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# Radioactive substances, especially radium

*Nobel Lecture, June 6, 1905*

Allow me, first of all, to tell you that I am happy to speak today before the Academy of Sciences which has conferred on Mme. Curie and myself the very great honour of awarding us a Nobel Prize. We must also tender you our apologies for being so tardy in visiting you in Stockholm, for reasons quite outside our control.

I have to speak to you today on the properties of the *radioactive substances,* and in particular of those of *radium.* I shall not be able to mention exclusively our own investigations. At the beginning of our studies on this subject in 1898 we were the only ones, together with Becquerel, interested in this question; but since then much more work has been done and today it is no longer possible to speak of radioactivity without quoting the results of investigations by a large number of physicists such as Rutherford, Debierne, Elster and Geitel, Giesel, Kauffmann, Crookes, Ramsay and Soddy, to mention only a few of those who have made important progress in our knowledge of radioactive properties.

I shall give you only a rapid account of the discovery of radium and a brief summary of its properties, and then I shall speak to you of the consequences of the new knowledge which radioactivity gives us in the various branches of science.

Becquerel discovered in 1896 the special radiating properties of *uranium* and its compounds. Uranium emits very weak rays which leave an impression on photographic plates. These rays pass through black paper and metals; they make air electrically conductive. The radiation does not vary with time, and the cause of its production is unknown.

Mme. Curie in France and Schmidt in Germany have shown that thorium and its compounds possess the same properties. Mme. Curie also showed in 1898 that of all the chemical substances prepared or used in the laboratory, only those containing uranium or thorium were capable of emitting a substantial amount of the Becquerel rays. We have called such substances *radioactive.*

Radioactivity, therefore, presented itself as an atomic property of uranium and thorium, a substance being all the more radioactive as it was richer in uranium or thorium.

Mme. Curie has studied the minerals containing uranium or thorium, and in accordance with the views just stated, these minerals are all radioactive. But in making the measurements, she found that certain of these were more active than they should have been according to the content of uranium or thorium. Mme. Curie then made the assumption that these substances contained radioactive chemical elements which were as yet unknown. We, Mme. Curie and I, have sought to find these new hypothetical substances in a uranium ore, *pitchblende.* By carrying out the chemical analysis of this mineral and assaying the radioactivity of each batch separated in the treatment, we have, first of all, found a highly radioactive substance with chemical properties close to bismuth which we have called *polonium,* and then (in collaboration with Bémont) a second highly radioactive substance close to barium which we called *radium.* Finally, Debierne has since separated a third radioactive substance belonging to the group of the rare earths, *actinium.*

These substances exist in pitchblende only in the form of traces, but they have an enormous radioactivity of an order of magnitude 2 million times greater than that of uranium. After treating an enormous amount of material, we succeeded in obtaining a sufficient quantity of radiferous barium salt to be able to extract from it radium in the form of a pure salt by a method of fractionation. Radium is the higher homologue of barium in the series of the alkaline earth metals. Its atomic weight as determined by Mme. Curie is 225. Radium is characterized by a distinct spectrum which was first discovered and studied by Demarçay, and then by Crookes and Runge and Precht, Exner, and Haschek. The spectrum reaction of radium is very sensitive, but it is much less sensitive than radioactivity for revealing the presence of traces of radium.

The general effects of the radiations from radium are intense and very varied.

*Various experiments:* Discharge of an electroscope. - The rays pass through several centimetres of lead. - A spark induced by the presence of radium. - Excitation of the phosphorescence of barium platinocyanide, willemite and kunzite. - Coloration of glass by the rays. - Thermoluminescence of fluorine and ultramarine after the action of radiation from radium on these substances. - Radiographs obtained with radium.

A radioactive substance such as radium constitutes a continuous source of energy. This energy is manifested by the emission of the radiation. I have also shown in collaboration with Laborde that radium releases heat continuously to the extent of approx. 100 calories per gram of radium and per hour. Rutherford and Soddy, Runge and Precht, and Knut Ångström have also measured the release of heat by radium, this release seems to be constant after several years, and the total energy released by radium in this way is considerable.

The work of a large number of physicists (Meyer and Schweidler, Giesel, Becquerel, P. Curie, Mme. Curie, Rutherford, Villard, etc.) shows that the radioactive substances can emit rays of the three different varieties designated by Rutherford as α–, β– and γ -rays. They differ from one another by the action of a magnetic field and of an electric field which modify the trajectory of the α - and β -rays.

The β -rays, similar to cathode rays, behave like negatively charged projectiles of a mass 2000 times smaller than that of a hydrogen atom (electron). We have verified, Mme. Curie and I, that the β -rays carry with them negative electricity. The α -rays, similar to the Goldstein's canal rays, behave like projectiles 1,000 times heavier and charged with positive electricity. The γ-rays are similar to Röntgen rays.

Several radioactive substances such as radium, actinium, and thorium also act otherwise than through their direct radiation; the surrounding air becomes radioactive, and Rutherford assumes that each of these substances emits an unstable radioactive gas which he calls *emanation* and which spreads in the air surrounding the radioactive substance.

The activity of the gases which are thus made radioactive disappears spontaneously according to an exponential law with a time constant which is characteristic for each active substance. It can, therefore, be stated that the emanation from radium diminishes by one-half every 4 days, that from thorium by one-half every 55 seconds, and that from actinium by one-half every 3 seconds.

Solid substances which are placed in the presence of the active air surrounding the radioactive substances, themselves become temporarily radioactive. This is the phenomenon of *induced radioactivity* which Mme. Curie and I have discovered. The induced radioactivities, like the emanations, are equally unstable and are destroyed spontaneously according to exponential laws characteristic of each of them.

*Experiments:* A glass tube filled with emanation from radium which was brought from Paris. - Discharge of an electroscope by the rays from the induced radioactivity. - Phosphorescence of zinc sulphide under the action of the emanation.

Finally, according to Ramsay and Soddy, radium is the seat of a continuous and spontaneous production of helium.

The radioactivity of uranium, thorium, radium and actinium seems to be invariable over a period of several years; on the other hand, that of polonium diminishes according to an exponential law, it diminishes by one-half in 140 days and after several years it has almost completely disappeared.

These are all the most important facts which have been established by the efforts of a large number of physicists. Several phenomena have already been extensively studied by them.

The consequences of these facts are making themselves felt in all branches of science:

The importance of these phenomena for *physics* is evident. Radium constitutes in laboratories a new research tool, a source of new radiations. The study of the β -rays has already been very fruitful. It has been found that this study confirms the theory of J. J. Thomson and Heaviside on the mass of particles in motion, charged with electricity; according to this theory, part of the mass results from the electromagnetic reactions of the ether of the vacuum. The experiments of Kauffmann on the β -rays of radium lead to the assumption that certain particles have a velocity very slightly below that of light, that according to the theory the mass of the particle increases with the velocity for velocities close to that of light, and that the whole mass of the particle is of an electromagnetic nature. If the hypothesis is also made that material substances are constituted by an agglomeration of electrified particles, it is seen that the *fundamental principles of mechanics* will have to be profoundly modified.

The consequences for *chemistry* of our knowledge of the properties of the radioactive substances are perhaps even more important. And this leads us to speak of the source of energy which maintains the radioactive phenomena.

At the beginning of our investigations we stated, Mme. Curie and I, that the phenomena could be explained by two distinct and very general hypotheses which were described by Mme. Curie in 1899 and 1900 *(Revue Générale des Sciences,* January 10, 1899, and *Revue Scientifique,* July 21, 1900).

1. In the first hypothesis it can be supposed that the radioactive substances borrow from an external radiation the energy which they release, and their radiation would then be a secondary radiation. It is not absurd to suppose that space is constantly traversed by very penetrating radiations which cer-

accompanies uranium in minerals. And it has even been found that the ratio of radium to uranium is constant in all minerals (Boltwood). This confirms the idea of the creation of radium from uranium. This theory can be extended to try to explain also other associations of elements which occur so frequently in minerals. It can be imagined that certain elements have been formed on the spot on the surface of the Earth or that they stem from other elements in a time which may be of the order of magnitude of geological periods. This is a new point of view which the geologists will have to take into account.

Elster and Geitel have shown that the emanation of radium is very widespread in Nature and that radioactivity probably plays an important part in *meteorology,* with the ionization of the air provoking the condensation of water vapour.

Finally, in the biological sciences the rays of radium and its emanation produce interesting effects which are being studied at present. Radium rays have been used in the treatment of certain diseases (lupus, cancer, nervous diseases). In certain cases their action may become dangerous. If one leaves a wooden or cardboard box containing a small glass ampulla with several centigrams of a radium salt in one's pocket for a few hours, one will feel absolutely nothing. But 15 days afterwards a redness will appear on the epidermis, and then a sore which will be very difficult to heal. A more prolonged action could lead to paralysis and death. Radium must be transported in a thick box of lead.

It can even be thought that radium could become very dangerous in criminal hands, and here the question can be raised whether mankind benefits from knowing the secrets of Nature, whether it is ready to profit from it or whether this knowledge will not be harmful for it. The example of the discoveries of Nobel is characteristic, as powerful explosives have enabled man to do wonderful work. They are also a terrible means of destruction in the hands of great criminals who are leading the peoples towards war. I am one of those who believe with Nobel that mankind will derive more good than harm from the new discoveries.