RADIUM—ITS EXTRAORDINARY PROPERTIES.

BY C. W. KANOLT.

In 1896 Prof. Henri Becquerel, of the Conservatoire des Arts et Métiers at Paris, discovered the radio-activity of uranium. He found that all compounds of uranium, as well as the metal itself, continually emit radiations, which act upon photographic plates and have a penetrating power similar to that of the X-rays. This was one of the first of a series of quite remarkable discoveries. Investigators immediately experimented with various materials with the hope that they might find other substances having the same property as uranium. Of the elements already known, thorium as well as uranium was found to be radio-active. But research has led to the discovery of three new radio-active substances, which are looked upon as new elements. These are radium, polonium, and actinium. Of these radium alone has been obtained in a pure condition, and it is the one which has been most experimented with.

Prof. Curie, of the Ecole de Physique et de Chimie Industrielles at Paris, and Madame Curie turned their attention to pitchblende, a mineral which consists largely of oxides of uranium. They found that some samples of this mineral from Bohemia possessed a greater activity than either uranium or thorium, the only substances then known to be radio-active. This fact led them to the conclusion that the activity of the pitchblende must be due to some new element of great activity. In order to find this new substance, they dissolved a quantity of pitchblende in acids and, by the ordinary chemical methods, separated the material into portions containing different elements. They then observed which of these portions possessed radio-activity. This could be done by exposing photographic plates wrapped in opaque paper to the substances and observing which plates were acted upon. But it could be done more expediently by another method. Becquerel had observed that the new radiations—"Becquerel rays" as they are now called—render the air through which they pass a conductor of electricity. They are now known to have a similar effect upon many other substances which do not ordinarily conduct electricity. The Curies had but to measure the conducting power of the air in the immediate neighborhood of the material under investigation, to find whether the material was radio-active and to obtain a measure of its activity, if it possessed any. Guided by such experiments, they gradually concentrated the active substances into small portions of the material. One portion they believed to contain a new element, which they called "polonium;" another yielded radium.

The radium greatly resembled barium chemically, and its separation from barium was the last and most difficult part of the operation. It was at length accomplished by fractional crystallizations and fractional precipitations, and in 1902 Madame Curie announced the preparation of pure radium chloride. E. Demarçay examined the spectrum of this material, and found that it consisted of lines which were not those of any previously known element, thus proving quite conclusively that the radium was actually a new element.

Something about the rarity and the cost of radium may not be without interest. According to Prof. Curie, there are not two pounds of radium in existence. In the last three years not more than one and one quarter pounds have been manufactured. Even this small quantity is of all grades of purity. Absolutely pure radium does not exist as a metal. Only its salts are known. The substance with which chemists experiment is chloride of radium associated with barium. Of the value of radium many fantastic accounts have been given. It goes without saying that so rare a substance is costly—more precious indeed than any precious stone. Prof. Curie has in his possession what is probably the only pure specimen of chemically pure radium in the world. The sample is about the size of a buckshot, weighs not quite half a grain. So many tons of pitchblende were required for the reproduction of this small amount that Prof. Curie has said it could not be bought for $20,000. Indeed such a specimen of radium has almost any commercial value its possessor chooses to give to it. A firm of manufacturing chemists of Paris furnish tiny tubes of radium of a lower grade, containing an appreciable quantity of barium, and weighing about as much as Prof. Curie's precious specimen, for $5,000. Preparations containing barium salts and small quantities of radium are on the market at the much lower price of $4.50 to $100 per gramme, the gramme being equal to 15.42 grains.

The amount of radium contained in pitchblende is so small that it must be brought to a concentration no less than five thousand times as great before it can be detected by that exceedingly delicate instrument, the spectroscope. It is needless to say that the discovery of some mineral yielding radium in greater quantities, is much to be desired. Sir William Crookes, reasoning from the facts that radium is very similar chemically to barium, and that elements of similar nature are likely to be associated in minerals, experimented with a number of specimens of barium minerals with the hope of finding radium in them; but none of them were radio-active.

Radium has never been prepared in the metallic state. The radio-activity of the pure salts is very great. Prof. Curie states that it is a million times as great as that of uranium. The radium rays will act upon a photographic plate in a few seconds, while uranium requires hours.

The radiations themselves are very interesting. They cannot be refracted, polarized, or regularly reflected, as ordinary light can be. They are quite different from light. Prof. Becquerel observed that a part of them are deflected by a magnet. This immediately reminds one of the cathode rays of a Crookes tube, which are similarly deflected. The cathode rays are now known to be nothing less than streams of most minute particles, carrying negative electricity and moving with enormous velocities. All evidence points to the deflectable portion of the Becquerel rays being quite the same thing. The Curies have shown that they also carry negative electricity; and Prof. Becquerel has shown that, like the cathode rays, they are deflected by electrostatic forces. From the results of these experiments, Prof. Becquerel has calculated the velocity of these particles. They do not all move at quite the same rate. A portion of them have a velocity of 100,000 miles per second, a velocity quite comparable with that of light, 186,000 miles per second. The cathode rays in a Crookes tube have a velocity of about two-thirds that of light.

Prof. Becquerel has also calculated the ratio of the mass of the particles to the quantity of electricity which they carry, and this too has about the same value as in the case of the cathode rays. Prof. J. J. Thomson has shown that the particles in a Crookes tube have a mass only about one-thousandth of that of a hydrogen atom, which we have always looked upon as the smallest particle of matter existing. We have reason to believe that the particles of the Becquerel rays are of the same size.

One might reasonably inquire whether radium does not rapidly lose weight as the result of the constant emission of these particles; but Prof. Becquerel has calculated that one square centimeter of radium surface would lose only 1.2 milligrammes of matter in a thousand million years. However, A. Heydweiller has recently found that radium does lose weight perceptibly. He found that 5 grammes of a material containing a small percentage of radium lost about 0.02 milligramme per day, and he observed a total loss of about ½ milligramme.

The portion of the Becquerel rays which are not deflected by a magnet, appear to consist largely of very penetrating rays resembling the X-rays; but there are also rays of a third kind, easily absorbed.

One of the most striking properties of radium is its luminosity. The pure radium chloride emits enough light to enable one to distinguish printed characters. The rays from radium excite phosphorescence in many bodies, such as zinc sulphide, diamond, and even common salt. The luminosity of radium is perhaps but the phosphorescence produced by its own rays. If a small quantity of radium is held against the forehead while the eyes are closed, one will see light. The rays penetrate to the retina, and cause it to phosphoresce.

Certain chemical changes are brought about by the rays from radium. Under their influence, oxygen is converted into ozone, yellow phosphorus into red phosphorus, glass becomes violet and almost black.

The physiological action of the rays is quite marked. If a small quantity of radium be kept near the skin for a few hours, the rays produce a serious sore. Prof. Becquerel once slipped a small quantity of radium contained in a glass tube into his vest pocket. He carried it in all about six hours. For some days no result was observed, but at length a sore developed, which required seven weeks to heal. The hands of persons working with radium are likely to be affected. The fingers become inflamed and very painful. Prof. Curie has said that he would not venture into a room containing one kilogramme of radium, as it would probably destroy his eyesight, burn off his skin, and even kill him.

E. Aschkinass and W. Caspari have exposed cultures of a species of bacteria, *Micrococcus prodigiosus*, to the rays from radium, with the result that the bacteria were killed. It was necessary to place the radium quite near to the bacteria, as the action seemed to be due to those of the rays which are easily absorbed by the air.

When any body is placed near to a radium salt exposed to the air, it becomes radio-active itself. This induced activity is only temporary, however. It disappears in the course of a few hours or days. It does not depend upon the nature of the body in which it is induced. Even the hands and clothing of the experimenter become temporarily active. The induced activity seems to be produced not by the radiations, but by a radio-active "emanation" or gas-like substance which is given off by radium and carried by the air. Exactly what this emanation is, is not known; but Prof. Rutherford and Miss Brookes have made a determination of its rate of diffusion, which indicates that its molecular weight lies between 40 and 100. F. Giesel states that a solution of radium bromide decomposes to some extent, with the liberation of bromine and the formation of radium hydroxide and other compounds; and that it also liberates a peculiar colorless gas which is radio-active. What this gas is has not yet been made known. It may be mentioned that Rutherford and Soddy have found that the emanation which is given off by thorium compounds has the chemical inertness of the gases of the argon group.

The energy of the rays from radium has been found to be quite considerable. Rutherford and McClung have estimated that a gramme of radium radiates in a year energy equivalent to 3,000 gramme-calories, which is about one foot-pound per hour, that is, the power necessary to raise a pound a foot in an hour. The source of this energy is a mystery. Several theories have been presented to account for it. Rutherford and McClung suggest that the energy is liberated by the breaking down of the atoms into smaller particles, the particles that are radiated.

Radium is not likely to find much practical use soon, although it has been made use of in a new electroscope for investigating the electrical condition of the atmosphere; but the properties of radium are very important from a theoretical standpoint, for they promise to give us much information concerning the deeper nature of matter.

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PROPOSED SUBWAY AND ELEVATED EXTENSION IN NEW YORK CITY.

In a report recently submitted to the Rapid Transit Commissioners, the Chief Engineer of the Commission, William Barclay Parsons, recommends that the Commission authorize the construction of a scheme of new subways, and extensions of the elevated railroad system, which will add enormously to the rapid transit facilities in this city. We give herewith a brief digest of the proposed work, and in a subsequent issue, we hope to publish plans and a more detailed description. The new subways include a two-track line from 42d Street and Broadway, south beneath Broadway to 14th Street, and thence below University Place, Worcester and Church Streets to South Ferry. A short spur will run from Broadway under 32d Street to the new Pennsylvania terminus at Seventh Avenue. Another line with three tracks would extend from the subway at 40th Street and Park Avenue, below Lexington Avenue to the Bronx. A third extension would be to carry a line from West Farms along the east side of Bronx Park to Wakefield and Mount Vernon.

During the construction of the subways, it is proposed to build the following additional elevated lines and tracks in the city: Two additional tracks on Second Avenue from the Harlem River to Chatham Square and over the Park Row line to City Hall; a third track from 59th Street to Ninth Avenue on the Third Avenue line, and a third track from south of the Harlem River to Westchester Avenue; an extension of the Sixth Avenue line along Christopher Street to Greenwich Street on the Ninth Avenue line, and the laying of a third track on the Sixth Avenue structure from Eighth Street northward; the laying of a third track from 14th Street on the Ninth Avenue line south to Cortlandt Street; the extension of the third track on the Ninth Avenue line from 116th Street north to 155th Street; the widening of the Putnam Railroad bridge across the Harlem to a three-track structure, and the extension of the Eighth Avenue line with three tracks by way of Jerome Avenue to Woodlawn, and thence to a connection with the Putnam Railroad in Van Cortlandt Park; the abolishing of the surface tracks of the New York Central Railroad below 59th Street on the west side of Manhattan, and the substitution therefor of a four-track elevated freight and passenger viaduct, which will extend by way of West Street to Battery Place. The estimated cost of these improvements, based on preliminary investigations, is from $45,000,000 to $50,000,000.

THE CURRENT SUPPLEMENT.

The current SUPPLEMENT, No. 1417, offers a wide variety of instructive articles. Mr. Frank C. Perkins describes some German and English tank locomotives, illustrating his text with photographs of engines. The English correspondent of the SCIENTIFIC AMERICAN continues his discussion of London's water supply. Electrical subjects are treated in articles on "The Theory of Wehnelt Interrupters," and the "Braun Portable Wireless Telegraph Equipments in the German Army." Mr. Henry R. Lordly's valuable paper on "Anti-Friction Bearings" is concluded. Of technological interest is an article on "Improvement in Sugar-Refining During the Last Twenty-five Years." The employment of balata as a substitute for gutta-percha is exhaustively discussed in a very readable article. Mr. Fred T. Jane continues his "Naval War Game" series, the present installment being a continuation of the account of the imaginary battle between an American and a German fleet.