RADIUM
ITS PRODUCTION AND USES

SYDNEY FAWNS

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M. Curie

RADIUM:

Its PRODUCTION and USES.

BY

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PREFACE.

IT is the object of the writer to try and present a complete sketch of the history, description, production, treatment, and uses of Radium. Technical terms have been used only where unavoidable. Although several works of an important nature have been written on Radium and Radio-active substances, no book dealing with the subject as a whole has yet appeared.

It is the hope of the writer that this complete sketch of the subject may prove serviceable to the Student as well as to the general public.

The FIRST CHAPTER deals with the History, Appearance, and Energy of Radium.

The SECOND with the Radio-activity of the Earth, Sea, Air and Sun, and a short account of the various Radio-active substances is added.

The THIRD gives a general description of the Rays, Emanations and Life of Radium.

The FOURTH contains a Summary of the chief medical and other uses of Radium.

The FIFTH has a short account of the best known mines producing Radium Ore.

The SIXTH is devoted to the treatment of the ore and the various processes necessary to the production of Radium.

For the Student who wishes to pursue the subject further, a Bibliography, giving a Synopsis of all the principal works in English on the subject, has been added.

The Writer wishes to acknowledge the generous assistance he has received in the preparation of this work.

SYDNEY FAWNS.

71 Onslow Square,
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CHAPTER I.

The History, Appearance, and Energy of Radium.

THE discovery of radium and its compounds is one of the romances of science. This new science, which we term "Radio-activity," breaks up old ideas, and forms a distinct step in the advance of knowledge. It has opened up new and undreamt of possibilities, but, as a matter of fact, it does not upset any of the old scientific laws, but has given them a fuller and truer meaning.

The discovery of the X-rays by Rontgen in 1895, with their wonderful power of penetration, caused great interest in the scientific world, and numberless experiments were undertaken.

Professor Henri Becquerel,[1] whilst engaged on some investigations on the X-rays, extended his experiments to the salts of uranium, which he had prepared some years previously; with these salts he obtained after an exposure of several hours, distinct photographic effects; and, after further investigations, he communicated his results to the Academy of Science in Paris on February 24, 1896. These simple experiments first marked the discovery of what we now know under the term of "Radio-activity," and it was the further investigation of them that led to such remarkable results. Later observations by Becquerel showed that the radiation of the uranium salts remained unaltered when kept continuously in darkness, and that the

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[1] Becquerel, C.R., p. 122, 1896.

radiation proceeded from the salts itself. These investigations extended over five years.[2] During this time Mme. Curie also conducted experiments by the electric method for the investigation of the radio-activity of this substance.

THE DISCOVERY OF RADIUM.

It was while conducting these experiments that Mme. Curie found a large number of minerals containing uranium and thorium were radio-active. M. and Mme. Curie[3] then set to work to try, and if possible, to separate this (then unknown) compound from the uranium salts. Their work was at length completely successful, and led to the discovery of two new substances, called Polonium and Radium. This important discovery was entirely due to the radio-activity possessed by these new substances. The account of these experiments might be given at length, but I do not think any useful purpose would be served by quoting all the details that led up to the final result, as it is now largely a matter of history.

The first discovered was Polonium, and this name was given by Mme. Curie in honour of the country of her birth. It was next observed that another active substance was separated with barium, and to this the name of Radium was given. The name is a happy inspiration, as it showed extraordinarily radio-active properties in its pure state. Radium is extracted from pitchblende and uranium minerals generally. It will be shown later that the weight of radium in most radio-active minerals is always proportional to the weight of uranium.

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[2] Becquerel opp. cit.

[3] M. and Mme. Curie and G. Bemont, C.R. 127, p. 1215, 1898.

Mme. Curie was presented by the Austrian Government with a ton of uranium residues from the State mine of Joachimsthal in Bohemia. Financial assistance was given by scientific societies and private individuals to defray the expenses of the long and laborious work of the separation of radium from these residues. Mme. Curie finally succeeded in separating about a decigram of pure radium salt, the atomic weight of which was found to be 226·45. Shortly after the discovery, the Curies arranged that preparations containing radium could be bought commercially through the Société Centrale de Products Chimiques, and it was this company that initially undertook the work of treatment of pitchblende residues for the Curies on a commercial scale. But it was Dr. Giesel, Chemist of the Chininfabrik Braunschweig, who first succeeded in putting preparations of nearly pure radium salt on the market.

APPEARANCE OF RADIUM.

The question naturally arises what is radium like? Anyone caring to spend a few shillings can buy a small instrument with radium in it, called a Spinthariscope, at any of the leading opticians. This instrument was designed by Sir William Crooks. By looking into the instrument in a dark room, the screen observed through the lens will be seen to be bright, and this brightness can either be concentrated or spread out by altering the position of the needle carrying the radium—placing it nearer or further from the screen. After the eye has become used to the darkness it will be seen that this brightness is not a continuous glow, but resembles a shower of small shooting stars. Minute, but bright, flashes of light in great numbers appear and disappear across the field of vision. These small flashes of light are caused by the A particles of radium. What seems to be impossible is that this minute speck of radium can really be producing this result.

In a lapse, say, of three months, if the instrument be re-examined, it will be found that the flashes of light are the same as before. After a further lapse of, say, two years the phosphorescent screen will be worn out by this incessant bombardment, and will require to be renewed. When replaced by a new one, the radium will be found to be as active as ever.

What, perhaps, is still more wonderful, is that the owner of the instrument will pass away, and the next four or five generations, before this speck of radium will show any signs of exhaustion. It is estimated that a grain of radium bromide expels every second ten thousand million A particles.

Contemplate for one moment that if this really incalculable swarm of atoms is thrown off every second, through probably hundreds of years, from an almost invisible amount of radium, a faint idea may be formed of the number of atoms in a single grain of matter, and how very minute a single atom must be.

The scientist of but a short time ago would have laughed at the idea of ever being able to see a single atom, and yet that is what you really see when you look through this simple instrument.

EXPLANATION OF "RADIO-ACTIVE."

It is difficult to give a clear and at the same time brief explanation of the term "Radio-active," and it may serve better for the purposes of this book to use it in a more restricted way than is usual. Consequently, the term "Radio-active" will be restricted generally to that class of substances comprised by uranium, thorium, radium, and their compounds which possess the property of spontaneously emitting radiations capable of passing through the plates of metal and other substances opaque to ordinary light.

ENERGY EXERTED BY RADIUM.

It must be remembered that energy is subject to exact measurement: this is done by converting the form desired to be measured into heat, and measuring it as such. The energy of radium, although in an entirely new form, is no exception to this rule. When radium is kept in a leaden vessel all its energy is transformed into heat. The amount required for this experiment is extremely small. The result of exact measurements has proved that one gramme, which is equivalent to 15·4 grains of radium bromide, gives out 133 calories per hour.

A simple calculation will show that radium, therefore, exerts eight hundred times the energy obtained from the same weight of coal. The energy contained in one ton of uranium, if it could only be applied, would light London for a year; and this store of energy in uranium would be much more than a thousand times the present value of uranium itself, if it could only be used. It is true there is a great quantity of energy in the world that at the present moment is unused. For instance, the energy exerted by the tides comes into this category. At present, however, it is a useless form of what may be called low-grade type of energy. The material energy of uranium is not of this nature, and the difficulties connected with its use are quite of another character. At present it is impossible to accelerate the energy evolved by the disintegration of an element; consequently, as the stored energy in uranium takes about a thousand million years to be given off, it is at present practically valueless for commercial purposes. The sources of energy now available to man are only what may be termed the leavings of Nature's supply.

Last century brought about a great change in scientific thought with regard to the nature of the gigantic forces which regulate the march of events throughout the universe. In the new force we term radio-activity we seem to have penetrated one of Nature's innermost secrets.

The outlook on the purely physical universe has been permanently altered. We are no longer the inhabitants of a slowly-dying universe, but of a universe which has in the stored-up internal energy due to radium the component materials that can rejuvenate itself over immense periods of time. Thus the world is probably of a much greater antiquity than physical science has thought possible.

With all our civilisation we still subsist, struggling amongst ourselves for a sufficient supply of the energy which alone is at present available to us, while all around are the vast potentialities of the means of sustenance; but, unfortunately, we do not know how to use them.

Radium has taught us that there is no limit to the amount of energy in the world available to support life, save only the limit imposed by the boundaries of knowledge.

The real wealth of the world is not the amount of gold it contains, but the amount of available energy it possesses. This is the modern philosopher's stone, which the old legend accredited with the power of transmuting metals, and acting as the elixir of life; and the problem still remains under the same form, but is now called transmutation of the elements. This problem is an old one, and we can only hope that one day man will attain the power to regulate for his own purposes the primary fountains of energy which Nature now so jealously conserves for the future.[4]

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[4] These theories are elaborated in "The Interpretation of Radium," by Frederick Soddy. To anyone wishing to pursue the subject further, no more delightful and fascinating book has been published.

CHAPTER II.

Radio-Activity of the Earth, Sea, Air and Sun.

RADIUM is a most widely distributed substance; this fact was established from a number of experiments carried on from time to time by Rutherford & Soddy,[1] Professors Joly, Eve, Strutt, Wilson and Sir G. Darwin. It is true the amount of radio-active substances in the surface of the earth is extremely small, and the question naturally arises, how is it possible to determine with any degree of accuracy a quantity so minute as a billionth of a gram? This determination is not only possible, but is now a recognised scientifically accurate measurement by means of the electroscope, which was invented by the Curies. A short description of this really simple but beautiful instrument is given in the third chapter.

The undoubted presence of a minute quantity of radio-active substances in the earth's surface crust, in the sea water, and also in the air, has led to many theories, which are now being slowly reduced to exact sciences. This fact has exercised considerable alterations in the geological estimate of the age of the world, and of the life of the sun.

RADIO-ACTIVE MATTER IN THE EARTH.

Eve[2] in his investigations found the igneous rocks—or, in other words, rocks made by the agency of heat—

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[1] Rutherford & Soddy, *Phil. Mag.*, May 1903. Joly, *Nature*, October 1, 1903. Eve, *Phil. Mag.*, August 1907, p. 231. Strutt, "Proceedings" R.S., 77a 472 and 7a 150. Wilson, *Nature*, September 21, 1903. Sir G. Darwin, "Proceedings" R.S., 77a 472 and 7a 150.

[2] Eve, *Phil. Mag.*, August 1907.

were more radio-active than the sedimentary rocks, or the rocks formed by the agency of water. There seems to be no doubt that the forces and heat engendered by the radio-active substances form an important part in the general development of the land surfaces as we now know them. It can be further shown that most of the earthquakes and volcanic actions have also a direct connexion with radio-active energy.

The important conclusion arising from the investigation of the radio-activity of the surface rocks is that a layer of highly radio-active materials must cover the earth, but can only extend downwards for a few miles. It will be quite fair to take this as a proved fact, and not merely as a theory. Of course, it is impossible to exactly estimate the amount of this radio-activity; the calculations can only be made on the quantity of heat escaping on the surface. Any accurate determination of the amount of radium in rocks by the ordinary methods has many difficulties, and Professor Joly[3] has devised a fusion method by which the liberated radium can be mixed with air and other gases, transferred into an electroscope, and its quantity measured. Professor Joly[4] found that the percentage of radium contained in the lava from Vesuvius was unusually high. A most interesting instance of the effect of radium on rocks was the producing of unexpectedly high temperatures on the rocks of the Simplon Tunnel in Switzerland. Professor Joly, from a radio-active analysis of these rocks, came to the conclusion that without undue assumption it is possible to explain the difference in the temperature of the rocks encountered in boring the tunnel by the difference in their radium

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[3] Joly, *Phil. Mag.*, 22, p. 134, 1911.

[4] Joly, *Phil. Mag.*, 18, p. 577, 1909.

contents. The presence in the rock of a proportion amounting to a few million millionths of radium above the normal quantity very nearly wrecked the whole enterprise. From the importance of radio-activity in this instance of a tunnel a few miles long bored through a mountain, some idea may be obtained of the significance of the new discoveries in the general problem of the thermal condition of the interior of the globe.[5]

RADIO-ACTIVE MATTER IN THE SEA.

An examination of the amount of radium in sea water has been made by Joly and Eve. The results of both observers show that the radium contents of sea water is very small compared with the radium contents of rocks. It seems clear that the active matter carried down into the sea by rivers is rapidly deposited in the bed of the ocean. This fact seems to be proved by the observations of Joly on the high radium contents of the deep sea deposits obtained in the "Challenger" expedition.

RADIO-ACTIVE MATTER IN THE AIR.

A large amount of work has been done in this interesting field of investigation, but it will only be possible to touch briefly on the main results of importance that have been obtained. Numerous observations made in various parts of the world show that the air is slightly radio-active everywhere. This activity is greater over land areas than over the sea, but seems to extend to great heights. Flemming[6] from balloon observations found that radio-active matter was present in the air at an altitude of 9,000 ft. At this

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[5] Soddy, "The Interpretation of Radium."

[6] Flemming, *Phys. Zeit.*, 9, p. 801, 1908.

height the same amount was present as at the surface of the earth.

RADIO-ACTIVITY OF THE SUN.

We have seen that radio-active matter is uniformly distributed through the crust of the earth, the sea water, and throughout the atmosphere. Strutt[7] examined a number of meteorites for the presence of radium, and found that a stony meteorite contained about as much radium as the terrestrial rock which it most resembled. If the earth originated from the same material as the sun it is only reasonable to suppose that the sun should contain the known radio-active elements. The origin and duration of the sun's heat has been discussed in detail by Lord Kelvin[8], who states that "the inhabitants of the earth cannot continue to enjoy the light and heat essential to their life indefinitely unless sources now unknown to us are prepared in the great store houses of creation." The discovery of the enormous amount of energy emitted during the transformation of radio-active matter renders it possible that the estimate of the age of the sun's heat can be indefinitely prolonged. Much as one would like to pursue these fascinating speculations, it will be necessary to consider in the following chapters the more practical side of the subject. It is now known that there are a number of highly active substances that can be separated from uranium minerals.

ACTINIUM.[9]

There seems to be no doubt that this is a new element possessing the radiating property almost equal

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7 Strutt, "Proceedings" R.S., a77, p. 472, 1906.

8 Kelvin, "Natural Philiosoph.," Appendix E., Thomson & Tail.

9 Rutherford, "Radio-active Substances," p. 19.

to that of radium, but up to the present it has not been found possible to produce it in a commercial form.

POLONIUM.

It has already been mentioned that this was the first active substance separated by Mme. Curie[10] from uranium minerals, Mme. Curie showed it was possible to concentrate the polonium by several methods, and to obtain preparations of polonium of high activity, and these preparations coated on a polished bismuth disc or rod, were some years ago placed on the market. There is no doubt that polonium itself is only one of a series of products resulting from the transformation of radium.

RADIO-LEAD.

Several observers note that the lead separated from pitchblende showed considerable activity. This was first thought to be due to the presence of small quantities of radium and polonium. Later work has shown that this active material has a slow rate of transformation, and seems to be identical with one of the products of radium. It may be of interest to note that preparations of radio-lead serve as a convenient source for the recovery of polonium, and the polonium present can at any time be easily separated by placing a bismuth plate in the solution.

IONIUM.

Boltwood[11] in 1907 discovered the presence of another radio-active substance in uranium minerals, which he called Ionium, but so far it has not been possible to

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[10] M. & Mme. Curie, *C.R.* 127, p. 175, 1898.

[11] Boltwood, *Amer. Journ. Sci.*, 24, p. 270, 1907. Elster & Greitel, *ann. d. Phys.*, 69, p. 83, 1899.

separate it from thorium. Ionium has a special interest, as it seems to be the parent of radium, and a preparation of ionium, apparently free from radium, is found to grow radium at a rapid rate.

OTHER RADIO-ACTIVE SUBSTANCES.

The problem of giving appropriate names to a large number of new substances is a difficult one, and it is not even yet certain that they have all been discovered. A small table of these new substances is given, where, for convenience, they have been tabulated as the products of the more permanent element from which they originated :—

LIST OF RADIO-ACTIVE SUBSTANCES.[12]

Uranium	Actinium	
Uranium X	Radio-Actinium	Radiothorium
Uranium Y	Actinium X	Thorium X
	Emanations	Emanations
Radium	Actinium A	Thorium A
Emanation	Actinium B	Thorium B
Radium A	Actinium C	C1
Radium B	Actinium D	Thorium C
Radumic C1	Thorium	Thorium D C2
C2		
Radium D	Mesothorium 1	
Radio-Lead	Mesothorium 2	
Radium E		
Radium F		
Polonium		

[12] Rutherford, *opp. cit.*, p. 24.

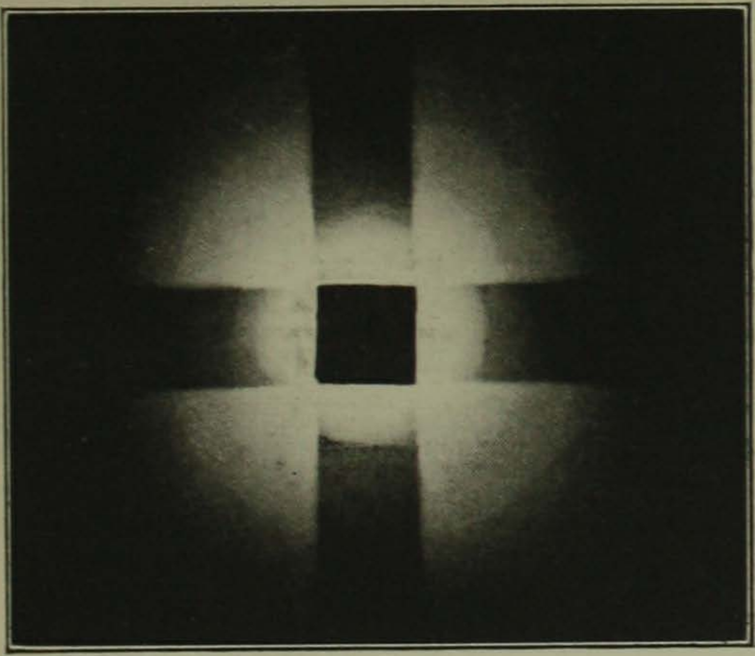
CHAPTER III.

Description of Radium Rays and Emanations.

IT must be quite understood that wonderful as the effects produced by the rays are, they are absolutely invisible, and can only be investigated by the effect they produce. There is a marked similarity to the X-rays, but they possess a power of penetration which is most extraordinary. As an example, the most penetrating radiation obtained from the X-rays is easily stopped by a thin sheet of metal. But the ray coming from even a small quantity of radium salts can be readily detected after passing through a centimetre of lead. A few milligrams will give a distinct impression on a photographic plate after the rays have passed through a considerable thickness of metal.

A sealed glass tube containing a small quantity of radium will give excellent radiographs of coins, keys, &c., when inside a purse, if given an exposure of an hour or so. This is done by merely supporting the tube for the requisite time a few inches above the plate with the purse laid on it. Radium also has a strong electrical effect, and the rays cause an intense ionisation of the air through which they pass. This property of ionisation means that radium has the power of separating the various particles in the air into elements, which are called ions, and charging them with electricity.

This peculiar property, which is common to all radio-active bodies, has been used for the measurement and comparison of the various radio-activities. In this way it has been possible to fix the standard of 2,000,000 for



Photograph of Radium Rays.

pure radium, by comparison of uranium, at 1. This quality of ionisation still remains the only one by which radio-active strength can be accurately estimated.

DESCRIPTION OF THE ELECTROSCOPE.

These measurements are done by means of an instrument called an electroscope. A good electroscope for ordinary work is easily constructed, the exact form being a matter of indifference so long as the insulation is good. The frame of the case may be wood or metal, the back and front being made of glass. The best insulating material is either sulphur or paraffin wax; ebonite is not so good, but is sometimes used. In the modern form of electroscope the rod passing through the insulating medium terminates in a metal plate to which the leaf is attached. The plate, being stationary, gives the fixed Zero point, and the angle between it and the leaf can be readily observed and measured when in use. The leaf may be either gold cr aluminium. In order to follow the motion of the leaf accurately, a scale is placed inside the instrument, and this is marked off into conspicuous divisions. Care must be taken when charging the instrument, or damage may result. Naturally the instrument must be kept dry and free from dust.

THE RADIUM RAYS.

Professor Rutherford classed the rays emitted by radium into three main types—A, B, and C. For convenience the symbols α (Alpha), β (Beta), and γ (gamma), which are the first three letters of the Greek alphabet, are generally used. These rays are distinguished from one another by enormous differences in their power of penetrating matter. In this book I am using the first three letters of the English alphabet instead of the Greek.

PROPERTIES OF THE A-RAYS.

The A radiation from radium is intense, but the power of penetration possessed by the rays is, of course, quite independent of the intensity, because the thickness of a certain medium which is sufficient to stop any one A particle will also be able to stop the whole radiation.

In consequence of the high velocity of an A particle, combined with its relatively large mass, it develops considerable energy, and it is owing to this energy that the A-rays possess their great power of ionising gases. It is estimated that each A particle (from radium) produces about 86,000 ions before its energy is so far reduced that its power of ionisation is gone. The A-rays exhibit a remarkable power of causing fluorescence in many chemical compounds and also some minerals.

Diamonds show a marked luminosity, but the compound which possesses the greatest sensitiveness to the A-rays is crystalline zinc sulphide, which glows a very beautiful and vivid green under the action of the A-ray of radium.

THE B-RAYS.

One of the first observations in connexion with these rays was the fact that a magnetic field was capable of modifying the conductivity of the air ionised by the radiation from radium. Consequently, the investigation of these particles by means of magnetic fields is not attended with the difficulty experienced in similar experiments with the A-rays.

Although the B-rays cause considerable ionisation in any gas through which they pass, the action is not so marked as with the A-rays. Owing to the exceptionally high velocities of the B particles, they have a very considerable power of penetration. A sheet of metal or mica sufficient to completely stop all A radiations leaves the B-rays almost unaffected. The photographic action of the B-rays is characterised by considerable intensity. An interesting fact which is attributed largely to the B-rays is that paper and india-rubber, after having been wrapped round tubes containing active radium compounds, become rotten.

THE C-RAYS.

The third type of radiation emitted by radium has an almost incredible power to penetrate matter. A few milligrams of radium bromide are sufficient to show the action of the C-rays by the fluorescence produced on a barium-platino-cyanide screen after the B-rays have been completely stopped by the interposition of 1 cm. of lead. Professor Rutherford states that the C radiation from 30 mgs. of radium bromide could be detected by the electroscope after passing through 30 cms. of solid iron. The photographic action of the rays is also intense. Fluorescent effects are produced by the C-rays to a marked extent in a wide variety of substances.

THE MAGNETIC FORCE OPERATING ON THE RAYS.

The magnetic test is of great service in analysing the three types of rays from radio-active bodies, and in determining the real nature of each. This is in addition to the tests applied to the varying powers possessed by the rays of penetrating matter.

The trajectories of some of the rays are powerfully influenced by a magnet, while others are hardly, if at all, affected. The B-rays, if caused to traverse the space between the poles of a magnet, are very strongly deflected, and, provided the magnet is a very powerful one, may be coiled up into closed circles. The C-rays are not at all affected by even the strongest magnetic force. The A-rays are only slightly deflected by either a magnetic or an electric field.[1]

RADIUM EMANATIONS.

The discovery of the emanations was due to some experiments conducted by Owens[2] on thorium compounds. This was confirmed by Rutherford,[3] but it was Dorn[4] who first proved that radium also gave off emanations. The amount of the emanation was small at ordinary temperatures, but was much increased when the radium compound was treated. The radium emanation behaved similarly to that of thorium, but lost its activity more slowly.

The gaseous nature of the emanation of radium having been recognised, it became a matter of importance to determine its chemical properties. In order to decide this question, the emanation has been brought into contact with a number of chemicals under widely varying conditions of temperature; but in all cases the emanation passed absolutely unchanged through the most drastic chemical operation. The volume of the emanation from radium is always exceedingly minute. Owing to the intense radioactivity of the emanation, it quickly decays into the A rays of radium, the process of disintegration being marked by the presence of the A particles when formed.

It can be easily understood that the explanation of

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[1] Rutherford, *Phys. Zeit.*, 4, p. 235, 1903.
[2] Owens, *Phil. Mag.*, 48, p. 360, 1899.
[3] Rutherford, *Phil. Mag.*, 49, p. 1, 1900.
[4] Dorn, *Abh. d. Naturforsch. Ges. fur Halle-a-S.*, 1900.

the various forms of rays has been given in the briefest possible manner, and for a full description of all the properties connected with these rays the student is advised to study that carefully written book of Professor Rutherford's "Radio-active Substances and their Radiation."

Radium is also found in various thorium compounds. Thorium, however, is much less radio-active than uranium, and the extraction is more costly and difficult. A very easy way to prove the radio-activity of thorium is to experiment with a Wellsbach gas mantle on a photographic plate, when it will be found that it is possible to get a very distinct impression. However, as the researches in thorium are being rapidly extended, doubtless more important data will be soon available; but, in the meantime, as a means of producing radium it is of little commercial value. It might be interesting here to give a short table of the relative life of radium and its rays and emanations. Radium itself has an ascertained life of 2,500 years; the emanation of 5·6 days:—

Radium A	... ...	4·3 minutes
Radium B	... ...	38·5 ,,
Radium C	... ...	28·1 ,,

The reason why some atoms are more stable than others is as yet entirely unknown. The only thing that can be done is to state the fact that has been arrived at after very careful investigation.

CHAPTER IV.

The Uses of Radium.

BECAUSE of its wonderful healing properties, radium possesses a personal interest to everyone. At first, on the discovery of radium, various experiments were tried on animals; but it was due to an accident that its effect on the human system was first discovered. The story is as follows:—

Becquerel, in 1901, was using for some experiments a tube containing a small quantity of pure radium. He put this tube into his waistcoat pocket, and carried it about for some hours; nothing was noticed at the time. A fortnight later a severe burn appeared which gave the outline of the tube. Consequently there could be no doubt as to what had caused it. This was the story of the famous "Becquerel burn," and has led to the somewhat erroneous idea that radium is practically a synonym for burn.

Professor Curie then made some experiments, and thought that radium might be of use in surgical and medical cases. He gave a small quantity to Mons. Daulos, of the St. Louis Hospital. This marked the commencement of what is now generally known as radium therapy.

The curative properties of radium have become a recognised fact in the medical world, and as fresh advances continue to be made, it seems safe to say nothing like its full usefulness has yet been discovered. A large number of persons suffering from diseases which have hitherto defied treatment have been greatly benefited by radium. Various special apparatus have been devised for the application of the radium and radio emanations. The apparatus generally in use is of two kinds. One variety, used in external applications, has radium on the outer surface. This is covered with a special varnish, by means of which the radium salts are stuck on.

The other variety consists of tubes which contain radium salts, and are used in cases of tumours and other internal troubles. Radium can also be used by means of injections, and the application of ointments and other substances. As the application by tubes is the more important, it may be as well to give a somewhat detailed description of the way they are used. One sort of tube is glass, through which the radium particles are seen to move and follow the inclinations of the tube according to the angle at which it is held. The other is enclosed in a second tube of either gold, silver, or platinum, and upon the thickness of this metal the amount of radio-activity required is determined. The length of application desired is a matter requiring the greatest care, skill and experience.

The medical profession, always ready to try a new form of healing, seized on radium, and after finding in unskilled hands it did not fulfil all that was expected, began to dismiss it as a curative agent of value. The present scientific use of radium medically is entirely due to the successful researches of Dr. Wickham, who put it on its present useful scientific basis. In the application of radium to medicine there are two great epochs—"Before Wickham" and "After Wickham."[1]

[1] Sir Malcolm Morris, British Medical Association, 1909.

The following are the various methods of application:—

A.—*Long applications.*—In order to increase the effect of the treatment, it is simply a question of prolonging the time of the application. The apparatus being easily worked, and causing no pain or but little inconvenience, can be allowed to remain for long periods, even in cases of infants. Given a certain ascertained amount of radio-activity, it is only necessary to calculate the length of time required to convey to the tissues the total amount of energy called for.

B.—*Very short applications.*—These would last at most one minute, and sometimes only half. Powerful instruments with large surfaces used without screening are employed in these cases.

C.—*Fractional doses.*—The action of the radium rays on tissue depends on the manner in which a given quantity of energy is applied. If thought necessary, this action may be divided into fractional doses. This method of applying the energy will ensure a larger total, acting differently than when applied without division.

D.—*Intervals between applications.*—When applied at varying intervals different effects may be produced. These are naturally variable, and require careful watching.

E.—*Internal application.*—Radium in tubes can be introduced when treating diseased parts, sometimes covered only with rubber, with lead, or with aluminium screens. In painful cases excellent results have been obtained with the help of cocaine. All the apparatus is carefully and minutely described in a book on "Radium Therapy," by Wickham and Degrais, from which these brief particulars are taken. Radium has a distinct action on the nervous system, experiments on small animals have proved this fact. Naturally the central nervous system is much more sensitive to its influence than other portions of the body. To instance one proof: A tube containing 1 centigramme of radium was placed beneath the skin of a mouse, one month old, exactly over the spinal column and part of the skull. Within three hours it developed symptoms of paralysis. In seven or eight hours the mouse was seized with convulsions, and, continuing the experiment, the animal was dead within twelve to eighteen hoùrs. Mice a year old, under the same conditions, live from six to ten days, showing death is rapid in young animals and slow in the older ones. The larvæ of insects placed in a box containing radium in a tube are affected in twenty-four hours, and die in from two to three days.

Mons. Danyz also investigated the action of radium on small animals at a distance, the effects produced were much the same, the difference being the time taken to arrive at the result. Beck applied a tube containing radium to thirteen rabbits and five dogs, and in some cases paralysis of the nerves was produced. Professor Raymond succeeded in arresting the shooting pains caused by neuralgia and neuritis by the application of radium. This was also done by Darier, who relieved pain in several cases of facial neuralgia by similar applications. Emanations from radium are not followed by any appreciable loss of weight, and practical means of utilising the radio-activity of these emanations have been found. Curie and Danyz investigated the action of the emanations on various organisms. Caterpillars placed in a tube of the emanations were paralysed much in the same way as by radium rays.

Bouchard, Curie, and Balthazad made similiar experiments with guinea pigs and mice, and the animals died after a stage of loss of heat, accompanied by torpor. The rapidity with which the fatal results are produced depends on the amount of emanations contained in the atmosphere which was used. In London similar results were obtained with frogs and mice. The emanations are distinctly more effective on the various forms of germ life than the direct rays. Danyz killed a culture of anthrax germs with emanations. Dorn, Ramnami, and Valentiner found the emanations arrested the growth of typhoid germs, mouse typhus, and diptheria germs are similarly affected.

The action of the emanations of radium has been more closely studied in Germany than elsewhere. The discovery that radium in its various forms is a cure for certain types of rheumatism has been now, I understand, completely proved after the most careful investigation. Rheumatism is such a common form of disease that few people escape. Dr. Guyenot writes as follows: "Uric acid, as we know, circulates in the blood in the form of urate of soda, of which there are two isomeric forms, differing from each other by their respective solubility, in the blood plasma. The soluble salt is converted into an insoluble form," which means that one atom of uric acid combines chemically with two atoms of soda, forming an insoluble compound, known as urate of soda.

The action of radium being to break up this compound, freeing one of the atoms of soda, and leaving the uric acid combined with one atom, this, I understand, is a soluble compound and can by means of carefully applied radium treatment be removed from the system and the patient freed from rheumatism.[2] The cases

[2] This discovery is due to Dr. Guyenot.

treated in this way by Dr. Guyenot, who is Director of the Physio-Therapeutic Institute at Aix-les-Bains, France, have given most successful results.

Superficial Diseases.—A wide field has been found for the use of radium in the treatment of superficial diseases. It is very difficult to suggest a limit to the powers of the substance in this respect, Some diseases, of course, yield more readily than others. Lupus, which is tuberculosis of the skin, is very resistant to radium treatment, but a great many other skin diseases, as well as *small* cancers of the tongue and lip, can be cured, while large rapidly-growing tumours, like sarcoma, can be destroyed by the method of burying tubes within them. Here, again, the fact is illustrated that these rays seem to concentrate their attack upon the young and most rapidly growing cells. The radium rays are extraordinarily selective, and they would destroy abnormal cells without affecting the normal. Similar therapeutic properties are also possessed by thorium.[3]

With regard to the treatment of cancer, successful results have been attained in many cases, but not in all, as the investigations are naturally beset with great difficulties. Doubtless, as time goes on, better results will be attained. With regard to other forms of disease, they have been treated at length in various medical works and papers, and a lengthy account here of cases treated would be out of place. Mineral waters containing radium have been used for medical purposes; it is interesting to note that those which contain the largest quantity of emanations are regarded as the most efficacious.

The most active radio-activity of mineral waters exists only at the source of supply, because the water soon

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[3] Sir James Davidson, Roy. Inst., February 2, 1912

loses its borrowed properties. It may be this fact which explains why there is such a difference between the therapeutic effect of mineral waters "consumed at the source" and those taken at a distance. The external application of the emanations may take the form of baths, compresses, or mud poultices. With regard to baths, it is probable that the effects are due to inhalations of the emanations in the water vapour, and not to absorption through the skin. In a prescribed quantity of radio-active water the patient is left for about half-an-hour and required to stir the water frequently. Compresses are prepared of various sizes. Before being applied they are steeped in boiling water, wrung out, and placed over the part to be treated, then covered by a waterproof sheet and left for twelve hours. Radio-active mud is a convenient form of treatment. It is prepared by mixing powdered pitchblende with twice its volume of hot water. This mud exercises a soothing effect, it does not irritate the skin, or give any inconvenient reactions.

I have endeavoured to describe very briefly how radium is used. It is interesting to note that in the medical world of Germany, France, and England there is a singular unanimity of views of the numerous observers; this is a rather rare fact in medicine, more especially as the medical world in each country has worked on entirely independent lines, the chief difference being that in France the treatment consists mainly of baths and mud poultices, and in Germany more importance is attached to taking mineral water charged with radio-active emanations. In England, I understand, the medical world has not evolved any separate form of treatment, but it is using both the methods employed in France and Germany. A possible use for radium on a large scale may be found in freeing water from all traces of harmful bacteria. In tropical countries it would be of enormous value to possess a means of ridding the water used for drinking of all germs of cholera, typhoid, and other diseases. A simple preparation of radium salts spread out on a large surface to give off the rays could be placed in a vessel immersed in the water, which would produce the desired result without appreciable loss of radium. As the action of the radium salts would go on for probably centuries, it would only be a matter of first cost. Experiments are being conducted on these lines. At present there is a large demand for radium at scientific institutions for research work, at hospitals, and for medical men generally. As the supply increases, doubtless new uses will be found for this wonderful element.

CHANGE OF COLOUR IN PRECIOUS STONES.

A number of precious stones were placed in contact with the radium rays for one month, when the following changes were noticed :—

Original Colour.	*New Colour.*
White or uncoloured ...	Topaz-like yellow.
Blue	Emerald green.
Violet	Sapphire blue.
Wine-coloured	Beautiful ruby.
Inferior dark-coloured ...	Deep violet.

CHAPTER V.

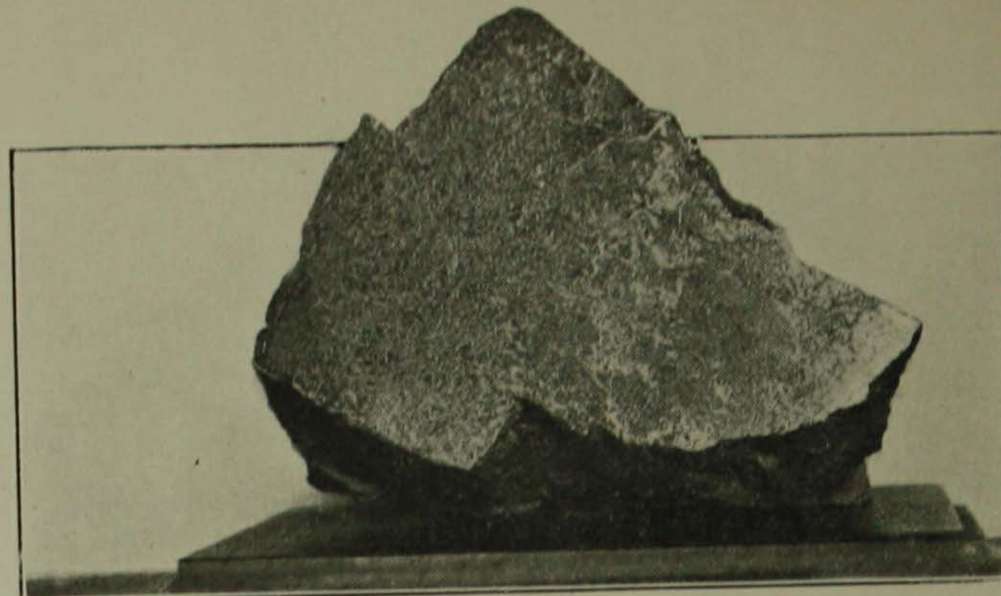
The Occurrences of Radium Ore.

RADIUM in minute quantities exists practically everywhere, but it is only in a very few places that it has been found in sufficient quantity to pay for its production. For some years past continuous search has been made in Asia, Africa, and South America, but up to the present no deposits of payable radium ore have yet been found in any of these places.

JOACHIMSTHAL MINE.

The main supply of radium in the past has come from the celebrated Joachimsthal mine in Bohemia. This mine was purchased by the Austrian Government, and has practically produced nearly all the radium that there is at present in the world. It will be remembered that it was from here that M. and Mme. Curie obtained the ore from which the first radium in quantity was extracted. The history of this mine is an interesting one, and according to G. Laube commenced at the end of the fifteenth century. As early as 1517 a mining settlement existed in the Valley, and in 1518 the first "Joachimsthaler" was minted, this coin being now known as the "Thaler."

In 1520 the settlement obtained the privilege of a free mining town. The total output for the first forty-four years is estimated at 40 tons of gold, that is to say, 4,000,000 gulden, reckoning silver at the value prevailing at that time. After 1545 the industry suffered



Daylight Photograph of Pitchblende.

a great decline, but acquired new vigour when the Cobalt and bismuth ores became valuable. In recent times the industry has languished because of the depreciation of silver. During the last decades special attention has been paid to the extraction of uranium. One of the most interesting features in this mine is the extraordinary mixture of ores. Without going into too many sub-divisions, the main ores of value found are silver, nickel, cobalt, bismuth, arsenic, uranium, galena, zincblende, pyrite, and also a variety of iron and copper ores.

From the numerous sections of the lode, published in an account written by F. Babenek, can be seen characteristic distributions of the ores and gangues. A brief description might be of interest. The country rocks of the neighbourhood of Joachimsthal are for the most part mica schists enclosed between masses of granite. In the eastern part of the mine, where there are some masses of included limestone, the lodes usually carry calcite as the predominating veinstone; but in the western part, where the veins are not infrequently associated with dykes of porphyry, the gangue is almost entirely quartz ore. There are seventeen veins striking north and south, and seventeen others of which the direction is east and west. It has been constantly observed that the former exhibit a tendency to become enriched where they pass through the porphyry or included limestone, while the latter set of veins are not similarly affected when they come in contact with these rocks. In the eastern division of the mine there are two shafts, situated about 1,560 ft. apart, the Einigkeit's shaft and the Kaiser Josef shaft. In 1864, when the former shaft had reached a depth of 1,640 ft., a heavy outburst of water at a temperature of 25° C. and evolving sulphuretted hydrogen, took place, and greatly interfered with the underground operations. It took two years before this water could be successfully tubbed off and mining proceeded with. The average annual production of uranium ore was only 878 lbs. for a period lasting from 1877 to 1880. About this time it became evident that the uranium oxide was the most valuable product of these mines, and workings were specially directed to develop the minerals yielding it. From 1881 to 1886 the average annual production was 38 tons of uranium ore. In the veins of the western division uranium ore was more specially sought for. These veins, of which the most important is the Geister lode, are worked through two shafts, the Werner, 1,416 ft. deep, and the inclined Elias shaft of 546 ft. deep. The average annual production of this division between the years 1881 and 1886 was 2,000 kilogrammes of oxide of uranium. The total production in 1894 was 26·4 tons.

Note.—The following are some of the more important publications upon Joachimsthal: G. Laube, "aus der Vergangenheit Joachimsthals," Prague, 1873; F. Babenek, "Geologic des bohemischen Erzgebirges," Prague, 1876; also the "Geologic bergin Karte mit Profilen und Bildern von den Erzgangen in Joachimsthal," 1891; and H. Miller, "Die Erzgange des Annaberger Bergrevieres," Geolog. Survey, Leipzig, 1894.

URANIUM MINES OF CORNWALL.

The Trenwith Mine, near St. Ives, Cornwall.—This mine was worked for tin as early as 1838 up to 1859. The returns show that 3,612 tons of tin ore were produced. Pitchblende occurred intermingled with tin ore; this, when the mine was worked many years ago, had no commercial value, and it was hand-picked and put in a waste heap. This heap has now been carefully sorted over, and a considerable quantity of pitchblende recovered and sold. Exploration has taken place underground, with the result that several large and small patches of pitchblende have been mined; but this mine, unlike the South Terras, does not possess any well-defined lode of uranium ore. The ore is treated at Limehouse, where the company's works are situated. The published returns show that 204,558 lbs. of hand-picked pitchblende ore have been recovered and treated.

South Terras Mine, now owned by the Société Industrielle de Radium, is situated near Grampound Road, Cornwall. The mine is chiefly interesting from the fact that it is the only one in the world that has been, and is, worked solely for uranium ore. The ore-body occurs in killas, the lode runs north and south, having a westerly underlay. Its thickness averages 3 ft., carrying a vein of pitchblende from 1 in. to 12 ins. thick. The country rock is a light bluish coloured killas, but greenstone was met with at a depth of 12 ft.

"From the surface down to about 50 ft. below the outcrop the vein was filled with a ferruginous gossan with earthy uranium ores of variable composition, but which consisted largely of uranates of copper and lime. Below the adit level the vein became harder, the gangue consisting chiefly of quartz coloured with oxide or iron, and the earthy ores replaced by pitchblende. Occasionally small bunches of copper ores and galena were found, the latter being argentiferous."[1] The minerals found in this mine have an extraordinary similarity to those

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1 This description is taken from a "Treatise of Ore Deposits," 1896 Edition, Phillips & Louis.

found in Joachimsthal—and the following is a table showing this similarity:—

South Terras Mine.	Joachimsthal Mine.
Silver ores (galena).	Silver ores (galena).
Nickel.	Nickel.
Cobalt.	Cobalt.
Bismuth.	Bismuth.
Uranite.	Uranite.
Pitchblende.	Pitchblende.
Torbernite.	Torbernite.
Zinc blende.	Zinc blende.
Copper pyrites.	Copper pyrites.
Pyrite.	Pyrite.
Arsenic ore.	Arsenic ore.
Lead ores.	Lead ores.
Iron ores.	Iron ores.

The ore was concentrated by hand picking into No. 1, containing 20 to 25 per cent. uranium oxide, and No. 2, containing 5 to 10 per cent. uranium oxide. The authentic published returns show it has produced 291 tons of concentrated uranium ore. Professor Jean Danyz, preparateur to Mme. Curie, visited the South Terras Mine in September of 1912, and made a thorough examination of the ore at the mine, having fitted up a small laboratory for the purpose. The results of these investigations were most satisfactory, and a report signed by Mme. Curie herself gave the following figures: "The ore which was tested from the dumps contained from 5 milligrams up to 190 milligrams of radium per ton. (Ore containing 190 milligrams of radium would represent a value of over £3,000 a ton). The water contains from 11·0 to 14·9 milligram minutes of radium per 10 litres of water. The radio-activity of the air in the south shaft was 0·71 milligram minutes of radium emanations per 10 litres of the air." Professor Jaques Danne and his brother, G. Danne, after a careful and prolonged investigation of the ore at the mine, write as follows: "The average radium contents given in our report of October 26, 1912, for the ores taken from the outer layers of the dumps, are maintained throughout the whole depth, and show a tendency to increase with such depth. In consequence, the amount of radio-active substances actually present on the dumps is considerably more important than had been estimated, the quantity of ore having been estimated in our previous report on the assumption of a useful depth of about 3 ft., corresponding to the average depth from which samples had been taken. This confirms, therefore, our previous conclusion (report of October 26) that the amount of 9,700 milligrams of radium bromide estimated to be actually present on the dumps was a minimum. This result was arrived at after three months' careful investigation." It is this ore which is being shipped to Giff (Seine-et-oise), France, for treatment, and which is giving such excellent results. When the mine itself is at work much richer ores will be treated.

G. Danne, in a report dated February 13, 1913, states that he had inspected the underground workings, which had been pumped dry, accompanied by the resident chemist, G. Malandrin, and the mine manager, J. Brenton. He says that we are able to bear out the fact that the former workers of the mine had evidently succeeded in extracting rich ore from the lode. The workings extend for a considerable distance, and right up to the surface. The cavity is now filled with debris and radio-active matter, and it was from here that the following samples were taken :—

Capacity.		Milligrams per ton. Ra Br^2 $2H_2O$.		Kilograms Ur per ton.
0·030	...	3·84	...	5·890
0·469	...	27·20	...	80·203
0·076	...	3·22	...	5·621
0·080	...	5·25	...	12·818
0·270	...	23·50	...	26·000

It is from the South Terras mine that the world will be able to obtain the much-needed supply of radium in the immediate future.

Other Ore Deposits.—As I stated in the first part of this chapter, investigations for the discovery of radio-active minerals have been pursued, but so far no solid results have been met with. Last year a very small amount was obtained in the Erzgebirge, in Saxony.

Radium Ore Mine at Guarda, situated in Eastern Portugal.—Here the National Radium Trust have worked a mine containing a radio-active ore called Autunite; this ore has a bright citron yellow colour, and is really a uranium-calcium phosphate. Investigations have proved that this ore is much poorer in radium than pitchblende, but I understand the ore will be treated by Professor Ebler's new process, when better returns are anticipated. The result of this process will be exceedingly interesting; so far nothing has been published.

URANIUM MINING IN U.S.A.

The U.S. Geological Survey report states that the shipment of uranium and vanadium ores during 1912 has been in the hands of about a dozen persons and firms; and, as in previous years, the ores have come mostly from south-western Colorado, with a smaller production from south-eastern Utah, between the San Rafaal Swell and the Colorado line. The production of uranium appears from preliminary estimates to have been equivalent to a little less than 26 short tons of uranium oxide, or approximately 22 tons of metallic uranium—a slight increase over 1911, when the production was equal to about 25 tons of uranium oxide, or 21·2 tons of the metal. The vanadium output of 1912 seems to have been equivalent to a little less than 300 tons of metallic vanadium, a somewhat larger quantity than that of 1911. The uranium-bearing ores were all carnotite—a variable compound of uranium and vanadium with other elements, found with several vanadium minerals in sandstones of Jurassic-Triassic age in the high plateau region of Utah and Colorado. So far the richest and largest deposits found are in Montrose County, Colorado, in Paradox Valley, Long Park, the McIntyre district and adjacent territory, extending into San Miguel, Dolores, and Mesa counties. In Utah the deposits mined are in Emery and Grand counties. Deposits which were unproductive during the year occur in Rio Blanco, Routt, and Moffat counties, Colorado; and in Uinta and San Juan counties, Utah. The percentage of uranium oxide in the ore varied from 0·5 to 6·32. The percentage of vanadium oxide in the same ores varied from 1·42 to 13·63. The relation between the uranium oxide and the vanadium oxide was likewise variable. At one extreme was an ore that carried 8·15 per cent. of vanadium oxide, and 1·54 per cent. of uranium oxide; at the other extreme was an ore that carried 5·79 per cent. of vanadium oxide and 6·32 per cent. uranium oxide. Of the more widely known uranium mineral, pitchblende or uraninite, a few hundred pounds were mined near Central City, Gilpin County, Colorado. It was all sold as specimens and to laboratories, probably for experimental work. A few pounds, partly altered to gummite and other secondary minerals, were found in mining mica near Penland, N.C. Prices varied much, but 25 to 30 cents a pound for the contained vanadium oxide, and $1.30 to $1.50 a pound for the contained uranium oxide where it exceeds 2½ per cent., seems to have been the rule. The prices were considered too low by some producers, and their ore was stored awaiting a rise.[2] Some of this ore is brought to England and the vanadium extracted, which is generally in greater proportion than the uranium, and the residues, containing a small percentage of uranium, are sold; but the percentage is very small, and the extraction of radium from this ore will be a difficult and costly process.

In Australia a company, called the Radium Hill Company, are working a deposit of uranium ore mixed with other minerals, and in 1912 2½ milligrams were prepared in Sydney, New South Wales. Mr. Radcliff, the company's chemist, hopes to extract a considerable quantity during the coming year. So far no ores of radio-active value have been discovered in Africa or South America. In Eastern Europe, in Russia, there are signs of the presence of radio-active bodies, but nothing of any commercial value has yet been discovered.

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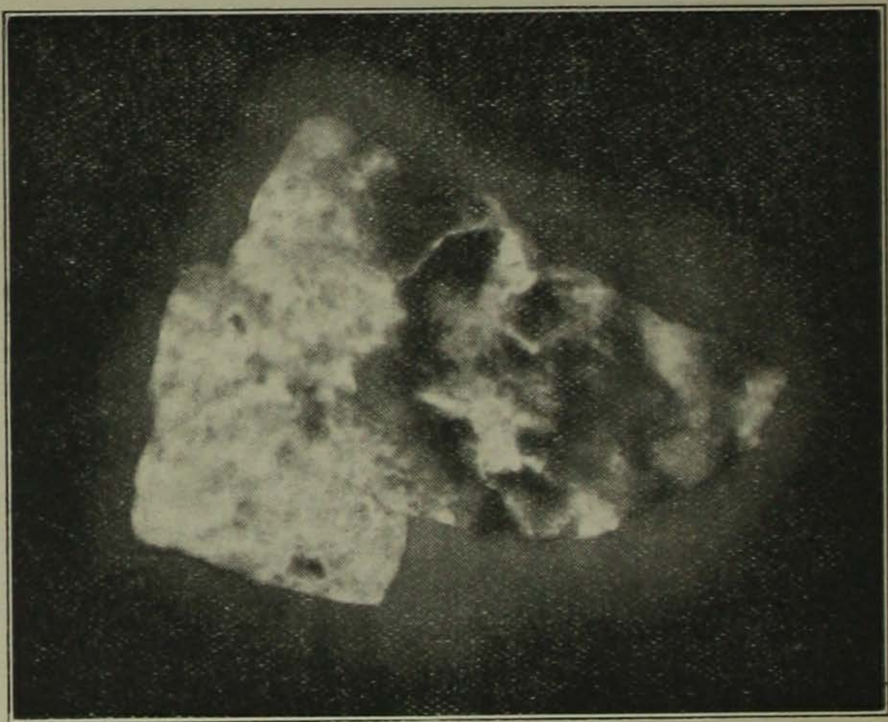
[2] *Mining Journal*, February 1, 1913.



Pitchblende imprinted in the dark by the rays of the substance.

CHAPTER VI.

Extraction of Radium.

IN describing a metallurgical process like the treatment of ore for radium, it is impossible, in order to describe the process fully, not to deal with the matter in a technical way. For the benefit of my non-technical readers I have written the following brief *résumé* of the methods used in the extraction of radium from its ores: The account given at length is the cne described by Madame Curie in her latest work, and the same methods with suitable modifications apply to all the present used means for the extraction of radium from all radium-bearing minerals. The finely crushed ore is first fused with carbonate of soda; the product is then cooled and broken up. The next step is washing it in nearly boiling water to which a little sulphuric acid is added. The fluid portion contains the uranium present, because uranium has been found to dissolve readily when mixed with sodium carbonate. The residue contains all the material that is radio-active, also any sulphates, mostly of calcium barium, possibly of lead if present. This residue is now freed from the sulphuric acid by treating it with caustic soda. This process dissolves the aluminum, calcium, and lead, which pass away, leaving the residue which contains the radium in a smaller bulk; this is washed, and some hydrochloric acid is added. The effect of this is that any actinium and polonium go into solution, and the barium is left which contains the radium. The actinium and polonium can be precipitated by sulphuretted hydrogen and collected. To the residue is now added sodium carbonate, and after some time hydrochloric acid, which converts the barium and radium present into chlorides. These chlorides are next treated with sulphuric acid, and the barium and radium become sulphates. The object of this is to reduce the bulk, and this process is repeated till a ton of ore is reduced to about 38 lbs., having a high radio-activity. This bulk of residue is next subjected to a succession of fractional precipitations which crystallises it, and after a long process chloride of radium is obtained in a comparatively pure state. This chloride then goes through an extended and tedious process to get the commercially pure radium bromide. Doubtless, as time goes on, the process of extraction will be much simplified and radium will be rendered cheaper.

EXTRACTION OF RADIUM FROM PITCHBLENDE.

The mineral is crushed and roasted with sodium carbonate, the resulting product being first treated with hot water, and next with weak sulphuric acid. The solution contains the uranium. The insoluble residue contains the radio-active substances, which are three to five times greater than uranium oxide, also sulphates of lead, lime, silica, alumina, and iron oxide. In addition, there are in varying quantities nearly all the metals—i.e., copper, bismuth, zinc, cobalt, manganese, nickel, ranadium, antimony, thalium, rare earths, niobium, tantalum, arsenic and barium. The radium is a sulphate contained in this mixture, being the least soluble of the sulphates. To dissolve it, it is necessary to eliminate as much of the sulphuric acid as possible. The residue is therefore treated with a boiling concentrated solution of soda. The sulphuric acid combines with the lead, alumina and lime, and also forms sulphate of soda, which is washed out. The alcaline solution takes up at the same time the lead, silica and alumina. The lead may be reprecipitated as sulphide, forming "radio-active lead." The insoluble portion, after being washed, is treated with hydrochloric acid; this breaks up the material and dissolves a large amount. From the solution so obtained, polonium and actinium are separated, the former by precipitation with hydrogen sulphide, the latter being mixed with the hydrates precipitated from the solution by ammonia. Radium is retained by the insoluble residue, which is washed and treated with a solution of boiling concentrated sodium carbonate, whereby the sulphates are converted into carbonates. After a thorough washing, the material is treated with pure, weak hydrochloric acid free from sulphuric acid; the solution contains the radium, also some polonium and actinium. This solution is next filtered and sulphuric acid added, sulphate of radiferous barium, containing some lime, lead and iron, with a little actinium being precipitated. The small amount of polonium and actinium remaining in solution can be separated, as in the hydrochloric acid solution. From 1 ton of residues, after extraction of uranium, 10 to 20 kilos. of crude sulphates are obtained, having a radio-active value thirty to sixty times greater than metallic uranium. The crude sulphates so obtained are boiled with a solution of sodium carbonate, and converted into chlorides. Hydrogen sulphide is passed through the solution, producing a small quantity of sulphides containing some polonium; the solution is filtered and peroxidised by chlorine and pure ammonia added; the precipitate contains the oxides and hydrates, which are very radio-active, due to the presence of actinium; to the filtered solution sodium carbonate is added; the precipitated carbonates are washed and turned into chlorides, which are dried and washed with pure concentrated hydrochloric acid, which practically dissolves all the calcium, the radiferous barium chloride remaining nsoluble. By this means from 1 ton of original residues about 8 kilos. of radiferous barium are obtained, the radio-activity of which is about sixty times greater than metallic uranium; chlorides so produced are now ready for final treatment by fractionisation to obtain pure radium salts.

PREPARATION OF PURE RADIUM SALTS.

This account was translated especially for the writer from Mme. Curie's "Traiti de Radio-Activités" by Mr. James Thame.

The process which I have adopted for the extraction of pure radium chloride from radiferous barium chloride consists in submitting the mixed chloride to a fractionated crystallisation. First in pure water, next in water containing hydrochloric acid. By this method I make use of the difference in the solubilities of the two chlorides, radium chloride being more soluble than that of barium. At the commencement of the fractionisation I employ pure distilled water. The chloride is dissolved and the solution is saturated at boiling temperature. The crystallisation is then allowed to take place by cooling in a covered evaporating dish. At the bottom of the dish fine adhering crystals form, and the supernatent solution can then be easily decanted. If a sample of this solution is evaporated to dryness it is found that the chloride obtained is about five times less active than the crystals in the basin. By this means we have divided the chloride into two parts, A and B, the portion A being much more active than B. The same operation is repeated on each of the chlorides A and B, and from each of them two new portions are obtained. When the crystallisation is terminated, the fraction the least active of chloride A and the fraction the most active of chloride B are mixed—these two having about the same activity. By these means three portions are obtained which are submitted to the same treatment.

The number of portions is not increased, because this would only cause loss. The operation is repeated till the most soluble portion is so poor in radio-active matter that it can be eliminated.

In the same way, when a suitable amount of the residue, "the richest in radium," is obtained that is also eliminated. The same operation is repeated on the remaining quantity under treatment. After each of these series of operations, the saturated solution of one portion is poured on the crystals produced from the last portion treated.

After one of the series of operations, the most soluble fraction is then eliminated. In the following series a new quantity is made up with the soluble portion separated. The crystals constituting the most active portion when formed are then eliminated by employing in succession alternately these two methods of operation. A mechanical fractionisation is thus obtained, in which the number of portions and the radio-activity of part of these remain constant, each portion being about five times more radio-active than the last. We can then eliminate on one side (at the end) a product which is nearly inactive, whilst we collect on the other side (at the top) a chloride which is rich in radium.

The quantity of the portions thus treated naturally becomes smaller as the operations proceed, they also become more radio-active.

It has been found that the chloride eliminated at the end only contains 0·1 of the activity of uranium.

After a large quantity of the inactive material has been removed, the residue has a relatively small bulk. A portion at the end of the fractionisation is suppressed, and a portion is added to the top, which contains the active chloride previously collected, the result of this operation being that it is possible to now collect a chloride richer in radium than previously. This system of treatment is continued until the crystals on the top represent pure chloride of radium. If the fractionisation has been carried out properly, a very small quantity remains in the intermediate products.

C. Radcliff, of Victoria, Australia, has applied for a patent for treating radium ores, April 10, 1911. The chief features are as follows: Crushed radium ores are fused with sodium bisulphate and sodium chloride or an oxidant, such as potassium chlorate, sodium nitrate, &c. The cooled and powered melt is treated with water, the turbid liquor being decanted from the heavy residue (which after washing is rejected), and the radium and barium sulphates are allowed to deposit as a slime, which is further treated for radium sulphate in the usual way. To the solution, sodium carbonate is added, avoiding excess. The filtrate is rejected, while the precipitate is boiled with sodium carbonate to dissolve uranium, which is finally recovered as sodium uranate by precipitation, with sulphuric acid or caustic soda or as uranium oxide by adding ammonium chloride or sulphate and igniting the precipitated ammonium uranate, and the remaining precipitate is treated with sulphuric acid, which dissolves the rare earths leaving the oxides of the "acid earths," niobium, titanium, and tantalum. The rare earths—cerium, didymium, lanthanum, thorium, &c., are recovered from the solution by precipitating as oxalates and igniting the precipitate.

Radium in commercial quantities is produced at Joachimsthal, Austria, Giff (Seine-et-Oise), France, London, England, and Sydney, New South Wales, Australia.

It is at present estimated that there is only about 30 to 35 grammes of pure radium bromide in use, and the present consumption of the world would be equal to from 10 to 15 grammes per annum, could it be obtained.

USES FOR URANIUM METAL.

If the output of uranium is much increased, there are several uses to which it can be put to, because uranium, being one of the best-known conductors of electricity extant, a reduction in price would inevitably increase its use in electrical construction. Uranium mixed with steel is said to form an alloy of high quality, so that, when its supply can be maintained in regular quantities, it will be utilised in the manufacture of ordnance, for fine sword steel, and for other purposes of a similar character.

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WICKHAM, LOUIS, and DEGRAIS, Dr.—"Radium-Therapy." Tr. by S. E. Dore, with Introduction by Sir M. Morris. 10 in. 326 pp. 92 illus. 1910. (Cassel; 12s. 6d. net.) The pioneer work on scientific radium-therapy. The authors, who have had the advantage of studying the subject under the most favourable conditions, clearly prove that "radium has a wide field of therapeutic usefulness."

APPENDIX.

TABLE OF WEIGHTS METRICAL.

1 gramme = 15.43235 grains troy, and is the weight of a cubit centimetre of distilled water at 40 centigrade or 39.2 degs. Fahr.

Weight.	Grammes.	Avoirdupois ounces.	Avoirdupois lbs.	Grains troy.
Milligramme ...	.001 ...	— ...	— ...	.015
Centigramme ...	.01 ...	— ...	— ...	.154
Decigramme ...	.4 ...	— ...	— ...	1.543
Gramme	1. ...	.035 ...	.0022 ...	15.4323

CALCULATION OF RADIUM FROM URANIUM.

Knowing the percentage of uranium in a given mineral, the amount of radium can at once be deducted without measurement. (Rutherford, "Radio-active Substances and their Radiation," p. 462.)

The amount or radium per gram of uranium is 3.4 × 10-7 gram—consequently one gram of radium is present in a mineral containing 3,000 kilos of uranium.

AUTOMATIC WEIGHT OF RADIUM.—Mme. Curie[1] has made successive determinations of the atomic weight of radium with specimens of increasing purity. The first determination gave a value of the atomic weight at 225. A second, made in 1907, with a larger quantity of radium, gave a value of 226.4.

Thorpe,[2] using about 70 milligrams of radium, found the atomic weight to be 226.7.

Gray and Ramsay,[3] using about 200, found the atomic weight was 226.45.

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[1] Mme. Curie, C.R., 129, p. 760, 1899; 131, p. 382, 1900; 135, p. 161, 1902; 145, p. 422, 1907.

[2] Thorpe, "Proceedings" R.S.A., 80, p. 298, 1908.

[3] Gray & Ramsay, "Proceedings" R.S.A., 86, p. 270, 1912.

ATOMIC WEIGHT OF URANIUM ORES.

Uranium has the highest atomic weight, 238.5, of any known element.

It is ordinarily separated from the mineral uraninite, where it is always found associated with the radio-active substance ionium, radium and actinium. (Rutherford, *opp. cit.*, p. 444.)

RADIUM-PRODUCING ORES.

First.[4]—Uraninite—pitchblende—uranium oxide.

Colour.—Grayish—brownish—or velvet-black.

Lustre.—Submetallic or dull.

Streak.—Black.

Opaque.

Crystalisation.—Isometric. In octahedrons and related forms, also massive and botryoidal.

General Composition.—Uranium, 81.50 per cent.; oxygen, 13.47; lead, 3.97; iron, 0.40. H_2O 0.88.

The oxides of uranium are used in painting upon porcelain, yielding a fine orange in the enamelling fire, and a black colour when the porcelain is baked.

Second.—Tobernite—uranite—autunite.

Colour.—Emerald and grass green.

Lustre.—Pearly.

Transparent to *subtranslucent.*

Crystalisation.—Tetragonal, in square tables, thinly foliated, brittle.

General Composition.—A uranium copper phosphate, consisting of pure phosphorus, pentoxide, 15.1 per cent.; uranium trioxide, 61.2; copper oxide, 8.4; water, 15.3.

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[4] "Manual of Mineralogy," Dana, p. 186, 187.

ANALYSIS OF RADIO-ACTIVE WATERS OF

SOUTH TERRAS.		ST. JOACHIMSTHAL.
11	...	8
12.3	...	9
14.4	...	10
14.9	...	—
——		27
52.6	Average ...	9
Average ... 13.15		

Professor Joly, who analysed the South Terras water, states : "It is much the most radio-active water I have as yet examined."

TABLE OF RADIO-ACTIVE MINERALS.[5]

Minerals.	Locality.	Activ-ity.	Radium per 100.	Uranium per 100.	Ratio $\frac{Ra.}{Ur.}$
Chalcolite	Saxony	—	0.714×10^{-5}	39.29	1.82×10^{-7}
Carnotite	Colorado	0.76	0.375 ,,	16 00	2.34 ,,
Gummite	Germany	1.23	0.58 ,,	17.37	3.34 ,,
Autunite	Autun	1.52	1.20 ,,	46.92	2.56 ,,
,,	Tonquin	1.50	1.22 ,,	47.10	2.59 ,,
Chalcolite	Germany	1.20	0.905 ,,	28.80	3.14 ,,
Pitchblende	Joachimsthal	1.90	1.48 ,,	46.10	3.21 ,,
Chalcolite	Portugal	1.70	1.30 ,,	39.03	3.33 ,,
Samarskite	India	0.42	0.295 ,,	8.80	3.35 ,,
Broeggerite	Norway	3.90	2.10 ,,	63.89	3.29 ,,
Thorianite	Ceylon	2.32	0.66 ,,	18.60	3.55 ,,
Chalcolite	Cornwall	2.00	1.70 ,,	48.66	3.49 ,,
Pitchblende	,,	1.40	1.07 ,,	28.70	3.74 ,,

[5] Rutherford, "Radio-active Substances and Radiation," p. 463.

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S.

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