

Perhaps the simplest way to test the postulate directly would be to observe the Doppler effect with a concave reflecting grating so set as to form the image on the normal to the surface of the grating (cf. Tolman, *Phys. Rev.*, 35, p. 136, 1912); the retardation then occurs entirely before reflection, and it is the wave-length of incident light which is measured by the deviation. Any uncertainty as to the relative speed of the reflected rays can be removed by making the line of motion of the source pass through the centre of the grating, and then observing the effect of the motion upon the position of the central image when the grating is turned so as to bring this image into the position formerly occupied by the diffracted one. In these circumstances, for reasons of symmetry the speed of the incident waves along two rays equally inclined to the direction of motion must be the same; if it then turns out that the position of the central image is unaffected by the motion, it will follow that the speed must likewise be the same along the two corresponding reflected rays. This conclusion will hold also for the two diffracted rays which take these paths in the main experiment.

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On the N-Series in X-Ray Spectra.

WITH the new and very powerful X-ray-spectroscopic outfit constructed by Prof. M. Siegbahn (described in *Comptes rendus*, 1921, p. 1350) I have endeavoured to find a weaker group of lines in the X-ray region than the lines previously known as M-group. I have been able to find some lines which most probably must be referred to the N-series of the elements uranium and thorium. Hitherto, the measured wave-lengths for these lines lie for uranium between 8.6-12.0 A.U. and for thorium between 9.4-13.5 A.U.

From the theoretical and experimental work done by Coster and others, we are able to estimate the wave-lengths of the lines in the N-series. For the elements uranium and thorium we really find that some of these lines must have wave-lengths of about the measured value. For bismuth, however, and the elements in its neighbourhood, all the N-lines must have a wave-length of more than 13 A.U. so that in the present state of spectroscopy it will be very difficult to measure the wave-lengths for these elements.

I am continuing these researches.

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A Proposed Laboratory Test of the Theory of Relativity.

WITH the present interest so strong in devising experiments to test the theory of relativity, it may not be amiss to suggest the possibility of yet another method. According to recent hypotheses, it seems that the stars are the factories producing complex elements from simpler structures. Inside the stars, hydrogen atoms may unite to form helium, and with hydrogen and helium as intermediates, the more complicated atoms may be built. As pointed out by Harkins, Eddington, Perrin, and others, the synthesis of an atom of helium from four hydrogen atoms necessitates the loss of 0.774 per cent. of the mass of the hydrogen atoms. Since we cannot conceive of mass being annihilated, the only obvious solution is to say

that mass is electromagnetic in origin and that, in the helium nucleus, the four protons are brought so near to the two electrons that their fields overlap and neutralise each other to some extent, accompanied by a loss of mass. According to the theory of relativity, 1 gram of matter is equivalent to 9×10^{20} ergs or 2.1×10^{13} calories. Both Harkins and Perrin have calculated the amount of heat that must be produced by the transformation of four gram atoms of hydrogen into one gram atom of helium. It has the enormous value of $0.0078 \times 2.1 \times 10^{13}$ or 1.6×10^{11} calories.

It may be possible for several helium nuclei to unite to form heavier nuclei, such as oxygen for example, without such a great evolution of heat. More accurate determinations of the atomic weights of the so-called "pure" elements would be necessary before we could say much concerning the energy relations in such sub-atomic reactions.

When the nuclei become so large that they are unstable, then the process of synthesis in the stars would stop. But there might be an over-shooting of the mark. With the enormous amount of energy free in the interior of the stars, some of this energy might be absorbed, according to the theorem of Le Chatelier, in the formation of nuclei which would be unstable in an environment not containing so much energy. Energy would be considered as one of the terms in a mass law equation, to use a well-known chemical analogy. The result would be the radioactive elements—uranium, thorium, etc.

Now let us calculate with the aid of the above equation, derived from the theory of relativity, the effect on the mass of a radioactive substance that would be caused by this addition of energy. Rutherford, in his book "Radioactive Substances and their Radiations," p. 582, states that 1 gram of radium in disintegrating to lead gives off 3.7×10^9 calories. If 1 gram of mass = 9×10^{20} ergs = 2.1×10^{13} calories, then 1 gram of radium in disintegrating to lead would give off 0.00017 gram and 1 gram atom of radium, 0.038 gram in the form of energy. If the atomic weight of RaG (radium-lead) is taken as 206 exactly, then the atomic weight of its parent, radium, may be calculated as follows:

1 gram atom of RaG	206.000	grams
5 gram atoms of He	20.000	"
4 gram electrons	0.0005	"
3.7×10^9 calories	0.038	"
	226.038	"

Therefore the atomic weight of radium should be 226.038. Calculations of this type for radioactive substances have been made by Harkins, but he does not state that they may be applied as a test of the theory of relativity.

This calculation involves six assumptions: (1) that the weight of one gram atom of RaG is 206.000, (2) that the atomic weight of He is 4.000, (3) that the weight of 4 gram electrons does not exceed 0.0005 by any great extent when incorporated in the nucleus of Ra, (4) that the amount of energy given off in the disintegration of Ra is substantially that calculated by Rutherford (a 20 per cent. decrease in the value given by him would not change the value for energy in grams in the second decimal place), (5) that the relativity equation connecting mass and energy holds, and (6) that the energy given off in radioactive disintegrations is derived from the atoms themselves and not photochemically from Perrin's hypothetical radiations of extremely short wave lengths. In trying to verify the results of such an equation, there are two more assumptions necessary: that the atomic weights of RaG and of Ra are determined for the pure substances, that there are no contaminating isotopes.