CHAPTER V
THE DREAM BECOME A REALITY. THE DISCOVERY OF RADIIAM

I HAVE already said that in 1897 Pierre Curie was occupied with an investigation on the growth of crystals. I myself had finished, by the beginning of vacation, a study of the magnetization of tempered steels which had resulted in our getting a small subvention from the Society for the Encouragement of National Industry. Our daughter Irène was born in September, and as soon as I was well again, I resumed my work in the laboratory with the intention of preparing a doctor's thesis.

Our attention was caught by a curious phenomenon discovered in 1896 by Henri Becquerel. The discovery of the X-ray by Roentgen had excited the imagination, and many physicians were trying to discover if similar rays were not emitted by fluorescent bodies under the action of light. With this question in mind Henri Becquerel was studying uranium salts, and, as sometimes occurs, came upon a phenomenon different from that he was looking for: the spontaneous emission by uranium salts of rays of a peculiar character. This was the discovery of radioactivity.

The particular phenomenon discovered by Becquerel was as follows: uranium compound placed upon a photographic plate covered with black paper produces on that plate an impression analogous to that which light would make. The impression is due to uranium rays that traverse the paper. These same rays
can, like X-rays, discharge an electroscope, by making the air which surrounds it a conductor.

Henri Becquerel assured himself that these properties do not depend on a preliminary isolation, and that they persist when the uranium compound is kept in darkness during several months. The next step was to ask whence came this energy, of minute quantity, it is true, but constantly given off by uranium compounds under the form of radiations.

The study of this phenomenon seemed to us very attractive and all the more so because the question was entirely new and nothing yet had been written upon it. I decided to undertake an investigation of it.

It was necessary to find a place in which to conduct the experiments. My husband obtained

Pierre and Marie Curie in their laboratory, where radium was discovered.

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from the director of the School the authorization to use a glassed-in study on the ground floor which was then being used as a storeroom and machine shop.

In order to go beyond the results reached by Becquerel, it was necessary to employ a precise quantitative method. The phenomenon that best lent itself to measurement was the conductibility produced in the air by uranium rays. This phenomenon, which is called *ionization*, is produced also by X-rays and investigation of it in connection with them had made known its principal characteristics.

For measuring the very feeble currents that one can make pass through air ionized by uranium rays, I had at my disposition an excellent method developed and applied by Pierre and Jacques Curie. This method consists in counterbalancing on a sensitive electrometer the quantity of electricity carried by the current with that which a piezo-electric quartz can furnish. The installation therefore required a Curie
electrometer, a piezo-electric quartz, and a chamber of ionization, which last was formed by a plate condenser whose higher plate was joined to the electrometer, while the lower plate, charged with a known potential, was covered with a thin layer of the substance to be examined.

Needless to say, the place for such an electrometric installation was hardly the crowded and damp little room in which I had to set it up.

My experiments proved that the radiation of uranium compounds can be measured with precision under determined conditions, and that this radiation is an atomic property of the element of uranium. Its intensity is proportional to the quantity of uranium contained in the compound, and depends neither on conditions of chemical combination, nor on external circumstances, such as light or temperature.

I undertook next to discover if there were other elements possessing the same property, and with this aim I examined all the elements then known, either in their pure state or in compounds. I found that among these bodies, thorium compounds are the only ones which emit rays similar to those of uranium. The radiation of thorium has an intensity of the same order as that of uranium, and is, as in the case of uranium, an atomic property of the element.

It was necessary at this point to find a new term to define this new property of matter manifested by the elements of uranium and thorium. I proposed the word radioactivity which has since become generally adopted; the radioactive elements have been called radio elements.

During the course of my research, I had had occasion to examine not only simple compounds, salts and oxides, but also a great number of minerals. Certain ones proved radioactive; these were those containing uranium and thorium; but their radioactivity seemed abnormal, for it was much greater than the amount I had found in uranium and thorium had led me to expect.

This abnormality greatly surprised us. When I had assured myself that it was not due to an error in the experiment, it became necessary to find an explanation. I then made the hypothesis that the ores uranium and thorium contain in small quantity a substance much more strongly radioactive than either uranium or thorium. This substance could not be one of the known elements, because these had already been
examined; it must, therefore, be a new chemical element.

I had a passionate desire to verify this hypothesis as rapidly as possible. And Pierre Curie, keenly interested in the question, abandoned his work on crystals (provisionally, he thought) to join me in the search for this unknown substance.

We chose, for our work, the ore pitchblende, a uranium ore, which in its pure state is about four times more active than oxide of uranium. Since the composition of this ore was known through very careful chemical analysis, we could expect to find, at a maximum, 1 per cent of new substance. The result of our experiment proved that there were in reality new radioactive elements in pitchblende, but that their proportion did not reach even a millionth per cent!

The method we employed is a new method in chemical research based on radioactivity. It consists in inducing separation by the ordinary means of chemical analysis, and of measuring, under suitable conditions, the radioactivity of all the separate products. By this means one can note the chemical character of the radioactive element sought for, for it will become concentrated in those products which will become more and more radioactive as the separation progresses. We soon recognized that the radioactivity was concentrated principally in two different chemical fractions, and we became able to recognize in pitchblende the presence of at least two new radioactive elements: polonium and radium. We announced the existence of polonium in July, 1898, and of radium in December of the same year.

In spite of this relatively rapid progress, our work was far from finished. In our opinion, there could be no doubt of the existence of these new elements, but to make chemists admit their existence, it was necessary to isolate them. Now, in our most strongly radioactive products (several hundred times more active than uranium), the polonium and radium were present only as traces. The polonium occurred associated with bismuth extracted from pitchblende, and radium accompanied the barium extracted from the same mineral. We already knew by what methods we might hope to separate polonium from bismuth and radium from barium; but to accomplish such a separation we had to have at our disposition much larger quantities of the primary ore than we had. It was during this period of our research that we were extremely handicapped by inadequate conditions, by the lack of a proper place to work in, by the lack of
money and of personnel.

Pitchblende was an expensive mineral, and we could not afford to buy a sufficient quantity. At that time the principal source of this mineral was at St. Joachimsthal (Bohemia) where there was a mine which the Austrian government worked for the extraction of uranium. We believed that we would find all the radium and a part of the polonium in the residues of this mine, residues which had so far not been used at all. Thanks to the influence of the Academy of Sciences of Vienna, we secured several tons of these residues at an advantageous price, and we used it as our primary material. In the beginning we had to draw on our private resources to pay the costs of our experiment; later we were given a few subventions and some help from outside sources.

The question of quarters was particularly serious; we did not know where we could conduct our chemical treatments. We had been obliged to start them in an abandoned storeroom across a court from the workroom where we had our electrometric installation. This was a wooden shed with a bituminous floor and a glass roof which did not keep the rain out, and without any interior arrangements. The only objects it contained were some worn pine tables, a cast-iron stove, which worked badly, and the blackboard which Pierre Curie loved to use. There were no hoods to carry away the poisonous gases thrown off in our chemical treatments, so that it was necessary to carry them on outside in the court, but when the weather was unfavorable we went on with them inside, leaving the windows open.

A view of the extraction of radium in the old shed where the first radium was obtained
In this makeshift laboratory we worked practically unaided during two years, occupying ourselves as much with chemical research as with the study of the radiation of the increasingly active products we were obtaining. Then it became necessary for us to divide our work. Pierre Curie continued the investigations on the properties of radium, while I went ahead with the chemical experiments which had as their objective the preparation of pure radium salts. I had to work with as much as twenty kilogrammes of material at a time, so that the hangar was filled with great vessels full of precipitates and of liquids. It was exhausting work to move the containers about, to transfer the liquids, and to stir for hours at a time, with an iron bar, the boiling material in the cast-iron basin. I extracted from the mineral the radium-bearing barium and this, in the state of chloride, I submitted to a fractional crystallization. The radium accumulated in the least soluble parts, and I believed that this process must lead to the separation of the chloride of radium. The very delicate operations of the last crystallizations were exceedingly difficult to carry out in that laboratory, where it was impossible to find protection from the iron and coal dust. At the end of a year, results indicated clearly that it would be easier to separate radium than polonium; that is why we concentrated our efforts in this direction. We examined the radium salts we obtained with the aim of discovering their powers and we loaned samples of the salts to several scientists, in particular to Henri Becquerel.

During the years 1899 and 1900, Pierre Curie published with me a memoir on the discovery of the induced radioactivity produced by radium. We published another paper on the effects of the rays: the luminous effects, the chemical effects, etc.; and still another on the electric charge carried by certain of the rays. And, finally, we made a general report on the new radioactive substances and their radiations,
for the Congress of Physics which met in Paris in 1900. My husband published, besides, a study of the action of a magnetic field on radium rays.

The main result of our investigations and of those of other scientists during these years, was to make known the nature of the rays emitted by radium, and to prove that they belonged to three different categories. Radium emits a stream of active corpuscles moving with great speed. Certain of them carry a positive charge and form the Alpha rays; others, much smaller, carry a negative charge and form Beta rays. The movements of these two groups are influenced by a magnet. A third group is constituted by the rays that are insensible to the action of a magnet, and that, we know to-day, are a radiation similar to light and to X-rays.

We had an especial joy in observing that our products containing concentrated radium were all spontaneously luminous. My husband who had hoped to see them show beautiful colorations had to agree that this other unhopec-for characteristic gave him even a greater satisfaction than that he had aspired to.

The Congress of 1900 offered us an opportunity to make known, at closer range, to foreign scientists, our new radioactive bodies. This was

one of the points on which the interest of this Congress chiefly centered.

We were at this time entirely absorbed in the new field that opened before us, thanks to the discovery so little expected. And we were very happy in spite of the difficult conditions under which we worked. We passed our days at the laboratory, often eating a simple student's lunch there. A great tranquillity reigned in our poor, shabby hangar; occasionally, while observing an operation, we would walk up and down talking of our work, present and future. When we were cold, a cup of hot tea, drunk beside the stove, cheered us. We lived in a preoccupation as complete as that of a dream.

Sometimes we returned in the evening after dinner for another survey of our domain. Our precious
products, for which we had no shelter, were arranged on tables and boards; from all sides we could see their slightly luminous silhouettes, and these gleamings, which seemed suspended in the darkness, stirred us with ever new emotion and enchantment.

Actually, the employees of the School owed Pierre Curie no service. But nevertheless the laboratory helper whom he had had to aid him when he was laboratory chief had always continued to help him as much as he could in

![A view of the extraction of radium in the old shed where the first radium was obtained](image)

the time at his disposal. This good man, whose name was Petit, felt a real affection and solicitude for us, and many things were made easier because of his good will and the interest he took in our success.

We had begun our research in radioactivity quite alone, but because of the magnitude of the undertaking, we were more and more convinced of the utility of inviting collaboration. Already in 1898, one of the laboratory chiefs of the School, G. Bemont, had given us temporary aid. And toward 1900 Pierre Curie associated with him a young chemist, André Debierne, preparator under Friedel, who held him in high esteem. André Debierne gladly accepted Pierre Curie's proposal that he occupy himself with the investigation of radioactivity; and he undertook, in particular, the search for a new radio element, which we suspected existed in the iron group and in rare earths. He discovered the element actinium. Even though he carried on his work in the laboratory of physical chemistry at the Sorbonne, directed by Jean Perrin, he frequently came to visit us in our storeroom, and was soon an intimate friend of ours, and of Doctor Curie and the children.

About this same time, George Sagnac, a young physicist engaged in the study of X-rays,
often came to discuss with my husband the analogies one could expect to find between these rays, and their secondary rays, and the radiations of radioactive bodies. They worked together on the investigation of the electric charge carried by the secondary rays.

Besides our collaborators we saw very few persons in the laboratory; however, from time to time some physicist or chemist came to see our experiments, or to ask Pierre Curie for advice or information; for his authority in several branches of physics was very well recognized. And then there were discussions before the blackboard, -- discussions which are pleasantly remembered to-day, because they stimulated an interest in science and an ardor for work without interrupting any course of reflection, and without troubling that atmosphere of peace and contemplation which is the true atmosphere of the laboratory.

Notes

[7] This last publication was issued in common with G. Bemont, who had collaborated with us in our experiments.

[8] I quote, as an example, a letter addressed to Pierre Curie by A. Paulsen, thanking him for radioactive products loaned him in 1899:
"Den Damke Nordl's Expedition
Akureyi, 16 Oct. 1899.
Monsieur, and most honored colleague,

"I thank you warmly for your letter of August 1, which I have just received in the north of Iceland.

"We have abandoned all the methods hitherto employed to establish in a fixed conductor the potential that exists at certain points in the mass of air that surrounds it, and are using only your radiant powder.

"Accept, Monsieur, and most honored colleague, my respectful salutations and my renewed thanks for the great services you have rendered my expedition.
"ADAM PAULSEN."
Pierre and Marie Curie in their laboratory, where radium was discovered.
A view of the extraction of radium in the old shed where the first radium was obtained.
Pierre Curie with the quartz piezo-electroscope he invented, by which rays of radium are measured.
A view of the extraction of radium in the old shed where the first radium was obtained.