known as "Prout's hypothesis," which made hydrogen the primordial stuff, and all the other elements simply groups of hydrogen atoms. This hypothesis rested, so far as experimental evidence is concerned, upon the observed fact that the weights of many of the atoms are almost exact multiples of that of the hydrogen atom. But more careful weighing showed that this hypothesis wouldn't work—that there are some elements whose weights are not at all exact multiples of the weight of hydrogen. Nevertheless, men kept seeking for connections and relationship between the elements, for to many a man the idea of a world built up of eighty different things, with no suggestion of a relationship between them, has been intolerable. In 1863 a new type of relationship was indeed discovered by a man by the name of John Newlands. This discovery was developed chiefly by the Russian chemist Mendeleeff, and is now known under the name of "Mendeleeff's Periodic Law." The essential thing in this law is this: If you write down in a horizontal row the elements in the order of their atomic weights, leaving out hydrogen for the present, and, after getting up as far as fluorine, go back and start another row, putting that element which is eighth in order of weight under that which is first, the ninth under the second, and so on, and then, when you reach the fluorine column, go back again and put the sixteenth under the first, the seventeenth under the second, and so on, the elements in all the vertical columns are found to bear striking resemblances in both chemical and physical properties. The relationship is sometimes surprisingly close, as, for example, in the case of the alkali metals lithium, sodium, and potassium, or of the strong reducing agents oxygen, sulphur, and chromium.

To go into a complete study of this so-called periodic law of the elements would be beyond the limits of this article; but its immense significance may perhaps be understood if I say that it is necessary only to know the atomic weight of any element in order to predict beforehand practically all of its chemical and physical properties. To convince ourselves of how certainly this relation ship does exist, we have only to have our attention called to one of the most remarkable scientific prophecies which has ever been made and verified. In 1871, when Mendeleeff first published his periodic table of the elements, he found it necessary to leave three blanks in his table, in order to get the related elements into vertical columns. He therefore jumped at the conclusion that three elements probably existed somewhere in nature, which had not yet been discovered, and which had the atomic weights which belonged to the blank spaces in his table. And so confident was he of his ground that he proceeded to predict very minutely the properties which these three elements would be found to have when discovered, judging of these properties from the properties of the other elements which were in the same column. He told what their atomic weights would be; what their specific gravities would be; what colours, what solubilities and what combining powers they would have. He never dreamed that he would live to see the discovery of these elements which he had so minutely described; but in a very few years every one of them had been found, and *they had exactly the properties which he had assigned to them.*

Now, let us ask ourselves what bearing this periodic law has upon the problem of the transmutability of the elements. First, it tells us in perfectly unmistakable terms that the elements are not and cannot be independent, ultimate things, for it shows that they have relationships. They group themselves into definite families. It shows that if you add something to the weight of an element, you change in a perfectly definite and predetermined way its properties. Does not this point in an almost unmistakable way to the conclusion that the elements have a common origin, that they are built up from a common material; and that our world is indeed at bottom, as Aristotle thought, something less complex than a compound of eighty different, independent things?

THE ANSWER OF MODERN ASTRONOMY.

Let us next turn from chemistry to the study of the stars, and see whether this field of investigation has added anything to our knowledge of the transmutability of the elements. It is now less than fifty years since the spectroscope was invented (1859) by the Germans, Kirchoff and Bunsen, the one a physicist and the other a chemist; but this instrument has already added more to our knowledge of the stars than did all the work of the astrologers and astronomers who lived before its time.

What has it taught? Primarily these two things:—First, it has taught us to determine with certainty what elements exist in the sun and stars; and, Second, it has given us a means of estimating the relative temperatures of the heavenly bodies. And it does this in a very simple way, for it separates into different coloured lights the complex

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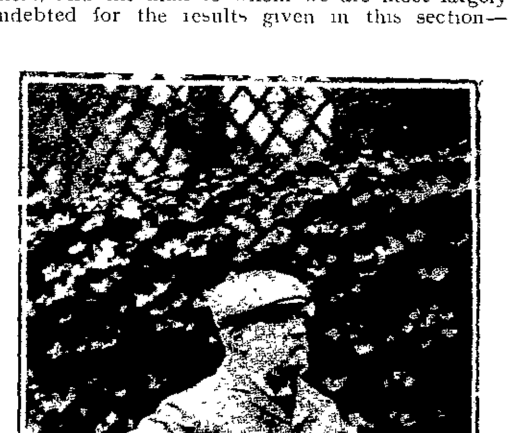
light emitted by any glowing body, and thus enables us to determine just what colours are found in any given luminous source. Since each different element emits a light of a characteristic colour, we have only to compare the colour of the light emitted by an incandescent element on the earth with the colour of the light emitted by the sun or by a star, to find whether this particular element exists in the sun or star. Again, since we find that when a body first grows hot enough to emit light the light given out is red, and that the hotter the body becomes, the more abundantly does it emit, first yellow, then green, then blue, then violet, and so on; it is obvious that, if we find that of two bodies, which we can study only through their spectra, the one emits much more blue light, for example, than the other, then we may conclude that the first body is the hotter of the two. Thus we have been able to make rough estimates of the temperatures of the stars, and Sir Norman Lockyer—perhaps the most noted of living astronomers, and the man to whom we are most largely indebted for the results given in this section—



SIR NORMAN LOCKYER PROFESSOR OF ASTRONOMICAL PHYSICS IN THE ROYAL COLLEGE OF SCIENCE

has calculated that the hottest stars have temperatures as high as 30,000° Centigrade, and from this frightful degree of heat they run down to about 5000° Centigrade, which is only about one thousand degrees higher than the temperature of the electric arc, the hottest temperature which we have so far been able to produce on earth. He estimated the temperature of our sun as about 10,000° Centigrade.

Now, before we consider what the spectroscope has shown about the constituents of the stars of varying degrees of hotness, let us reflect upon the effect which we know temperature to have upon the compounds with which we are familiar on the earth. In general, the hotter a compound body becomes, the more does it tend to break up into its constituents, until, at the highest temperatures which we can produce on earth, all known compounds are broken up into their constituent elements. Now, if the elements themselves are compounds, as the Periodic Law would seem to indicate, what might we expect to happen to them if we could produce temperatures enormously higher than those attainable on earth? It would be natural at least, to expect to find the elements themselves decomposed into simpler substances. Now, since these high temperatures exist in the sun and in the stars, it ought to throw much light upon our search to investigate the kind of substances which are present in the hottest stars. The following is the result of Lockyer's and other astronomers' studies with the spectroscope:—

The hottest stars consist almost exclusively of the very light gases hydrogen, helium, and a gas called "asterium," which is so far unknown on earth. In the stars of somewhat lower temperature there begin to appear some of the heavier elements, like calcium and iron, and in the coldest stars we find nearly all the elements which exist on the earth. In other words, as a general rule, as the temperature decreases, the elements put in their appearance—approximately, at least—in the order of their atomic weights. Since, then, a star which is very hot has but few elements, and since more and more appear as it grows cold, is not the evidence of modern astronomy at least as strong as the evidence of modern chemistry, that *the heavier elements have evolved in nature's laboratory from the lighter?* In other words, that the elements are indeed transmutable?

THE ANSWER OF MODERN PHYSICS.

Such was the state of our knowledge up to about ten years ago. No one had ever decomposed an atom. Could it be done? Out of the laboratory of the physicist came the answer. Yes, we can decompose atoms at will. In 1879, Sir William Crookes began the study of the so-called "cathode rays," which appear in an exhausted tube, such as an X-ray bulb, when a discharge of electricity is produced within it. It was he who first brought forward the hypothesis that these cathode rays consisted of streams of projected particles shot with enormous velocities from the surface of the negative electrode. And these particles he thought to be, not atoms, but something much smaller than atoms. By the year 1898, it had been definitely settled, largely through the labours of Prof. J. J. Thomson, of Cambridge, England, that the cathode rays do indeed consist of particles of matter which have a mass only about 1-2,000 of that of the lightest of the atoms of the elements—namely, the atom of hydrogen. Furthermore, no matter from what sort of metals these cathode rays come, or what the nature of the residual gas that is in the tube in which they are produced, these cathode-ray particles are always found to have precisely the same mass. Again, all hot bodies, when their temperatures are sufficiently high, are found to emit these same particles; and, finally, the spectroscopic study of the effect of a powerful magnet upon light, has made it practically certain that it is the vibration of these same particles within the atom which produces light. The conclusion, therefore, seems to be inevitable, that these particles are constituents of all the elements; and J. J. Thomson has brought forward the hypothesis that they themselves constitute the primordial stuff of which all matter is built up. Whether this hypothesis is correct or not, the experiments made upon cathode rays by many investigators—the foremost of whom have been Crookes, of London; Thomson, of Cambridge, and Lenard, of Kiel, Germany—have shown beyond a doubt that the elements themselves are, under proper conditions, decomposable into simpler forms.

But the physicists have gone still farther than this. In 1896, the strange phenomenon of radioactivity was discovered by Becquerel, of Paris, and physicists were groping about in the attempt to find an explanation of what it might mean, when Prof. Ernest Rutherford, of McGill University, Canada, solved the mystery. He proved almost beyond a doubt that the radio-active elements—radium, uranium, and thorium—are actually in