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THE SIGNIFICANCE OF RADIUM[1]

WE are met to-night to honor a discovery and the discoverer, and we are doing it in a way which I am sure delights her soul as much as it does mine. The custom of mankind, when it would do honor to one who has had the good fortune to be of service to his fellows, is to make a hundred thousand dollar parade, or to fire a hundred thousand dollar salute, or, in rarer instances of sounder judgment, to build a hundred thousand dollar monument. Compare that sort of an expenditure of the fruits of human toil with the glad donation which you are making to-night of a hundred thousand dollars, not merely for the alleviation of suffering and the arrest of disease—that is important—but for something which is vastly more important and more fundamental than that, namely, for the purpose of making it possible to peer farther into the secrets of matter, for upon that vision and the control of nature which that vision must precede depends the weal or woe of our children and our children's children for countless generations.

I wish to add a second element of uniqueness to this occasion. Knowing Madame Curie, as I have had the good fortune to do, I am sure that she would not wish me to speak a word of fulsome praise or to picture her as a superman; she is that because she is a woman, but not because she has had the capacity and the good fortune to make discoveries of the first importance. It is a common and a pathetic spectacle to see military, political, and social leaders who come conspicuously into the public gaze, lose their sense of perspective and begin to regard themselves as holding a commission from the Al-

[1] An address delivered at the National Museum, Washington, D. C., on the evening of May 25, in connection with the presentation of a gram of radium to Madame Curie.

mighty. I have never known a great scientist to make that blunder. And there ought never to be one who makes it because the business of science is to see things as they are. Madame Curie has always remained simple, modest and unaffected in the face of the world's applause. That is the highest compliment which a fellow scientist can pay her, and the surest sign that she is not an ordinary person. With that I have paid my tribute of respect and honor and admiration to the discoverer.

Now for the discovery. How did it come about? What is it? What is its significance immediate? What is its significance remote and far-reaching? In order to answer that series of questions I wish to begin by disabusing your minds of the idea, if they harbor it, that a discovery in science is an isolated event. A science grows in the main as does a planet by the process of infinitesimal accretion. Practically every experiment in physics is a modification of an experiment which has gone before. Almost every new theory is built like a great mediæval cathedral, through the addition by many builders of many different elements, one adding a little here and another a little there so that to the eye of a distant observer in the clouds the whole structure seems to move forward in a practically continuous way. Even when you get close up and begin to see the discontinuities, for they are there, each experiment in the development of a given field of science is found to have a pedigree just as truly as has a race horse. Man-o'-war did not develop his marvelous speed in one generation. A dozen sires and dams contributed to that result. In precisely the same way, when in 1896 Henri Becquerel, professor of physics in the University of Paris, discovered the new, extraordinary property which certain types of matter were found to possess and which was named radio-activity, that discovery was sired by one made a year before by Roentgen, and Roentgen's was sired by Leonard's, and Leonard's by that of Hertz in 1886, and Hertz's by the work of Maxwell, and Maxwell's by that of Faraday in 1831, and Faraday's by that of Oersted in 1819, and Oersted's by Volta's, and Volta's by Franklin's, and so on without limit. And the point to which I wish to call your attention now is that it is of incalculable importance that there should be people like those who have given this gramme of radium to Madame Curie who have a vision that extends, not to this generation only, but to the generations that are to come a hundred, two hundred years ahead, and who consciously set about starting such a train of scientific discovery and progress.

But for our present purpose I wish to break into this chain of scientific development at the discovery by Professor Becquerel of this extraordinary phenomenon of radio-activity made in the physical laboratory in which Madame Curie had been studying for some years. The discovery itself was really a simple thing, as are practically all great discoveries. The year before Roentgen had found his X-rays, as he called them, which had the peculiar property of making it possible for one to see his own skeleton. That attracted the world's attention and Professor Becquerel was endeavoring to see whether rays that would penetrate in that fashion could be produced from other sources. He naturally took uranium, because of its fluorescent property, to see whether it, under the action of light, might perhaps transmute the light waves into penetrating waves of the kind Roentgen had obtained. What did he find? He tried it in the light and he tried it in the dark, and he found that it was not necessary to have light at all, but that a bit of uranium put away in a black paper on top of a photograph plate, itself would blacken the plate. In other words, there was a property of self-activity in that uranium. It emitted rays of some kind which would affect a photographic plate and discharge an electroscope. The discharge of an electroscope, in popular language, is simply this: When you comb your hair on a cold winter day and it stands out in all directions, it is because it becomes electrically charged. If now a bit of radioactive substance is held above your head, your hair will fall down again, *i.e.*, your electroscope will be discharged. The laboratory electroscope is merely a gold-leaf which stands out like your hair when it is charged and collapses when it is discharged. The electroscope then became the chief agent by which radio-activity could be tested, and Madame Curie with her husband—for she had been married the year before to Pierre Curie, professor of chemistry in the University of Paris—began the study of other substances than uranium to see how general this new property was, and they found that the two heaviest elements in nature, uranium and thorium alone of the then known elements, possessed it, but they also found that the natural ore of uranium, which we commonly call pitchblende, and which is more than fifty per cent. uranium oxide, although it contains many other minerals like barium and lead and bismuth—that this pitchblende discharged the electroscope approximately four times as fast as did pure uranium oxide. This meant, as the Curies at once interpreted it, that there must be some hidden elements in the pitchblende which had the same radio-active property as uranium but in larger degree. And so they began the search to see if they could not separate the element which was responsible for that activity, and after two or three years of arduous work Madame and Monsieur Curie were able to announce that, by using the ordinary methods of chemical analysis, by making precipitates and testing the activity both of the precipitate and filtrate to see with which the activity went and therefore what were the chemical properties of the substances that had it, they had been able definitely to discover the existence of these two new radioactive elements of which Dr. Walcott spoke. The first of these did not exist in sufficient amount so that it could be detected by any other properties than its activity. This was named polonium, in honor of the land in which Madame Curie was born, for her father was a professor in the Technische Hochschule at Warsaw. This polonium, by the way, has been one of our most useful agents in getting at the inner properties of the atom, because is has the power of emitting one type of ray alone and not a mixture of rays as does the other and more famous radio-active element which the Curies discovered. This other new element they named, appropriately, radium because it had a radio-activity a million times, weight for weight, that of the pitchblende, and three or four million times that of pure uranium.

This is the simple, unadorned tale of the discovery of radium, but I am sure you do not appreciate the kind of painstaking research and labor which that simple tale represents. You may perhaps get a little glimpse of what it means—of what a search for a needle in a haystack it was—when I say that the amount of radium in uranium is one part in 3,200,000; or that, in order to get the little gram of radium which is being presented to Madame Curie to-day it was necessary to take 500 tons of Colorado carnotite ore, which possesses two per cent. of uranium and to treat it with 500 tons of chemicals, apart from water and coal. So that, you see, the problem of bringing to a successful issue that search was one that places Madame Curie and her husband in the front rank of the world's scientific men and women.

The Nobel prize for 1903 was awarded jointly to Henri Becquerel and Monsieur and Madame Curie for their studies in radioactivity, and in 1911 the Nobel Prize was awarded to Madame Curie alone for isolating radium—getting it as a pure metal (in the early experiments it was a bromide or chloride), and for determining its atomic weight, which comes at 226.0. The heaviest element, uranium, has an atomic weight of 238, so that this is only twelve units lower than that.

So much for the way in which the discovery came about. But what is radio-activity? Perhaps I can tell you in as few words as possible by this simple statement. This gram of radium which you are giving to Madame Curie to-day, the volume of which is just that which I hold in my hand, and which you can see when the room is darkened—that gram of radium is continuously shooting off per second 145,000 billion particles which we call alpha particles, and with speeds which reach the stupendous value of twelve thousand miles per second. Now, when you recall that the super-guns which bombarded Paris could not eject a projectile with a speed of more than about a mile per second, you see how feeble imitations of nature we have as yet been able to produce. No band of Mexican bandits running amuck on a Texas town can compare for a moment with a colony of radium atoms which perpetually bombard their neighbors with broadsides having muzzle velocities of 12,000 miles per second. Not only that; these atoms of radium have lighter ordnance also. They shoot off in addition each second 71,000 billion particles that are one eight-thousandth as heavy as these particles which I have called the alpha particles, and which are essentially helium atoms. If we call these alpha particles the 13-inch guns of the radium atoms, then we might say that they have also seventy-five millimeter guns which shoot off relatively light projectiles. These, however, have a speed which is more than ten times as great as that of the alpha particles. We call them beta rays. They are simply free negative electrons, endowed with a speed which is close to the speed of light, namely, close to 186,000 miles per second. But even that is not all. There is still one other type of rays that are being given off by this gram of radium. These other rays are the wireless waves of the denizens of the sub-microscopic world. They are ether waves just like light or just like wireless waves, except that the vibration frequency—the number of oscillations per second which the electronic inhabitants of the atom send off—amounts to thirty billion billions per second. These are the so-called gamma rays.

Now as to penetrating powers. The alpha rays or helium atoms, shoot right through the walls of a thin glass tube just as though there were no wall there at all, and that, in itself, has thrown new light on the structure of matter. It has shown us that the atom is itself an existence which is mostly empty space. It is like a miniature solar system through which it is entirely possible for a new satellite or planet to shoot without meeting anything. One of these alpha particles shoots on through hundreds of thousands of atoms before it is brought to rest. It goes through seven centimeters of air which is of the order of a third of a foot. That is as far as the heavy projectiles which are shot off from the radium atoms can go. The lighter ordnance shoots a hundred times as far and the gamma rays are a hundred times more penetrating still. I have thought you would be interested in actually seeing for yourselves the effects of these rays. I shall show first the effect of the gamma rays because, being those that are used in therapeutics, they are the ones you are most likely to be interested in. The gamma rays are simply ether radiations of very short wave-length, and whenever they pass through the atoms of matter they have the extraordinary power of ejecting with great speed from these atoms the electrons which are contained within them. And when these electrons pass in turn through other atoms they knock new electrons out of these atoms and thus put many of them into a condition in which they can make new combinations more readily than when they are not thus "*ionized.*" Now there can scarcely be any doubt that the therapeutic effects of radium are simply due to the fact that these ionized atoms have been put into a condition to make new chemical unions, *i.e.,* to produce new substances which are destructive of the normal tissues as well as of the cells of the disease which it is desired to destroy. But in some instances, at least, the disease is more susceptible than are the normal cells and consequently it becomes possible to arrest the growth of those disease cells. As a matter of fact, so far as the therapeutic effects of radium are concerned, the doctors who are in charge of the radium institutes will all tell you that you must not regard radio-active treatment as a cure for cancer. The only cure for cancer—the only certain cure—is surgical. Nevertheless, the effects of radium rays are to retard the growth of the malignant tumors and therefore to prolong life, so that, even in the case of cancers which are not capable of being operated upon—deep-seated concers—life can often be prolonged several years by radium treatment.

The medical specialists will also tell you that there are certain types of superficial tumors and skin diseases which can be permanently and effectively cured, so that this kind of treatment has already been of sufficient use in therapy so that all who are familiar with it are at one in believing that it is highly desirable to introduce in all large centers of population these radium and X-ray hospitals of the kind which exist in Boston, New York, Chicago, Buffalo, Los Angeles, and several other cities, and which Paris is now to have because of the gift which you are making to Madame Curie.

The electroscope which by looking at the inverted image upon the screen you now see discharging rapidly under the influence of the gamma rays from the radium, is exposed only to the rays which have passed through more than a half inch of lead; for the radium is completely enclosed in lead walls of that thickness. This gives you some idea of the marvelous penetrating power of these gamma rays. I now wish to show you some of Dr. C. T. R. Wilson's photographs of the actual tracks of the alpha, beta and gamma rays through air. After seeing these straight line tracks of the alpha and beta rays you will not doubt that radium is actually shooting off big and little projectiles of the kind I told you about. The wiggly, snaky tracks due to the gamma and X-rays are perhaps even more interesting and enable you to visualize somewhat what goes on in your body when you are taking X-ray treatment. Can you now wonder that these rays tend to destroy the tissues and to produce burns?

Now a word as to the significance of this radio-active process. The therapeutic significance I have already referred to, but from my point of view the insight which radium gives into the nature of matter is of vastly more importance than any possible effects it has in the cure of disease or in the alleviation of pain. Twenty-five years ago if we had been told that any kind of matter possessed the property of throwing out projectiles with these enormous speeds we would have said "impossible." But not only in the enormity of the speeds of these projectiles is radium astonishing and revolutionary. There is something sublime about its ceaseless, unaltering and apparently unalterable activity, its complete indifference to intense heat or to extreme cold, to electrical or to chemical treatment of any kind. It is a property of the atom itself which we can not at present control in any way.

But the third effect of this discovery is more important still, for what does it show that matter is doing? These alpha particles which are being shot off are portions of the atom of uranium or of the atom of radium and the thing which is left after the ejection of the alpha particle from an atom of uranium is no longer uranium. Its chemical and physical properties have entirely changed. The uranium atom in shooting off one of these alpha particles is thereby transmuting itself into another element. When it has shot off three alpha particles it has transmuted itself into radium, and when it has shot off five more it has transmuted itself into lead. We have seen in the laboratory the growth of lead out of uranium, and have followed the whole chain of transmutation of elements through this radio-active process. This necessitates a conception of the nature of matter which was absolutely foreign to our thinking in the nineteeenth century, and it is revolutionary in its significance. It means that these "eternal" elements—this radium and this uranium which we have here—are not eternal at all. The average life of the atoms of this radium is just 2,500 years, and after that time the average atom will have disappeared as radium, and if the world's supply of radium has not then mostly disappeared it will be because new radium is being produced all the time out of uranium. But uranium is the heaviest element we know of, and what is happening to it? It too is disappearing. But whence came it? It is true that the average life of the uranium atom is approximately eight billion years, so that when you go back so far as that, you may be inclined to say that it doesn't make much difference to this particular Republican administration where it did come from. Ah, but wait! In your thinking you have been forced to admit for the first time in history not only the possibility but the fact of the growth and decay of the elements of matter. With radium and with uranium we do not see anything but the decay. And yet somewhere, somehow, it is almost certain that these elements must be continually forming. They are probably being put together now somewhere in the laboratories of the stars. That is still something of a guess, it is true, and yet the spectra of the nebulæ show that they contain only the lighter elements. Can we ever learn to control the process? Why not? Only research can tell. What is it worth to try it? A million dollars? A hundred million? A billion? It would be worth that much if it failed, for you could count on more than that amount in by-products. And if it succeeded—a new world for man! But what have we got already through the discovery of radio-activity? An immensely stimulating new conception of the universe and of the way matter is behaving.

Next the significance of radium with respect to the question of the availability of energy. The amount of heat given off from one gram of radium in disintegrating into lead is 300,000 times as much as the amount of heat given off in the burning of one gram of coal. There is, then, in the radium a supply of sub-atomic energy, and this raises the question as to whether such energy exists locked up in other atoms and as to whether there is any possible way we can get at it? Do not be too sanguine about it as far as radium is concerned, because if all the radium at present in the world were set to work, although it is 300,000 times as potent as coal per gram in giving off energy, it would not suffice to keep the corner popcorn man's outfit going. It does not exist in sufficient quantity.

But what has its discovery done then in the field of energy? It has opened our eyes to the fact that certain kinds of matter certainly possess these stores of energy and it is almost a foregone conclusion that similar stores are also possessed by the atoms which we have not yet found to be changing—which are not radio-active. The astronomer has for years been completely puzzled to account for enormous amounts of energy which the sun and stars emit. He has not been able to find its source. It is impossible that the sun is simply a hot body cooling off, because we have evidence that it has lived longer than it could have lived if that were the case. The astronomer has now, however, seized upon the facts of radio-activity and surmises that these sub-atomic energies may be the source of the sun's radiation. If so the supplies are not so limited as we thought.

Look now at another side of this same problem. I am thinking particularly of the work of Professor Joly and Lord Rayleigh, who have made measurements of the amount of radio-activity of the ordinary surface rocks. Professor Joly has computed that if there are two parts of radio-active material for every million million parts of other matter throughout the whole volume of the earth, and this is considerably less than he has found on the average in the earth's crust, then this earth, instead of cooling off, is actually now heating up; so that in a hundred million years the temperature of its core will have risen through 1,800 degrees centigrade. That is a temperature which will melt almost all of our ordinary substances. What does it mean? It means that the life history of our planet is perhaps not at all what we have heretofore thought that it was. It means that a planet that seems to be dead, as this our earth seems to be, may, a few eons hence, be a luminous body, and that it may go through periods of expansion when it radiates enormously, and then of contraction when it becomes like our present earth, a body which is a heat insulator and holds in its interior the energy given off by radio-active processes, until another period of luminosity ensues. What I am now pointing out is the growth in our conception of the world, the growth in the thoughts of men that has come out from these studies. Do not think that this is not of importance. When Galileo discovered the moons of Jupiter he was doing just about as useless a thing from the standpoint of its immediate applicability to human relations as he could have found to do. And yet what did he actually accomplish? He started off the train of thought, the mode of attack upon physical problems which has made this industrial age what it is, and therein lies the tremendous significance of a discovery of the kind which we are honoring to-night.

We are so close to this age in which we live that we do not see what it means; we do not see it in its relation to other centuries. And therefore I should like to take you up in an Einstein airplane that violates all the relations of space and time so that you may see with me a few spots in geography and in time. Suppose we sail first, in the present, to the banks of the Tigris or Euphrates and see a picture which Professor Breasted drew to my attention when he came back from a recent mission to the near east. He pictured the inhabitants of that region tilling the ground with a crooked stick, bringing their hard-earned produce to the shores of the river, putting it on crude rafts which were made from the skins of goats and sheep, and paddling it laboriously across to the other side. Then he threw on the screen a photograph of an ancient Babylonian tablet which showed the inhabitants of that region four thousand years ago doing exactly the same thing in exactly the same way. Four thousand years without a bit of progress—each generation simply following the last in living a miserable existence, reproducing its kind and then passing on. Leave that! It is a discouraging picture.

Fly over into India and see this! I heard last winter Mr. Sam Higinbotham describe the conditions prevailing in that land now, where, as he said, millions of men go out into the fields in the morning with only a handful of grain—all they have to eat for the day; work a long day in perpetual hunger and feel that they would be perfectly happy if they could get all they wanted of such raw grain to eat. What wonder that Heaven for these men is Nirvana—the escape from existence!

Now fly over China. To do so, you have only to look at the sign in front of this museum: "Millions starving to death in China unless they can get help from this western world!" Discouraging pictures! What is wrong with the world? Fly back to this country and perhaps the following sights may suggest an answer. Circle above the Mississippi near New Orleans, and contrast what you see with the picture on the banks of the Tigris. See a train on the Southern Pacific Road bearing five hundred tons of produce from Texas, pulled upon a great ferry without even uncoupling the engine. See it in fifteen minutes on the other side ready to distribute its huge load of food stuffs raised with the aid of automatic planters, tractor-plows and steam threshers on the broad plains of the west, to the millions of inhabitants in the eastern half of our country. Or, again, fly over the biggest copper mine in the world which is near Salt Lake City and look at a mountain of two per cent. copper being shoveled away by great steam shovels with comparatively little human labor. See forty thousand tons a day of ore pulled in huge hundred-ton cars a few miles to the mill. Then see one of those huge cars elevated, wheels and all with no apparent human assistance, sixty feet high, turned slowly over and made to dump its load of ore into the mighty mill where a great, senseless, iron Cyclops grinds it into powder. Then watch the unseen natural forces of cohesion and adhesion in the flotation process pick out the ore from the gangue, without human aid, though controlled by human brains, and thus produce from sources altogether unusable fifteen years ago, the cheapest copper which the world has ever seen, the copper with which you are now harnessing new water power and building new electric railroads across the continent, with which famine is made an impossibility in any part of these United States.

Now, what is the most essential and most significant element of difference betweeen the two pictures which you have seen, the one here, the other half way around the earth? In this country, where the giant forces of nature have been set at work, the cheapest paid laborer on a building or in a steel plant, or on a farm, got before the war for eight or nine hours of labor, and he gets now, more than twenty times as much, not merely in money but in actual goods to be purchased with his money, as does that man in India or in China. In other words, the common, unskilled laboring man in America has more than twenty slaves, but they are senseless, iron slaves, each of the same effectiveness as a common Indian laborer, who are doing his work for him. Why? Because Galileo and a few men like him a few hundred years ago got the idea that it was important to study out how nature worked. It is that study which has resulted in this modern scientific and industrial age. And it is only in the regions of the earth where that idea has got started, namely, in Western Europe and in this country, where the conditions under which the average man lives and works have been thus alleviated. Note that I say "have been" not "are to be." True, they may be immensely more improved than they are now. I can see little, immediate, practical needs as well as you. But let us not yet alight from our airplane. When you look at what *has already be done* by the advance of modern science—by getting an idea into a few men's minds—you begin to see that, after all, the important thing in this world is not the immediately practicable; the important thing is the growth of the human mind, the development of a few big ideas. Other things come from that, and therein lies the far-reaching significance of the experiments with radium; they have opened our eyes to new possibilities; they have given us a new conception of the growth and decay of the elements, and of the possibility of the human control of these processes; they have revealed the existence of new sources of energy which some time we may hope to be able to tap, and with the aid of which we may perhaps enrich human life in as yet undreamed of measure.

The first step is to see whether it is possible by any means at our control, to disintegrate atoms. And we have already found that we can do it, and radium has helped us to make that discovery. But we have only begun on this type of work. Its possibilities are untold.

From my point of view there are two things of immense importance in this world, two ideas or beliefs upon which, in the last analysis, the weal or woe of the race depends, and I am not going to say that belief in the possibilities of scientific progress is the most important. *The most important thing in the world is a belief in the reality of moral and spiritual values.* It was because we lost that belief that the world war came, and if we do not now find a way to regain and to strengthen that belief, then science is of no value. But, on the other hand, it is also true that even with that belief there is little hope of progress except through its twin sister, only second in importance, namely, belief in the spirit and the method of Galileo, of Newton, of Faraday, and of the other great builders of this modern scientific age—this age of the understanding and the control of nature, upon which let us hope we are just entering. For while a starving man may indeed be supremely happy, it is certain that he can not be happy very long. So long as man is a physical being, his spiritual and his physical well-being can not be disentangled. No efforts toward social readjustments or toward the redistribution of wealth have one thousandth as large a chance of contributing to human well-being as have the efforts of the physicist, the chemist, and the biologist toward the better understanding and the better control of nature.

Finally, the most significant thing about this evening is the way in which this contribution to further progress has been made: Not through a public grant—that is not the method through which the genius of Anglo-Saxon civilization has ever expressed itself, but rather through private initiative. A large group of public-spirited people have, of their own free will, decided that they wished to have a part in the development of a new chain of scientific discovery. It is that spirit and that method which has made America what it is, and it is in the spread of that sort of intelligence among one hundred million people that our future lies.

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