however, because they are not reflected or refracted, and substances opaque to light may be permeable by these rays, while other substances, transparent to light, may be impermeable by these the X or Roentgen rays.

A very important characteristic of the X-rays is that when they pass through air it becomes a conductor of electricity. The air is said to be ionized. The molecules of the air are to a certain extent (a very small extent only), grouped into clusters some charged positively some negatively. In dry air the negative clusters are probably smaller than the positive. The clusters of molecules are called ions because they carry electricity.

In ionized air an electrified body is discharged. If the body is positively charged, its change is taken away by the negative ions, if it is negatively charged, its charge is taken away by the positive ions. An electrified body, therefore, when brought within the influence of a bulb in which Roentgen rays are being produced, is discharged.

The character of the Roentgen or X-rays was, as the latter name indicates, unknown, and many researches were started for the purpose of elucidating the matter. It was found that the exhausted bulbs in which the X-rays were produced always fluoresced and it was thought for a time that the fluorescence was the origin of the X-rays. Becquerel, on this assumption endeavored to find out whether fluorescent substances produced an effect on a photographic plate. For this purpose he made use, among other substances, of some fluorescent compounds of uranium and found that they affected the plate. But he discovered further that these uranium compounds even in the dark, under which circumstances they do not fluoresce, as well as those uranium compounds that do not fluoresce at all, produce the same effect on the plate.

Working under Becquerel's direction, Mme. Curie found that some ores of uranium, especially some pitchblendes, were more radioactive than pure uranium or pure uranium salts, and she separated from large quantities of ore small quantities of material very much more radioactive than the original pitchblende. She considered that she had obtained an element like bismuth (a radioactive bismuth), to which in honor of her country she gave the name polonium. It is doubtful whether polonium is really an element in the usual sense. Later, Mme. Curie obtained salts like those of barium, but with very great radioactivity, and she was able to determine the atomic weight of the new element to which the name radium was given. The quantity of radium in the most radioactive pitchblende is very small, only a very few grains to the ton.

Radium and its compounds have three very conspicuous properties; they act on the photographic plate so that sciographs, or shadow pictures, may be taken; they cause fluorescence in a number of substances, and they ionize air and other gases. This last effect is the most readily observed, and is so delicate that a few grains of inactive material containing $\frac{1}{10,000,000,000}$ of its weight of radium shows the presence of the latter by its power to discharge an electrified body. This quantity is about a millionth of what can be weighed on an ordinary good chemical balance. That the electrified body is not discharged by particles sent out by the radium is proved by the fact that both positive and negative bodies are discharged.

One of the most remarkable features about radium is that it sends out several kinds of rays. Newton considered that light consisted of particles sent out from the luminous body. This theory proved to be incorrect, but now we have a case in which the evidence is almost, if not quite, decisive, that material is shot out from the body. Three kinds of radiations from radium have been detected, called, respectively, alpha, beta, and gamma. The alpha radiations consist of particles whose mass is approximately double that of the hydrogen atom, the beta radiations consist of particles about one-thousandth the mass of the hydrogen atom, and the gamma radiations are most probably ethereal waves.

The proof that alpha and beta radiations consist of particles with electrical charges sent out with immense rapidity lies in the fact that the radiations may be deflected by the influence of a magnet. It is well known that if a current of electricity is passing through a wire which is free to move, the wire may be moved by the influence of a magnet and the magnitude of the motion will depend upon the strength of the current and also upon the strength of the magnetic influence. This principle is made use of in some forms of telegraphic instruments. If a number of electrified particles are moving in one direction, they form a current of electricity which is practically the same as a current in a wire, and just as a wire with a current flowing through it is deflected by a magnet, so the electrified particles would be deflected. The amount of deflection will depend upon the quantity of electricity on each particle, upon the mass or weight of the particles, upon their velocity, and upon the strength of the magnetic influence. If the particles are charged with negative electricity, they would be deflected to one side of the natural path, if charged with positive electricity, they would be deflected to the other side. The beta radiations are found to be deflected to the side which shows that the particles are negatively charged; the alpha radiations are deflected to the other side and consist therefore of positive particles. The amount of deflection of the beta rays is much greater than that of the alpha rays, and from a comparison of the amount of deflection, it is found that while the alpha rays consist of particles of about twice the mass of the hydrogen atom moving with a velocity about one-tenth that of light, the beta rays consist of particles approximately one-thousandth the mass of the hydrogen atom moving with a velocity between one-third and nine-tenths that of light. Some of the particles move faster than the others, the limits being approximately those given above.

The energy of the alpha radiations is much greater than that of the beta radiations, because though the velocity is less the mass is much greater. Moreover, in a given time about four times as many alpha particles, as beta particles, escape from radium. But though the alpha particles have more energy than the beta, they are more easily stopped, just as a person might stop a cricket ball thrown from the hand, but would not care to stop fine shot from a gun. A very thin metal foil, even a sheet of paper or a very few inches of air, stop by far the greater number of alpha particles. The beta particles are much more penetrative. The gamma rays have so far not been deflected by a magnet, and are, therefore, probably not material. They are the most penetrative of all. The penetrating power is pretty nearly in ratio: 1:100:10,000.

I have said that air is ionized by these radiations being formed into positive and negative groups of molecules, but it will be seen that these are not to be confused with the positive and negative particles emitted by radium, the alpha and beta radiations. For one thing we know from other considerations that the groups of molecules of air are very much larger in size, than the particles emitted by radium, and for another thing, the charges of electricity carried by the particles sent out from radium, are much less than can be carried by ionized air. Hence, though radium is sending out more positive particles than negative, the radium does not become negatively charged since ionized air in the neighborhood carries away all the charge. For the same reason, a conductor placed in the neighborhood of a radium compound is not ordinarily made positive by the alpha rays or negative by the beta rays. But a special experiment has been devised in which a conductor was made negative by the beta radiations. The radium compound was enclosed in a metal box thin enough to allow beta radiations to go through, but impermeable to alpha radiations. The beta radiations were allowed to fall upon a conductor surrounded by a non-conductor such as a coating of wax. Hence though the air was ionized, electricity could not escape from the conductor, and it became charged negatively. It is said that the metal box containing the radium became charged positively owing to its having retained the alpha radiations.

The ionization of the air is mainly due to the alpha rays, the ratio of the ionizing powers being nearly the inverse of the penetrating powers, namely, 100,000:100:1. On the other hand, the photographic effect is chiefly due to the beta rays, though the alpha rays are also effective. Fluorescence is in some substances due to beta rays, in other cases to alpha rays.

(To be continued.)