and in how many directions the aid of chemistry must be invoked.

HENRY G. BARBOUR
McGILL UNIVERSITY

THE PRESENT SITUATION IN THE RADIUM INDUSTRY[1]

DISCOVERY OF RADIUM

THE discovery of X-ray in 1895 by Roentgen paved the way for the discovery of radioactivity which occurred about a year later. Becquerel, stimulated by the observations of Roentgen, investigated the field of phosphorescent light and found that phosphorescent uranium compounds emitted a type of radiation similar to X-ray in that it traversed material bodies.

This property of uranium salts was later found to be due to the disintegration of the uranium atom and not to phosphorescent light, and this eventually led to the discovery of the entire uranium series consisting of fifteen radioactive elements.

UNITED STATES THE PRINCIPAL PRODUCER IN THE PAST

Although radium has been found in many countries of the world, including Bohemia, Portugal, Australia and England, the United States has been the principal producer.

It has been estimated that 150 grams of radium, costing approximately $20,000,000, have gone into consumption to date in the United States, of which 90 per cent. has come from the carnotite ores of southwestern Colorado and southeastern Utah, which clearly shows the commanding position the American industry has enjoyed. This industry is naturally exceedingly young, not having existed more than fifteen years. During this time about ten domestic companies have engaged in the production and sale of radium. Last year five companies were still operating.

In spite of the youth of the industry, approximately $10,000,000 have been expended by American companies, this capital being entirely represented by mines and plants.

PROBLEMS OF AMERICAN PRODUCER

American carnotite ore is low grade, running about 2 per cent. uranium oxide content. The deposits, although extensive, are spotty and must be prospected by means of the diamond drill. It is true that the ore occurs near the surface, but after it is mined it has to be hand-sorted, put in canvas bags, packed several miles by mules to a motor truck line, hauled by motor truck to a narrow gauge railroad line, transferred from narrow to standard gauge and transported to Denver. The cost per ton varies between $40 to $70 depending on the location of the ore and on 2 per cent. ore; this means that 98 per cent. of these high freight rates is paid on sandstone.

As ore bodies are widely scattered, and as one pound of acid is required to treat each pound of ore, it would not be profitable either to treat the ore at the mines or to put up a mill for water concentration.

Besides the physical difficulties of prospecting and of transporting the ore to the plant, exceedingly complicated chemical problems are met with in the treatment of the ore, 200 to 400 tons having to be treated to produce one gram of radium. This can be understood when it is remembered that radium is a disintegration product of uranium, there being only one part of radium to 3,200,000 parts of uranium in any ore.

Never a year went by but rumors were circulated of the discovery of rich deposits of radium-bearing ore which would put the American producer out of business and these rumors had to be carefully investigated at heavy expense.

RADIUM IN THE BELGIAN CONGO

Strange to say, during all this time deposits of radium bearing ores, many times as rich as the American carnotite ore, existed in the Belgian Congo.

These ores were discovered in 1913 near Elizabethville in the province of Katanga, in the course of prospecting work which was being done on the Luiswishi copper owned by the Union Miniere de Haut Katanga, a powerful Belgian corporation.

Shortly after the discovery and before any commercial operation of the deposits could be attempted, the war broke out and the Union

[1] A paper given before a joint meeting of the American Chemical Society, the American Electrochemical Society and the Société de Chimie Industrielle, New York Sections, February 9, 1923.

Miniere found its technical and commercial staff depleted. In addition, it was forced to increase its output of copper to 40,000 tons per year for use by the allied countries and these conditions temporarily prohibited the exploration and development of the radium properties.

It must also be remembered that the outcome of the war could not be accurately predicted; hence the Belgians endeavored to keep their discoveries secret, thinking that should the war be lost they might still control the output of radium.

After the war, the company recruited its staff and commenced development. The policy of secrecy was still maintained, however, and no announcement was published until the largest plant in the world for treatment of radium ore had been completed at Oolen, Belgium, and the Belgian company was in readiness to start production.

RESULT OF BELGIAN COMPETITION

The announcement of the Belgians was received by American producers with considerable concern; hence when the Belgians invited two of the large American companies to confer, they were quick to send their representatives to Belgium.

It was immediately recognized that the African deposits must be of considerable size to warrant the erection of the Oolen plant, in spite of the fact that this plant could be used for other purposes than the treatment of radium ores.

While it is true that the Belgians must transport their ore 2,000 miles down the Congo River, across the ocean to Antwerp and thence by rail to Oolen, this procedure is much more economical than endeavoring to treat the ore in the heart of Africa, and notwithstanding this long haul, Belgian radium can undersell the American product by a large margin.

The conference between the representatives of the American companies and the Belgians resulted in The Radium Company of Colorado forming a joint selling organization with the Belgians, and the new company will market radium throughout the world.

With the appearance on the market of the Belgian product, the American mines shut down and the price of radium dropped to $70 per milligram, the lowest price on record.

The question of a tariff to protect the American radium industry naturally occurred to the American producers and although the difficulty of obtaining protection was realized, the moral issue at stake was really the factor which decided against action in this connection. The world needs radium to combat cancer and it was recognized that the lower the price the more widespread would be the use of this valuable agent.

RADIUM PRESENTS DIFFICULT SALES PROBLEMS

The sale of radium is a most complicated problem. Radium therapy is a new science and the first essential is to bring home to the doctor the value of radium in the treatment of various conditions and for this purpose medical departments are maintained. These departments publish periodicals containing the latest articles on the therapeutic use of radium and act in a general consulting capacity to doctors using or contemplating the use of radium.

Once the doctor is convinced of the value of radium, the work is but half done. Radium is a dangerous agent and must be handled with great care. Hence the American companies were obliged to dot the country with postgraduate schools qualified to give adequate instruction to the purchasers.

Again there is the question of instruments for the therapeutic application of radium and the companies have had to maintain elaborate medical research departments to devise and manufacture the most efficient accessories possible. No doubt these departments do some of the most precise work being done to-day, although the volume of their output is comparatively limited.

Besides these special departments, the commercial companies have had to maintain elaborate chemical and physical departments and hence the Belgians have gained a large advantage by being able to draw on the accumulated technical and sales knowledge of their American associate. The net result of the consolidation will undoubtedly result in as cheap and probably cheaper radium than had the consolidation not taken place.

METHODS OF MANUFACTURE AND PRECAUTIONS REQUIRED

Just a brief sketch of the methods of producing radium from the American carnotite ore and precautions required may be of interest.

The ore is crushed, the radium leached out and the solution treated with sulphuric acid to precipitate the insoluble radium barium sulphate. This precipitate is changed into the soluble carbonate and this resulting solution is converted into the bromide and that in turn into the chloride. Radium always occurs with barium and a physical property of the radium chloride is used to separate it from barium chloride as the former is less soluble in saturated solution than the latter. About 2,200 separate crystallizations are required to produce radium chloride of 95 per cent. purity.

Large fans are in constant operation over the vats containing the radium liquors. These serve to drive off the gaseous emanation and prevent it from breaking down and depositing in the immediate vicinity as radium a, b and c which are solids and which give off destructive rays.

There is no particular danger in handling radium sulphate freshly precipitated, as it does not start disintegrating to any appreciable extent for three or four days after precipitation. Therefore preparations of these salts can be made up with comparative safety.

Continued handling of radium preparations lowers the blood count and produces a general anemic condition. Because of this fact, the United States Bureau of Standards and the commercial companies take the blood count of their employees regularly. If the employee's health has become impaired, he is given a vacation, away from radium, to enable him to recuperate.

COMMERCIAL USES OF RADIUM

You will have gathered from some of the previous statements that one of the chief uses of radium is in the medical profession.

It was early discovered that radium broke down successively into radium emanation, radium a, radium b, radium c and radium d, gaining equilibrium with these decay products in approximately 30 days. During this process of disintegration, three rays are given off—alpha, beta and gamma. The first has little penetrating power and is stopped by a sheet of paper. The second is more penetrating, while some of the third will penetrate ten inches of steel. Shortly after the discovery of radium it was found that the last two rays were destructive to certain kinds of cells and the medical use of radium in the treatment of various conditions is built around this susceptibility of the cell to the action of radium rays.

Many different conditions are treated by radium, including cancers and tumors, although radium is also used in much less serious conditions; for example, the removal of birthmarks, warts and tonsils.

At present extensive work is being done on cancer. Except in very advanced cases, this disease can be arrested, but the big problem is to prevent its recurrence. In case it does not recur in ten years, it can be considered to have been cured. Ten years, however, is a very long time for experimental purposes, and interesting experiments are now being carried on with mice and flies. If the disease does not recur in ten weeks in the case of mice, it has been eradicated, while in the case of flies, the time can be measured in days. Hence these experiments will shortly give knowledge which would require an exceedingly long time to acquire by the treatment of human beings.

Two general methods are being followed today in the use of radium in medicine. The first is the use of radium sulphate put up in needles, tubes and plaques. The needles most widely used are the 10 milligram non-corrosive steel needle having a diameter of 1.5 millimeters and a length of 29 millimeters (about the width of a pin head and a trifle longer than the ordinary pin), and the 5 milligram needle having the same diameter with half the length. The barrel of these needles is bored out to provide a radium chamber into which the radium is inserted. Asbestos packing is then placed next to the radium, the eye is inserted and then soldered into place.

In the treatment of disease these needles are buried directly in the affected tissue and left until the required radiation has been delivered.

The tubes employed are made of glass, filled with radium, sealed, and are usually enclosed in small metal capsules which are placed against the tissue to be treated.

Plaques are flat surface applicators containing a fine layer of radium salt underneath a layer of non-corrosive steel, the latter being usually about one tenth of a millimeter in thickness. This permits a large proportion of the hard beta rays to pass, these rays being beneficial in many skin conditions.

An adequate initial supply of radium for the individual doctor would be about 100 milligrams, costing around $7,500, including applicators which are now furnished without charge with the radium. As radium has a half life period of 1,760 years, this amount would decay to 50 milligrams in that time. Hence for all practical purposes it is everlasting.

Insurance rates on radium in the forms mentioned are relatively high, amounting to about 2½ per cent. per annum. These high rates are due to the chances of loss surrounding the use of the element as above mentioned.

A second method is the use of radium emanation which is the first disintegration product of radium and a gas. This necessitates the use of a solution of some radium salt, preferably the bromide, which is unstable. The radium solution is usually placed in a closed container in a safe with a tube leading to a pumping and collecting apparatus, the gas being pumped off and collected in fine glass capillary tubes. These are sealed off by flame and imbedded in the tissue-like needles except that needles are extracted while the glass spicules are left in. The radioactivity in these spicules loses 16.5 per cent. of its activity the first day, 16 per cent. of the balance the second day, and so on, becoming entirely inactive in 30 days.

The minimum quantity of radium necessary for this technique plus the cost of an emanation apparatus would run at to-day's prices in the neighborhood of $40,000. Insurance charges on the radium in this form are less than on needles, tubes and plaques, being about ½ per cent., but there is the added cost of keeping a trained physicist to collect and measure the emanation. However, this method, supplemented with needles and plaques, would be extensively used were it not for the large initial cost.

One of the properties of the radium rays is that they ionize a gas and this property is used in making measurements by means of the electroscope instead of using the weight measure which would be impractical with such minute quantities. Radium is usually sold on United States Bureau of Standards certificates as to amount of radioactivity present as determined by the electroscope, the radium companies guaranteeing the purity of the radium. Determination by the electroscope is exceedingly accurate and Soddy has stated that if half a grain of radium bromide were divided equally among every human being in the world, one such portion could be detected.

The second largest use of radioactive substances is in the manufacture of luminous material for a variety of uses, such as for watch dials, electric switches, pendants and novelties. Here again the rays emitted by radium are made use of. Zinc sulphide crystals when bombarded by radium rays become luminous and a compound of this substance and a radioactive element is mixed with varnish and applied to the area where the luminosity is desired. The life of these luminous substances is roughly from two to ten years, depending on the quantity of radioactive substance present. Zinc sulphide crystals break down under the constant bombardment, so the greater the luminosity the shorter the life.

The radium companies get out a spinthariscope for display purposes. This is a short metal cylinder about one inch high and half an inch in diameter. In the bottom is placed about one twentieth of a cent's worth of radium mixed with zinc sulphide crystals, and when this is viewed in the dark room through a lens at the top of the cylinder, a myriad of tiny flashes can be seen. Were it not for the destruction of the zinc sulphide crystals these flashes would continue for 2,500 years, which gives an idea of the size of the atom. Rutherford has calculated one gram of radium in equilibrium with its decay products emits 140,000 billion alpha particles per second.

THE FUTURE OF RADIUM

The future of radium in the medical and luminous material field is assured. As to other future uses it would be idle to speculate. Certainly its properties as a catalyzer and ionizer are worth careful investigation. Here is a substance combining infinitesimal bulk with maximum energy. Those who are engaged in the radium industry would not be surprised to see this substance in use in many commercial fields within the next few years. As a matter of fact, its ionizing properties are now being tried out by several companies along commercial lines.

H. E. BISHOP

EASTERN MANAGER,
RADIUM COMPANY OF COLORADO

CHANGES IN LONGEVITY OF AMERICANS IN THE LAST DECADE

EVIDENCE was given by the writer in the issue of SCIENCE of July 7, 1916, in the form of abridged mortality tables to show that the average length of life has been increasing for the whole span of life for both sexes of the registration area of this country, at least ever since the federal government began to compile statistics which could be safely used in the construction of such tables. The same tables showed also, however, that this improvement in longevity was being realized in spite of a deterioration or retrogression at certain advanced ages and that the average length of life corresponding to those advanced ages was less in 1910 than it had been for at least twenty years. The record of the females seemed, however, to be a little more promising than that of the males because the retrogression of that sex was less pronounced in the decade from 1900 to 1910 than from 1890 to 1900 while in the case of the males it was a little more pronounced except that, as also in the case of the females, slight evidence appeared in the last decade of a "come back" at the extremely advanced ages.

The purpose of this paper is to extend the results of the paper just mentioned to include those of 1920. It will be noticed that the record of both sexes shows remarkable changes. Although the explanation of the method[1] of constructing abridged mortality tables and the mortality tables themselves are omitted here it should be said that whereas the populations were necessarily changed slightly during the earlier investigation in order to include the year 1890 this investigation includes only the years 1900, 1910 and 1920. The mortality tables then were constructed from the population and mortality statistics of each of the three years just mentioned for the ten registration states, Connecticut, Indiana, Maine, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Rhode Island and Vermont. Since the tables are constructed from the statistical data of single years and without any process of smoothing it is well to repeat the statement of the earlier paper that no claims are made in regard to the accuracy of the absolute results. Attention is called merely to the *trend* of the death rates and longevity. Moreover, it is obvious that the conclusions of this paper refer particularly to the populations of the states included in the investigation but should apply in a general way to populations of states of the same general geographical area. The abridged list of death rates and corresponding differences are as follows:

DEATH RATES PER 10,000

AGES	1900	DIFF.	1910	DIFF.	1920
			FEMALES		
10	39	—9	30	—4	26
20	58	—15	43	+3	46
30	83	—20	63	+6	69
40	98	—14	84	—3	81
50	143	—11	132	—10	122
60	262	+2	264	—15	249
70	549	+20	569	—1	568
80	1206	+44	1250	—25	1225
			MALES		
10	39	—7	32	—2	30
20	60	—12	48	—3	45
30	83	—13	70	—8	62
40	109	—3	106	—23	83
50	159	+8	167	—35	132
60	293	+22	315	—34	281
70	606	+27	633	—29	604
80	1323	+45	1368	—36	1332

There is substantial agreement of the results of this paper and of the earlier paper cited above for the decades covered by both papers although it will be noticed on comparison that the ages considered are different. Thus, the death rates of females decreased for ages 50 and below but increased at the higher ages for the decade 1900 to 1910. In the decade from 1910 to 1920, however, two remarkable results are to be noticed. First, there is a substantial decrease in death rate at that period of advanced ages at which there has always been a retrogression. Second, an unexpected retrogression in the neighborhood of ages 20 to 30 is indicated. The latter is surprising because both males and females have never before in the previous twenty years failed to register a significant reduction in the death rate at all the earlier ages. It is especially surprising that this retrogression should occur among the females when we recall that the females al-

[1] October, 1919, Bulletin of the American Mathematical Society.