it is doubtful whether it can be shown. The transmission of these rays by metals indicates that the wave-length must be shorter than any ultra-violet waves which have been obtained from any light source.

The radiation seems to be of the nature of a persistent phosphorescence. But the source of energy of this radiation is at present unknown.

These rays, like X-rays, are not homogeneous.

They have all the properties that X-rays possess, such as photographic action, exciting fluorescence, making gases conductors, augmenting the formation of fogs, and exciting thermo-luminescence. In every case the similarity is very striking. The principal difference we find between the

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1 C. R., 122, p. 693.  
2 C. R., 122, p. 766.  
3 C. R., 122, p. 694.  
4 Lond. Elect., 38, p. 313.
two is the absence of regular reflection and refraction of X-rays. When we remember that for very short transverse waves there should be no regular reflection or refraction, a very strong argument as to the character of X-rays is afforded. This leads us to the conclusion that X-rays are transverse ether waves, but very short, shorter than Becquerel rays.

Attempts to obtain diffraction and interference of X-rays have so far proved unsuccessful. But this does not warrant the statement that interference does not exist. If X-rays are extremely short waves, diffraction and interference will be obtained only with very great care, probably by methods better than now known.

There remains the subject of the polarization of X-rays. Polarization can be tested only by reflection or by unequal absorption of rays polarized in different planes. If any substance gives unequal absorption, it should also give double refraction. If double refraction exists, one, at least, of the indices will not be unity, and we should, therefore, have reflection. It follows that if no substance reflects X-rays, polarization cannot be tested. Therefore this failure to detect polarization cannot be used as an argument for its absence. The failure is only what should be expected from extremely short waves.

The similarity in the behavior of X-rays and Becquerel rays certainly presents a strong argument in favor of the theory that X-rays are short transverse ether waves; and, in the opinion of the author, it presents the strongest of the arguments in favor of this theory.

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