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MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Professor J. McKeen Cattell, Garrison-on-Hudson, N.Y.

THE ACTION OF RADIIUM, ROENTGEN RAYS AND ULTRA-VIOLET LIGHT ON MINERALS AND GEMS.*

THE purpose of this paper is to recount the results of our investigations as to the conduct of the gems and gem-material of the Tiffany-Morgan collection under the influence of Roentgen rays, ultra-violet light and emanations of radium preparations. By the courtesy of the American Museum of Natural History, we were permitted to make a careful study of the action of these agents upon the minerals in the handsome Morgan-Tiffany and Morgan-Bement collections. These undoubtedly are the most complete collections of authenticated minerals and gems on exhibition in the United States. The fluorescence and phosphorescence resulting from the action of ultra-violet light upon about 13,000 verified minerals were carefully observed. In addition to the above, we had an opportunity to submit selected stones from about 15,000 British Guiana diamonds and two particularly handsome diamonds (one being a tiffanyite) and several carbonadoes to these influences, the products of the most modern scientific investigations.

As there is no uniform meaning accepted for the term 'fluorescence' and 'phosphorescence,' in the outset we wish to emphasize our interpretation. Jackson would have

* Presented before the New York Academy of Sciences, October 6, 1903.

them meaning the same. Perhaps they are in reality the same phenomena; but in this paper by fluorescence we mean a luminosity, more usually evidenced by a play of color, lasting only during the direct influence of the exciting agent. By phosphorescence, we mean the emission or propagation of ethereal stresses, which affect the optical centers, producing light, white or colored, which persists after the removal of the cause. Substances may, therefore, be both fluorescent and phosphorescent.

The radium preparations of the highest activity used in these investigations became the property of the American Museum of Natural History through the liberality of Mr. Edward D. Adams, a member of the Board of Administrators of the Museum and of the New York Academy of Sciences. His gift of the necessary funds was applied to the purchase of one portion of radium bromide of 300,000 activity and another of 1,800,000; uranium being taken as the standard at 1. The preparations were obtained from the Société Centrale des Produits Chimiques at Paris. Unfortunately, although the order was authorized and material assured, it has been impossible to obtain the bromide of the highest strength in time for presentation at this meeting. The results here announced have to do with the radium of 300,000 and of 7,000 activity (chloride) and 240 (chloride) and of 100 radium barium carbonate. The compounds of lower activity were purchased by the authors.

The intense penetrative powers of radium preparations have been previously noted by numerous investigators—as the Curies, Strutt, Rutherford and others—mentioned later. The bibliography is so extensive that no effort is made to give all the references in this abbreviated paper. A remarkable illustration, almost startling, of its penetration was demonstrated with the following experiments: Radium bro-

mide of 300,000 activity was placed in a sealed glass tube contained in a rubber thermometer-holder, the top of which was tightly screwed down, and the whole placed in a water-tight tinned-iron box; over the box were placed, first, a heavy silver tureen 1.5 mm. thick, then four copper plates, such as are used for engraving, and finally a heavy graduated measuring-glass 10 cm. in diameter filled with water to a depth of 15 cm. A diamond was then suspended in the water and became fluorescent immediately. Whenever the tube with radium was withdrawn a distance of more than one meter, the fluorescence ceased, but was resumed on replacing the radium under the tureen. This experiment showed that the influence of the radium was exerted successively through glass, rubber, silver 1.5 mm. thick, four copper plates, glass 0.5 cm. thick, and finally 8 cm. of water.

With all these wonderful properties of radio-activity, there is yet a certain amount of discussion at the present time between the German and the French investigators. Some of the former say that radium of 300,000 activity seems to them improbable; and that no scientific man should take this expression seriously. They believe that if metallic radium is ever obtained its activity will not exceed 100,000. This view is reiterated by others, who also state that these activities are only surmised, that they are not accurately determined, and can not be sustained by definite measurements. Madame Curie unhesitatingly speaks of the difficulties attending accurate measurements of such high radio-activity.

Incidentally it may be well at this point to call attention to the complex nature of these radiations. While a number of researches from such physicists as Becquerel, Professor and Madame Curie, Meyer and von Schweidler, Giesel, Elster and Geitel, Villard and Rutherford have proved the

intricacies of the radiations of these radioactive bodies, without doubt the last named has given us the clearest conception of their nature. Professor Rutherford, as a result of his investigations, resolved them into three classes, which for convenience are designated α , β , and γ rays. They possess the following characteristics:

I. "The α -rays are very slightly penetrating, and appear to constitute the principal part of the radiation. These rays are characterized by the laws by which they are absorbed by matter. The magnetic field acts very slightly upon them, and they were formerly thought to be quite unaffected by the action of this field. However, in a strong magnetic field, the α -rays are slightly deflected; the deflection is caused in the same manner as with cathode rays, but the direction of the deflection is reversed; it is the same as for the canal rays of the Crookes tubes.

II. "The β -rays are less absorbable as a whole than the preceding ones. They are deflected by a magnetic field in the same manner and direction as cathode rays.

III. "The γ -rays are penetrating rays, unaffected by the magnetic field, and comparable to Roentgen rays."

From the experiments given above it appears that the γ -rays alone suffice to intensify the fluorescent properties of the bluish-white tiffanyite diamond.

While it is quite beyond the scope of this paper either to contribute much that is novel as to the real nature of radium or even to speculate thereon, some reference to a few of the numerous recent researches is essential for a clear understanding of a part of that which follows.

Professors Rutherford, Soddy and Dewar, and Sirs William Ramsay, William Crookes and William Huggins, with Lady Huggins, have obtained helium from radium preparations which are luminous in the dark. Professors Soddy and Ramsay have

obtained helium from thorium oxide, which is also radio-active, as first observed independently by G. C. Schmidt and Madame Curie. Indications are that the luminosity of radium has some relation with this stellar and telluric element and it has been intimated that its propulsion constitutes the α -rays. Professor C. Vernon Boys has even suggested that the tails of comets may be accounted for, perhaps, by the evolving of this form of radio-activity. W. E. Wilson and Joly have made the suggestion that the presence of radium in the sun might enter as an important factor in contributing to solar radiations.'

Radium preparations are to be had on the market from French and German sources which are *non-luminous*. We are not informed as to efforts to secure helium from this variety. We do know, however, that certain minerals, as willemite and kunzite, become strongly fluorescent and phosphorescent under the influence of luminous radium compounds. Further, as the result of experiment of one of us, we know that pulverized willemite immediately glows in the dark when in contact with non-luminous radium barium carbonate of 100 activity, as do also certain diamonds, and the minerals mentioned above.

Thorium dioxide does not become luminous in contact with the radium preparations we have been able to obtain, although Elster and Geitel state that a thorium oxide screen shows scintillating fluorescence even after positive electrification, similar to the zinc blende.

Why certain rays either alone or through their influence upon the surrounding media present the order of magnitude of visible light waves, we shall not undertake to say. It is quite evident, however, that particular substances, like the diamond, willemite, kunzite, etc., possess the power of 'stepping up or down,' as it were, the ethereal stresses propagated by the radium, so that visible

rays result, or the bombardment of electronic emanations produces such an effect. The luminosity can not be attributed solely to the α -rays, or helium, as thorium oxide does not respond (at least visibly to the eye unaided by magnifying lenses), unless it so happens that the helium exists in one radioactive body in a different form from that in the other. Further, we have tested a number of helium-bearing minerals and none responded to the strong radium bromide. It appears that the luminosity of such substances, so variable in their construction as those mentioned above, may be accounted for in a measure by the physical explanations adverted to; yet, the striking fact that four zinc compounds of totally different composition, willemite (zinc orthosilicate), zinc sulphide, zinc oxide and kunzite (which contains a fraction of a per cent. of zinc) all respond in the most pronounced manner to radium emanations, would indicate the presence of a new element, a 'radium-foil,' as it were, or some unusual combination of known chemical integers, which synchronize with the activities of this unique body, in fact radioactive responsive bodies. One is immediately reminded of the actinium that Phipson announced in the eighties as being present in zinc white. (This is not to be confounded with Debierne's actinium, resembling titanium, announced in 1898.)

Becquerel, as is well known, first observed that certain substances, without any previous artificial excitation, emit rays which affect a photographic plate in the dark. Non-luminous radio-active bodies readily give this evidence of the presence of 'Becquerel rays.' We have made a paint, composed of zinc sulphide and radium barium carbonate in linseed oil, for making prints directly upon sensitive photographic films. The exposures varied from thirty-five minutes to an hour, some being made through glass. This would indicate

the production of actinic rays and, furthermore, rays differing from those of the ultra-violet, the transmission of which are interfered with by glass.

Selected gems were mounted in paraffine blocks, held in wooden frames, obtained by pouring the hydrocarbon, after melting in a water-bath, into especially constructed boxes about 18 x 27 cm. and 1.5 cm. deep. The wooden bottoms attached to the frames by screws were readily removed. Each 'plate' was numbered by placing small hot wire nails on the paraffine. Where gems of the same species varied in color they were arranged according to the spectrum as far as practicable. Comparisons as to color effects could thus be had, but of course no comparison of penetrative effects, as the stones were of variable thickness. They were photographed in place.

These plates admitted of a careful comparative examination of the gems when subjected to the bombardment of the Roentgen rays produced by a Queen's self-regulating Crookes' tube with a twelve-inch spark coil. Many radiographs were also obtained with variable exposures, the iron markers adverted to, through their impenetrability, serving to identify the plates.

Perhaps no such complete collection has been studied in this manner, although Doelter in 1896 published a most interesting study of the conduct of some sixty-five minerals and other precious stones when subjected to the Roentgen rays. During the same year J. B. Cochrane published a very practical paper on the testing of precious stones by Roentgen rays. Without giving details, it may be said that their observations were verified, and in general, it was learned that the penetration of gem material by these rays is a matter of degree rather than kind, and sharper contrasts were obtained with certain precious stones when they were surrounded by metals, like gold or lead, than was had when they were

radiographed alone. The observations of the late Professor Ogden N. Rood on the deflection of Roentgen rays by crystal or cut faces were verified.

J. E. Burbank in 1898 published a work on mineral phosphorescence produced by X-rays. Of all the substances tried, he found 'in general minerals containing ores of the metals are non-phosphorescent' and that fluorite and calcite seemed most suitable for experimentation. J. Trowbridge states: "By them (X-rays) an electrical charge is communicated to fluorescent and phosphorescent substances. The resulting electrical energy, in being dissipated (by heat), produces the phenomenon of light" (see below). Thomas A. Edison directed the Roentgen rays upon some eighteen hundred chemical compounds, artificial and natural, seeking a fluorescent screen. Later (1900) Bary examined the conduct of a number of salts under the influence of Roentgen rays. "Those which become fluorescent belong, with the exception of uranium, to the families of the alkalies and alkaline earths. Similar results were obtained by exposure to the radiations from a radio-active metal supplied by Curie."

Robert Boyle in 1663 appears to have been the first to have made a truly scientific examination of the phosphorescence of diamonds, although the alchemist, Albertus Magnus, in the thirteenth century, said he had seen a diamond which glowed when it was put in hot water. Bernouilli remarked that when a diamond is rubbed on gold it becomes luminous 'like a burning coal excited by the bellows,' as Draper put it. 'A light, too, that cannot be extinguished by water, and yet so ethereal and pure that it can set nothing on fire' attracts the scientific imagination as much to-day as it did then.

Two hypotheses were offered in the eighteenth century in explanation of phosphorescence.

1. Léméry in 1709 maintained that phosphorescent bodies act like sponges to light, absorbing it and retaining it by so feeble a power that very trivial causes suffice for its extinction.

2. DuFay in 1735 held that it resulted from actual combustion taking place in the sulphureous parts of the glowing body. He first noted that the substance requires previous exposure to light; it glows in the dark with decreasing luminosity. DuFay also observed the effect of interposing colored glass between the phosphorescent body and the light.

In 1859 J. H. Gladstone exhibited diamonds strongly fluorescent in the sunshine. Silvanus Thomson used one of these diamonds in 1896 in a lecture on luminescence at the Royal Institution.

We are not offering a complete history of fluorescence or phosphorescence, nor explanations of these fascinating properties; but hints are given below which may serve to assist in their elucidation.

MM. Mascart and Chaumet examined a number of gems under the influence of violet light. One of us (K.), in 1889, with Mascart, and with Hallock in 1894, submitted bluish-white, opalescent diamonds (from Bagagem Mines, Brazil—tiffanyite) to electric light passing through glass of different colors.

Although, as will be mentioned, such compounds as alumina, alkaline earth sulphates and certain rare earth oxides, have been examined in vacuum tubes under the influence of electric sparks, we are not aware of any very extended examination of mineral or chemical substances when subjected to ultra-violet light produced by sparking. E. Becquerel in his 'La Lumière, ses Causes et ses Effects' states that 'the electric spark acts only by its light, but its action is more energetic than that of the sunlight by reason of its great intensity and the proximity of the source.' Wieder-

mann and G. C. Schmidt, in an article on luminescence, reached the conclusion that the *violet* light alone of the electrical discharge does not cause phosphorescence, which is 'due to peculiar discharge rays analogous to cathode rays.' M. W. Hoffman confirmed the above. J. Trowbridge reported, 'The action of the X-rays on this mineral (fluorite) was exactly similar to that of electrification,' and concluded that 'by them (X-rays) an electrical charge is communicated to fluorescent and phosphorescent substances.'

While there may be no question as to the above statements for the particular materials examined—and they are doubtless true for many other substances—yet in our observations there are some which do not admit of the sweeping conclusion that all fluorescent and phosphorescent phenomena observed in minerals subjected to rays coming from the sparking of high voltage currents with iron terminals are due to electrification.

The ultra-violet light was produced by a triple spark through quadruple iron terminals (we may so designate them) with a high voltage current. The direct current was taken from a 110-volt circuit passed through a Ruhmkorff coil with a 12-inch spark and stepped up by two Leyden jars in series. The sparker was provided with a quartz window surrounded by vulcanite and otherwise insulated to permit comfortable handling. As the number of observations to be made was very great, it was impracticable to remove each individual specimen from the exhibition cases and storage cupboards to the dark room, although this was done in many experiments. Flexible cables 200 feet long were joined to the apparatus. This was placed upon rollers and could be moved easily to the various aisles between the cases. The Pif-fard lamp was joined up with the apparatus by insulated wires, further protected

by rubber tubing, 36 feet long. About 13,000 minerals were thus examined by night.

A large mass of original material has been gathered, of which only a few general observations and tentative conclusions are here presented.

The three most responsive minerals to all three forms of activity were found to be willemite, kunzite and certain diamonds.

In a subsequent investigation with the still more rare and novel element actinium, the particulars of which will be given at the end of this paper, these same three minerals were found to respond markedly to that substance, though with some special features.

1. It was found that willemite from Franklin, N. J., is both fluorescent and phosphorescent with the Roentgen rays, ultra-violet rays and when exposed to radium emanations. These properties were retained, although in some instances the specimens were considerably altered by decomposition. Foreign specimens of the same species were not affected at all. The willemite retained its luminescence for more than twenty-four hours after it had been exposed to radium; the latter not being then within 100 feet of it. Willemite and diamond also responded to polonium that formed a coating on a bismuth rod.

Willemite has also been noted as triboluminescent, *i. e.*, emitting light upon attrition or percussion, even when it merely strikes the side of a glass in which it is suspended in water.

2. The calcite from Franklin, N. J., showed a distinct red glow with the ultra-violet rays. This mineral, as well as the associated willemite, showed very marked peculiarities of color, the willemite green and yellow-green, the calcite a red glow. These effects were so characteristic that it required but a moment to identify the

specimens in various parts of the collection as being from Franklin, N. J.

3. The gangue of all minerals from Pajsberg and Langban, Sweden, also showed this peculiar red glow; the limestone strikingly like the calcite from Franklin, N. J.

fluoresced with radium; those tested with magnesium light phosphoresced.

5. Hydro-zincite, from Algiers, showed a remarkable fluorescence, bluish in color, different from anything in the collection.

6. Autunite and another uranium mineral, from Mitchell County, N. C.,

Radio-active Minerals. Madame Curie's Table of Ampères, Intensity 1.	Kunz-Baskerville Observations on Phosphorescence or Fluorescence with	
	Ultra-violet Light.	Roentgen Rays.
Uranium	2'3	
Pitchblende from Johanngeorgenstadt.....	8 3	—
Pitchblende from Joachimsthal.....	7 0	—
Pitchblende from Przibram.....	6 5	—
Pitchblende from Cornwallis.....	1 6	—
Cleveite	1 4	—
Autunite	2 7	+
Sipylite	0 1	—
	0 3	—
Various thorites	0 7	—
	1 3	—
	1 4	—
Orangite	2 0	—
Monazite	0 5	—
Xenotime	0 03	—
Æschynite	0 7	—
Fergusonite (two samples).....	0 4	—
	0 1	—
Samarskite	1 1	—
Niobite (two samples)	0 1	—
	0 3	—
Tantalite	0 02	—
Carnotite	6 2	—
Columbite		—
Monazite		—
(171st St. and Washington Ave.)		
(Sand.)		
Polycrase	near	—
Euxenite		—
Portland, Conn.		—
Arendal, Nor.		—
Zlatoust, Ural.		—
N. Y. City.		—
Amelia C. H., Va.		—
Alexr. Co., N. C.		—
Rio, Brazil.		—
Tvedstrand, Nor.		—
Marietta, S. C.		—
Mitchell Co., N. C.		—

Column 1 is Madame Curie's list of rare minerals; 2 is K.-B. ultra-violet rays; 3, Roentgen rays. With one exception, neither of the latter shows any action.

4. All the minerals from Borax Lake, California—the cōlemanite, hanksite, glauconite, iddingsite and many others—with out exception phosphoresced with ultra-violet rays. The briefest exposure caused them to glow and to retain this luminescence for a considerable time; but none of these minerals either phosphoresced or

fluoresced wonderfully, while foreign specimens of the same species did not. Autunite appears to have two minerals present with it; one an orange and the other a lemon yellow; one pulverulent and the other in slight tabular crystals. The striking fluorescence obtained with ultra-violet rays was not produced

when glass, which is opaque to these rays, was interposed.

The yellow mineral labeled 'greenockite,' from Franklin, N. J., fluoresced in an identical manner, leading one to infer that this is itself a uranium mineral, or else contains the same substance that causes the autunites to fluoresce.

A comparative table is appended. It is self-explanatory and serves to illustrate the conclusions apparently inevitable, namely, the presence of something not previously recognized.

7. Hyalite (botryoidal), on a trachytic rock, from San Luis Potosi, Mexico, as colorless as the purest water, fluoresced most intensely, with a rich British green color; but these specimens did not phosphoresce. This green fluorescence could be observed when the source of the ultra-violet rays was five or six feet away. It did not persist on the removal of the source, but flashed in when the rays played upon it. The sparker held near, but without the rays playing upon the specimens, gave no fluorescent effects. Therefore, no other conclusion is tenable than that it is the ultra-violet rays that produce this change. The same remark may be made for many of the experiments carried on with the sparker as the source of the ultra-violet light, in the examination of these mineral substances. On the other hand, this hyalite neither fluoresced nor phosphoresced when exposed to the magnesium light, Roentgen rays or radium, in this respect behaving like the minerals from Mono Lake; no hyalites from other localities responded to any of these activities.

8. By the action of ultra-violet rays a number of fluorites both phosphoresced and fluoresced; some phosphoresced and did not fluoresce; some fluoresced and did not phosphoresce; and some did neither. Further, their color had apparently no influence in determining this result; it can not be

the fluorine or alkaline earth present that accounts for this variation, as artificial preparations gave negative results. It is more probably the presence of rare earths like yttrium and ytterbium. (A paper on this will appear.)

9. Chlorophane has long been known as a mineral very easily rendered luminous by heat. By some authorities it is stated, a century ago, that it was almost always luminous. This variety of fluorspar is found with other fluorspars—sometimes as a vein of purple between veins of green fluorspar. It proved very responsive to the ultra-violet rays. A variety from Amelia Court House, Virginia, became suddenly luminous from the heat of the hand.

This luminosity was lost upon further heating (about red heat) but the phosphorescent properties were restored in a measure by exposure to the Roentgen rays. Trowbridge has observed this with other fluorites (see above). The exquisite colored fluorescent properties were not regenerated however. Chlorophane is pyroelectric by attrition, and this peculiarity distinguishes it from the ordinary fluorites.

10. It was noted that gypsum from Sicily, when submitted to ultra-violet light, was from two to five times as responsive as specimens from Bavaria and other localities.

11. It was found that those topazes which had lost the sherry color—the tint so fleeting that some of the museums have been led to protect them from the light—showed no distinct phosphorescence with ultra-violet rays, while the unfaded crystals of that color responded, but no others.

12. Wernerite from New York phosphoresced, while specimens from foreign sources did not. Many apophyllites and calamines gave no response whatever.

13. Pectolite proved an exceptionally interesting mineral. Every specimen that was exposed to the ultra-violet rays showed

an active response; even some that were almost entirely altered to steatite. This is especially striking, as some of the specimens from New Jersey were loose delicate aggregates of needle-like crystals. Some were made up of crystals with a texture like felt; others of coarse crystals, and lastly the pectolite without any crystalline structure, homogeneous, and one time mistaken for jade, from Tehama County, California.

14. Wollastonite, whether from northern New York or associated with the rosolite garnet from Mexico, phosphoresced markedly, and with some duration, with ultra-violet rays, and responded strongly to radium (300,000).

15. Kunzite, the new variety of spodumene from Pala, California, when exposed to the action of radium of 300,000 activity for a few minutes, became wonderfully phosphorescent, the glow continuing persistently after the removal of the source of excitation. Six hundred grams of kunzite crystals were excited with 125 milligrams of radium bromide. Sir William Crookes in a personal letter, having repeated the experiment, remarks: 'I think this lilac variety of spodumene runs the diamond very close, if it does not surpass it sometimes.' Ultra-violet rays caused kunzite to phosphoresce for more than a minute. This remark applies to the faded or colorless kind; the highly dichroic appears to resist. All forms of kunzite become phosphorescent with the Roentgen rays. So pronounced is this, that a large crystal excited for five minutes afterwards affected the film of a sensitive photographic plate. A thirty-second exposure caused three cut gems to glow first golden pink, then white for ten minutes, 20 times the duration of exposure to the X-ray, the glow penetrating two thicknesses of white paper. Another crystal of kunzite, exposed to the Roentgen rays for ten minutes, was then laid on a sensitive plate for five minutes. The re-

sulting photograph was clear and distinct, but presented a very curious aspect not seen by the eye, as of a misty or feathery outflow from the side and termination of the crystal, suggesting an actual picture of invisible emanations. Kunzite is also pyroelectric, assuming a static charge, similar to topaz, when rubbed with a woolen cloth. It does not phosphoresce when heated.

16. The action of the quartz group was interesting. As a rule, quartz proper neither phosphoresced nor fluoresced with ultra-violet rays, allowing them to traverse it without any effect. Hence, the very few exceptions noted were doubtless due to the inclusion or intermixture of other substances. This was apparent in one or two cases of quartz pseudomorphs after barite and fluorite, which phosphoresced, evidently from the presence of some remainder of those minerals.

Chalcedonic quartz was also very unresponsive; one example only, from Uruguay, S. A., showing a bluish milky phosphorescence, and a specimen of agate in which one layer responded, between others that did not.

Opal, on the other hand, was frequently phosphorescent, very rarely fluorescent, and sometimes without any action. The variety quincite phosphoresced intensely, as did also specimens apparently pseudomorphous after gaylussite, which exhibited strong and long continued phosphorescence.

17. Among carbonates, calcite, witherite, strontianite and barytocalcite all phosphoresced; and aragonite, with occasional exceptions, was very marked in its action, far surpassing calcite. On the other hand, cerussite did not phosphoresce, save in a single specimen from Phoenixville, Pa.

There is here seen again the peculiar phenomenon noted in minerals from the Langban locality; and the suggestion is evident of the existence there, and at points where

similar exceptional results appear, as in Mono Lake, of the presence of some rare element (perhaps new) widely diffused in very minute quantities.

A similar indication is given by the behavior of the glauberite; those from Borax Lake, California, phosphoresced, as did those from Laramie and from Spain; while Chilian specimens did not.

18. It is notable that tourmaline, which is so markedly pyroelectric, gave no response; nor did beryl, save in three specimens from Haddam Neck, Conn.

19. American sapphires of various kinds, spinel, chrysoberyl, and almost all jades, declined to show any effects from ultra-violet rays. Most of the gem-minerals, except diamond, opal and kunzite, were little acted upon.

20. Only two of the rare earth oxides responded at all to the action of ultra-violet rays, namely, zirconium and thorium dioxides, which phosphoresced strongly. The thorium dioxide remained luminous in the dark for a greater length of time. The zirconium dioxide showed no radio-activity when tested by the electrical and photographic methods. It is strange that the two rare earths forming dioxides are the only ones to exhibit this property. The following oxides were examined: yttrium, ytterbium, erbium, gadolinium, samarium, lanthanum, cerium, neodidymium, praseodidymium, thorium, zirconium, titanium, uranium and variable mixtures of the same. They will be investigated further by one of us. (B.)

In view of the fact that these two earths give this characteristic response to ultra-violet rays, it became immediately of interest to learn the effect of these rays upon minerals carrying those substances in different proportions. The following selected minerals were subjected to the action of ultra-violet rays without a single

one of them giving either fluorescence or phosphorescence.

Samarskite.—Berthier Co., Que.

Thorite (Orangite).—Arendal, Norway.

Thorite.—Barkevik, Norway.

Thorite (Auerlite).—Green River, N. C.

Sipylite.—Amherst Co., Va.

Columbite.—Portland, Conn.

Monazite.—Arendal, Norway; Zlatoust, Ural; 171st St. & Washn. Ave., N. Y., Amelia Court House, Va., Alexander Co., N. C.

Monazite sand.—Rio, Brazil.

Monazite.—Tvedstrand, Norway.

Xenotime.—Cheyenne Cañon, Colo.; Alexander Co., N. C.; Hitteroe, Norway.

Euzenite (in Samarskite).—Mitchell Co., N. C.

Æschynite.—Hitteroe, Norway.

Polyerase.—Near Marietta, S. C.

Fergusonite.—Llano Co., Texas; Ytterby, Sweden.

TENTATIVE CONCLUSIONS.

1. It seems as though in willemite, hydrozincite and the artificial phosphorescent zinc sulphide and zinc oxide, there is present, with the zinc, some element probably not yet determined, that possesses peculiar properties; one that in combination with a zinc mineral gives the high luminosity by the application of radium, the ultra-violet rays, or the Roentgen rays or other radio-active bodies; an element possibly accompanying zinc and possessing an affinity for it, as polonium has for bismuth, perhaps Phipson's actinium mentioned above.

2. It seems likely also that there exists in fluorspar either yttrium or ytterbium, or some other related rare earth, or perhaps several of them, from the variable action of this mineral with the various kinds of rays.

3. In the case of the numerous minerals coming from Borax Lake, so various in composition and yet all responsive alike to ultra-violet rays, there seems to be present some element which is very highly active, but is not responsive to radium, and which appears in every single mineral

found here. This is evidently a substance not necessarily radio-active itself, but one that may possess the same or allied properties with the substance found with the zinc minerals.

4. The substance present in calcite, from Franklin, N. J., and from Langban and Pajsberg, Sweden, is probably yet another body, which also does not respond to radium; although the willemite found with it at Franklin becomes luminous at the approach of radium as if it were a fairy wand.

5. There probably exists in autunite, and another yellow-brown uranium mineral from Texas, a fluorescent substance which differs from anything that we have noted in the study of the minerals of the collection.

6. In the hyalite, from San Luis Potosi, a volcanic mineral, there is present something that responds with a beauty of color that strikingly reminds one of nitrate of uranium; this may be still another substance.

7. The most responsive of all, however, were the diamonds containing that peculiar substance that gives them what is known as the blue-white color—fluorescent like anthracene, and holding the luminosity for a long time—to which one of us (K.) gave the name of Tiffanyite.

In the examination of more than 15,000 diamonds from British Guiana and elsewhere, 44 were selected. After an exposure of 60 seconds to ultra-violet rays, these 44 diamonds phosphoresced brilliantly and continued to glow for a long time after exposure. The luminosity was so great that it penetrated one thickness of white velvet and from nine to twelve thicknesses of tissue and blue linen paper. But they did not exhibit their light through black velvet, nor apparently were they affected by the ultra-violet rays when surrounded by

black velvet. These diamonds when glowing brilliantly showed absolutely no action upon the barium platino-cyanide screen, nor upon screens of phosphorescent zinc sulphide, willemite or calcium sulphide.

The most remarkable specimen was a diamond of $14\frac{2}{3}\frac{1}{2}$ carats. (This was exhibited.) This stone possesses the power of absorbing sunlight and emitting it in the dark. An arc lamp will cause it to store up light and to give it out in the dark. Even a small hand-lamp of one candle-power has caused this diamond to phosphoresce. It responds to polonium, to the Roentgen rays and to the ultra-violet rays; to the rays that pass through a violet glass, and to radium, even in a more marked degree than willemite.

The print shown was made from a negative obtained by exposing a sensitive photographic plate to the blue-white diamond, and a transparent black stone of $16\frac{1}{6}$ carats, thin white paper intervening, after they had been exposed to ultra-violet light for one minute. The print is the result; except that the print of the black stone has been colored to show the reddish phosphorescence given out by it.

After another exposure of one minute, to our surprise, the black stone glowed red for fifteen minutes, almost surpassing the phosphorescence of the blue-white stone. At the end of fifteen minutes the red glow subsided, while the white stone phosphoresced five minutes longer; the light being held twenty minutes after exposure.

As stated above, from the work of Wiedemann and Schmidt, Hoffmann, and Trowbridge, it appears that the phosphorescent and fluorescent effects observed by the action of ultra-violet light, produced by sparking, with such metals as iron, is not due to this cause at all, but may be accounted for by the accumulation of an electric charge. The diamonds were

'grounded' by placing directly upon the iron radiator in the room and similar observations made, as when the precious stones were insulated.

It is interesting here to note that Marckwald reported the property of phosphorescence with polonium as belonging only to Brazilian diamonds. Rosenheim found that the rays from radio-active polonium possess the property of inducing fluorescence in a number of diamonds from different localities. The rays emitted by the diamonds under these conditions affect the retina and the photographic plate. "This actinic activity of the diamond," he says, "like its visible fluorescence, is entirely dependent on the presence of the polonium, not persisting after the removal of the latter. Even after long exposure to polonium rays no induced radio-activity could be detected." We found the fourteen and a half carat diamond from Brazil very responsive to the polonium; also some from British Guiana.

Almost all diamonds, of various weights and from many localities and of different colors, fluoresce and phosphoresce more or less with radium, except the black or carbonado. The degree to which these phenomena are observed is no criterion of the grade of the gem, however, as stones with flaws often fluoresced with even greater brilliancy than the pure ones.

8. It is quite evident through our study of the collection, that one or the other of these forms of luminosity and activity may have a value to detect elements or compounds that have escaped notice or are present in the minerals as impurities. These forms of investigation may also prove serviceable in chemical analyses. There should be a use for this line of research also in petrological determinations, as the slightest phosphorescence or fluorescence would aid in determining and locating a mineral, no matter how minute in

quantity. This we have done in several instances.

The original ultra-violet lamp was that of Gorl, of Munich, altered by the English into the St. Bartholomew lamp, and again improved and made practicable in the United States under the name of the Piffard lamp, after Dr. H. G. Piffard, of New York. It is an instrument of great utility and, in the convenient form with which we worked, can not fail to prove a valuable mineralogical and chemical as well as medical adjunct. In fact, Dr. Piffard has used it with much success in medical practice. It will also be useful in many instances for mineralogical determinations—at times to detect impurities which have escaped analysts and others.

9. In all observations on the effect of radium, ultra-violet light and the X-rays to determine whether an object becomes fluorescent or phosphorescent under the influence of either, it is essential that the eyes become thoroughly accustomed to the change of conditions when one is in a dark room. This usually requires from ten to twenty minutes, and in some cases half an hour. Attention has been called to this by preceding observers. Whether it be due to the accumulation of the visual purple, which von Kries states is a substance that supplies the retinal basis of vision at low luminosities, and whose accumulation is accountable for the great increase in sensitiveness of the dark-adapted eye, or to the ordinary physical changes in the optical lenses, or partly to both, we do not undertake to decide. But it was found to be advisable that just before the source of excitation was removed from the material examined, the eyes be closed, and not opened again until after the removal. Else, as was noted, the residual flash that remained might be mistaken for phosphorescence. In most of the experiments carried on, three observers watched each

test. When there was the least disagreement, the tests were repeated a sufficient number of times until a unanimous agreement was arrived at.

10. The Roentgen rays have been used with great success to locate fractures, misgrowths, deformities and abscesses in the bony processes; but as far as we are aware, little success has attended efforts to locate ruptures, growths, or peculiarities of the veins, intestines, etc., by this means. There seems a possibility, however, that if a highly fluorescent or phosphorescent substance could be injected into the veins, the stomach or the intestines, it would be feasible to locate lesions, growths and other peculiarities of these organs; possibly also to locate accretions and kidney or bladder concretions, especially calcareous, as well as, possibly, peculiarities in the structure of the heart and other organs. This it might be practicable to do by means of inert but phosphorescing materials in solution given in the food, or injected into the stomach or intestines when they are quite empty. It might be that a nearer location could be effected in the organs desired to be examined, if impalpable powders be given with the food. If it were possible to inject such a substance into the blood, the entire vein structure of the body might be rendered visible as well as the bony part. It seems not unlikely that such an active agent as radium or ultra-violet light may yet be found a great accessory in diagnosis and autopsies, as they have given promise of marvelous curative values in certain diseases.*

11. The final part of the work planned was an investigation of the influence of cathode rays upon gems and the gem material of these collections. The method utilized in the classical investigations of

* After presenting this paper we were informed that Dr. Morton and Mr. W. J. Hamner have investigations along these lines now in progress.

Becquerel, Crookes and de Boisbaudran, on the fluorescence and phosphorescence of a number of substances, especially alumina and the rare earths, in vacuo, and spectroscopic examination of the light emitted therefrom, offers possibly an answer to questions as to the nature of such substances as give tiffanyite its unique properties, for example. Small amounts may be used; the destruction of such valuable gems in chemical analysis being out of the question. The time at our disposal having been utilized in securing the observations briefly outlined above, we were forced to discontinue the research for a time, although a number of Crookes' tubes have been charged with material and exhausted. We hope to complete that phase of the undertaking, but confess, from what has been indicated above, that things have been seen that shine like a 'pillar of fire by night' and beckon us on.

12. From the summarized observations on minerals related above, it appears that there are evidently two properties recognizable—radio-activity and a property that responds to this activity. It is hence seen that we have two classes of bodies—radio-active, and those that are affected by radio-activity; and that these groups may be again divided into several minor divisions.

We seem to find here an analogy to certain well-known facts in electricity and magnetism; some bodies that are active and others that are acted upon in several different forms, which are evidently closely related, and yet are distinct in their modes of action. We are privileged, therefore, to offer for mineral substances a

TENTATIVE CLASSIFICATION.

Those minerals:

1. Not responding to radium, ultra-violet or Roentgen rays.
2. Responding to radium only.

3. Responding to ultra-violet rays only.
4. Responding to Roentgen rays only.
5. Responding to radium and ultra-violet rays (not to Roentgen rays).
6. Responding to radium and Roentgen rays (not to ultra-violet rays).
7. Responding to ultra-violet and Roentgen rays (not to radium).
8. Responding to radium, ultra-violet rays and Roentgen rays.

It is our purpose, further, to examine the same collections by the infra-red rays, for comparison with the ultra-violet; as it is quite possible that many minerals will give response of some kind with the infra-red that are not affected by the ultra-violet.

As for mineralogical determination, no large apparatus is necessary, as is used in medicine or for physiological investigations. In fact, very simple apparatus is sufficient. Therefore, we are devising a series of appliances such that the entire apparatus may probably be purchased for much less than one hundred dollars. And a photometer-like meter to measure the distance of penetration of the X-ray, the ultra-violet ray, and also the distance of the penetration of radio-active bodies.

We are also preparing a list of minerals, selecting those most readily obtainable, to illustrate these phases of activity or inactivity with the three useful accessories. For a small expenditure any school or college can obtain them for comparative study.

As the electric furnace has given us carborundum, artificial graphite and a series of absolutely *new* carbides, because with it we have attained temperatures of a height unknown before its introduction; and as the production of low temperatures has resulted in the liquefaction of all known gases and assisted in the discovery of new ones; so perhaps the application of these forms of energy may give us the means of identifying substances that have escaped all our earlier methods of observa-

tion; and it may be that we shall find a new series of elements. We are clearly on the threshold of a new field of scientific facts and perhaps generalizations and laws, which may yield results in the twentieth century as interesting and remarkable as the electrical discoveries were in the nineteenth. Indeed, some have already discarded atomic chemistry and assumed ionic chemistry, while pioneers like Crookes, J. J. Thomson and Lodge vouchsafe 'protyle,' 'corpuscles' and 'electrons,' with more or less experimental verification, although they do not quite reach Ostwald's metaphysical view.

Here we gratefully acknowledge the aid given us in free access to the collections, the construction of a special dark room, every facility of the museum's workshops, the encouragement and advice given by the museum's able director, Dr. H. C. Bumpus, and the attention and assistance of Dr. L. P. Gratacap, Mr. L. L. Seymour and Mr. Smith, of the mineralogical department, and of Mr. Dahlgren, the museum photographer.

SUPPLEMENTARY NOTE: ACTINIUM.

We have recently had the opportunity of making some experiments with a small amount of the exceedingly rare, novel, and hitherto almost unobtainable, element, actinium, described by Professor Debierne in the *Comptes Rendus*, 1898.

This actinium was a preparation of the oxide, with an activity of 10,000 (uranium being taken as unity), prepared by Dr. Debierne, and sent to one of us through the courtesy of Professor P. Curie. The emanations from it seemed most profuse, and although it had been exposed for two weeks, in a paper package in the mail, yet they were as energetic at the time of its arrival, and one week after, as they could have been at any time. The substance is wonderfully radio-active; in the few ex-

periments that we have made, it was found that, like radium, it causes the diamond to phosphoresce, and exerts the same action as radium upon kunzite and willemite, with the possible exception that the emanations from the small quantity of substance seemed to become luminous before they touched the willemite itself. The surface that was affected measured two square inches, many times the surface of the actinium. The effect produced on willemite was somewhat different from that due to radium; the luminescence apparently penetrated the willemite, and at the same time it almost seemed as if a luminous emanation left the material.

It was also found that on applying some powdered and granulated willemite to the inside of a closed jar, 12 cms. high, and putting this over the actinium, which was in a paper, the emanations made the entire interior of the jar luminous.

On the other hand, they do not appear to possess the penetrating power through glass that the radium compounds show; for in the same experiment they failed to affect the willemite on the outside of the jar, although the glass was only $1\frac{1}{2}$ mm. in thickness.

A platinum-barium-cyanide screen immediately responded when the actinium was held against the black paper on the back. The abundance of emanations from the substance, rather than their penetrative quality, seemed to be its characteristic.

One of the properties of actinium which Professor Curie mentions in his letters, is the emitting of many emanations, which last for some minutes. This last feature, of endurance, was not observed. On the other hand, a peculiarity of actinium, as compared with radium, is that the emanations, although much more profuse, disappear in a few seconds. Another marked feature is a certain visibility or materiality of the emanations. This has been already

referred to in some of the experiments above described in connection with willemite.

If actinium is placed in a paper over a screen of the phosphorescent sulphide of zinc (Sidot's blonde), the screen will become illuminated, and on slightly blowing, so as to produce a current of air, the light is carried along the screen with the emanations. It was found that the diamond was affected quite as permanently as with radium; so was the spodumene variety, kunzite, and a specimen of willemite more than two inches square. Emanations of the actinium, which was in a double paper, rose in a cone-shaped form and spread out in an inverted cone on the base of the willemite, illuminating both.

GEORGE F. KUNZ,
CHARLES BASKERVILLE.

AMERICAN ORNITHOLOGISTS' UNION.

THE twenty-first congress of the American Ornithologists' Union convened in Philadelphia, Monday evening, November 16. The business meeting was held in the council room, and the public sessions, commencing Tuesday, November 17, and lasting three days, were held in the lecture hall of the Academy of Natural Sciences.

Charles B. Cory, of Boston, was elected president, Charles F. Batchelder, of Cambridge, Mass., and E. W. Nelson, of Washington, D. C., vice-presidents; John H. Sage, of Portland, Conn., secretary; Dr. Jonathan Dwight, Jr., of New York City, treasurer; Frank M. Chapman, Ruthven Deane, A. K. Fisher, Thos. S. Roberts, Witmer Stone, William Dutcher and Charles W. Richmond, members of the council.

The ex-presidents of the union, Drs. J. A. Allen and C. Hart Merriam, and Messrs. William Brewster, D. G. Elliot and Robert Ridgway are *ex-officio* members of the council.

Dr. Samuel W. Woodhouse, of Philadel-