II. RADIUM FROM THE ASTRONOMICAL POINT OF VIEW.

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When I was requested by Dr. Coulter to take part in this symposium my reply to him was that my remarks would be as brief as the chapter on "Snakes in Ireland."

There is no direct evidence of radium or the other radio-active metals, uranium and thorium, in the spectrum of the sun or in the spectra of other celestial bodies. But it is proper that I should explain why there are no snakes in Ireland. I must also refer to the indirect evidence of the presence of radium inferred from the abundance of helium in certain celestial spectra.

The critical test for the presence of elements in celestial bodies is given by their spectra. If all or most of the characteristic lines of an element are found in the spectrum of a celestial body, we feel justified in asserting with great positiveness that that element is present. The converse, however, is not true: the absence of the lines of a given element from a celestial spectrum does not prove that the element may not be present in the body, but that its spectrum is for some reason suppressed. Hence the fact that no lines of the three elements referred to have yet been proven to exist in celestial bodies by no means justifies us in stating that those elements are not present in celestial objects.

Professor Crew has shown you the spectrum of radium and of the radium emanation in the slides that he has thrown upon the screen. Although there were some inaccuracies in the determination of the lines on the part of the eminent investigators, particularly in England, chiefly due to the presence of impurities due to barium (for radium) and hydrogen and xenon (for the emanation), it is nevertheless established that there are two characteristic and distinct spectra for radium and for the emanation. There seem to be no lines common to the two spectra. But these lines, with all those impurities eliminated, do not correspond to unknown lines in celestial spectra. Hence, if radium or its emanation are present in the sun and stars, the conditions are not suitable for the development of their luminosity to an appreciable extent.

The close connection of helium with radium is very remarkable, and may be of significance here. It seems to be established with almost perfect certainty that the α rays, which are spontaneously emitted by radium with an average velocity of some six thousand miles per second, actually consist of atoms of helium. Furthermore, a quantity of the emanation which at first gives its characteristic spectrum begins in a few days to show the helium spectrum. Hence helium is also developed by the emanation.

Helium is present in the sun, as has been known since its discovery there in 1868, more than a quarter of a century before it was found on the earth. Its appearance on the sun is peculiar in that it is seen only as a bright line at the edge of the sun with the spectroscope, and does not produce dark lines, as do the other elements which appear as bright lines when viewed at the sun's limb. Helium is also found in large prominences viewed at the edge of the sun with the spectroscope, but it does not rise as high in the solar atmosphere as do hydrogen and calcium vapors.

If the sun were one hundred times as far away from us as it actually is, we should probably be unable to detect the bright radiations of helium in its spectrum; they would be totally invisible at the distance of the nearest fixed star.

There is a certain class of stellar spectra, however, of which helium is the principal characteristic (in addition to hydrogen, which is found in every celestial spectrum with hardly an exception). These stars are called helium stars, or stars of the *Orion* type, and they are found chiefly in or near the Milky Way. When a series of different stellar spectra are arranged in a sequence merely by the similarity of spectra and gradual change from one type to another, without involving any theory of stellar evolution, these helium stars are placed by all investigators at the beginning of the series. They may be called blue stars, which precede the white stars in the sequence. Inasmuch as the helium found in the earth is attributed to the radium and uranium which are in a sense its parents, it might be regarded as a fair inference that radium must also be responsible for the abundance of helium in spectra of this type. I do not regard this as a necessary assumption, however, inasmuch as helium is a gas in some respects similar to hydrogen, and perhaps we are therefore not obliged to account for its presence as due to some other element any more than we are in the case of hydrogen.

It should be pointed out here that if radium were present in the sun or stars, and were giving out the alpha, beta, and gamma rays, it is unlikely that they would be able to penetrate either the atmosphere of the sun or star, or the atmosphere of the earth. As I understand it, the alpha rays penetrate but a few inches in air at atmospheric pressure; and the beta rays are soon absorbed. The gamma rays may readily be passed through a block of iron one foot thick, but the thickness of the reversing layer in the sun, while regarded as a very narrow stratum, will be for iron vapor probably at least two hundred miles, and for the gaseous elements many times this, up to five thousand miles or more. Hence it is clear that none of these rays would be expected to penetrate even the thinnest stratum in the atmosphere of sun or star.

It is an interesting fact that helium is found with hydrogen in the spectrum of the temporary stars, or *novae,* which flash out occasionally in the sky. We now know that they are not very uncommon, and perhaps, if we could observe them all, there would be found at least one (or more) each year. For instance, a *nova* was discovered in *Lacerta* on December 30th last. It has been shown that it was previously a star as faint as the thirteenth or fourteenth magnitude. It suddenly increased probably a hundred times in brightness and was of the seventh magnitude when it was first observed. On February 21, 1901, there suddenly developed a brilliant nova in *Perseus,* which was for a few days the brightest star in the northern sky. Various hypotheses of collision have been advanced to account for the extraordinarily sudden development of these stars, but it seems to me that we ought to take into account the possibility that some of the immense amount of energy which the study of radio-activity has shown to be present in the molecules of even the light gases has suddenly been released. We do not dare to say offhand how vast the amount of this intermolecular force is, but if it could be converted into the energy of moving masses, it would probably account for the forces which seem to be involved in temporary stars.

Similarly it seems to me that we ought to take account of such possibility in our theories of cosmogony. We endeavor to account for the momentum and energy we now find in our solar system and in stellar systems purely on the basis of masses of matter. If it shall ultimately be shown that conditions may arise which release the immense amount of energy in every molecule, it might assist in our understanding of the processes of cosmogony.

Finally, the tests thus far of the amount of helium in the earth's crust have indicated, on the assumption that all the helium has been produced from radium, an almost over-abundant amount of radio-active elements to account for the observed heat within the earth. The accepted view of the maintenance of the sun's heat is that it is due to the contraction of a gaseous body at a rate of about three hundred feet in diameter per annum. While this theory is in accordance with the laws of gaseous bodies and is also in agreement with the views of many as to the evolution of the solar system, nevertheless if the amount of radium in the sun is in proportion to that on the earth, as inferred from the abundance of helium in the earth, no doubt the supply of radium would fully account for the maintenance of the heat of our sun.