newly founded Kilgour chair of geology at Aberdeen.

DR. FRITZ STRAUS, of Berlin, has been appointed professor of chemistry at the Breslau School of Technology.

DISCUSSION AND CORRESPONDENCE

RADIATION A FORM OF MATTER

TO THE EDITOR OF SCIENCE: One sees the statement frequently made that, if one accepts Einstein's conclusion that the mass of a body is proportional to the total energy which it possesses, the principle of the conservation of matter must be abandoned. For if during any change energy is gained or lost by the body through radiation, there should be a corresponding gain or loss of mass. It has been calculated that in the case of radioactive disintegration the energy thus lost (or gained) through radiation represents an appreciable fraction of the total mass of the radioactive material. If, however, one takes the point of view that radiation is a form of matter, and that the amount of this matter is measured by the mass or inertia of the radiation, the total mass of the body plus that of the radiation emitted is unaltered by such changes. On this view the principle of the conservation of mass is strictly valid, being, as has been remarked, a corollary of the energy principle.

It is perhaps surprising to notice that according to the definitions of matter usually given electromagnetic radiation must be classed as matter. It is admittedly difficult to find a satisfactory definition. "Matter is that which occupies space," "matter is that which possesses mass or inertia," "matter is that which affects the senses," are, however, common statements. But radiation certainly occupies space; that it possesses mass is shown by the momentum which it imparts to a body which it strikes, producing radiation pressure; and who would deny that sunlight affects the senses? Unless, therefore, we change our idea of what is meant by the word "matter," this word includes not only solids, liquids and gases, but also the less tangible electromagnetic radiation.

The inclusion of radiation as a form of matter has important bearings in addition to the fact that it renews the validity of the principle of the conservation of matter. Thus, for example, we can no longer say that matter is composed wholly of positive and negative electrons, for the form of matter known as radiation includes no such electric charges. The statement that matter is composed of positive and negative electrons and electromagnetic radiation is, on the other hand, more complex than is required. We see rather that the fundamental thing in matter is not the electric charge but the electromagnetic field, for the electromagnetic field includes both the electrons and the radiation.

If the further simplification is made of considering the magnetic field as due to the electric field in motion, we may describe all forms of matter in terms of the intensity of the electric field at different points. The mass or inertia of the matter is proportional to the integral through the volume considered of the square of the electric intensity and of the magnetic intensity resulting from the motion of the electric field, whether this electric field is due to the presence of electrons or to the existence of electromagnetic radiation. The electric charge in an element of volume is proportional to the divergence of the electric intensity at the point. Thus all the fundamental properties of matter are determined if the intensity of the electric field throughout space and time is known. While the electrons can not be considered the fundamental elements which make up all matter, we have thus the intensity of the electric field as that which can be thought of as composing both the electrons and the radiation. Electric intensity, then, may be considered as that of which all matter is composed.

According to this point of view, matter is perfectly continuous. It is true that there are certain perhaps limited regions, the electrons, from which electric intensity diverges; but whether or not these regions of divergence are limited, the mass of the matter is associated with the electric intensity and is hence distributed through all space. Similarly, radiation propagated through space, as for example light coming from the sun to the earth, is on this view a continuous series of waves of

matter. The old argument for the existence of an ether because some medium is necessary to transfer the radiant energy from the sun to the earth has accordingly no weight. For we now see that the radiation may be its own medium, somewhat as the stream of water from a hose acts as the medium for a wave if the nozzle is shaken.

Perhaps the only new thing in this letter is that, according to the common significance of the word, radiation must be considered a form of matter. But it has seemed to me that a consideration of this fact shows more clearly than we have seen before that matter is essentially continuous, and that the fundamental thing in matter is not the positive and negative electrons but is rather electric intensity.

ARTHUR H. COMPTON
WASHINGTON UNIVERSITY,
ST. LOUIS, MISSOURI

RUSSIAN SCIENTIFIC AID

AT the request of the American Relief Administration, which has been receiving, repacking and forwarding the contributions of American scientific books, journals and papers published since January 1, 1915, for distribution in Russia, I wish to ask that any further shipments from contributors to the New York warehouse (Gertzen and Company, 70 West Street, New York) of the American Relief Administration should be made prior to December 30, 1922. Up to date approximately eleven tons of scientific literature have been sent to Russia by the American committee. This committee wishes to extend its warm thanks to all donors.

In response to the appeal for some money with which to relieve the distress of the hundred Russian intellectual exiles in Berlin, I have received up to this writing $865, of which $500 came as a single gift from Princess Cantacuzene and the rest in five and ten dollar lots from American scientific men. I have no doubt that the total of $1,000 asked for will be reached.

VERNON KELLOGG
NATIONAL RESEARCH COUNCIL,
WASHINGTON, D. C.

SCIENTIFIC BOOKS

THE WATCHERS OF THE SKY[1]

The romance of Science is not an infrequent phrase and it describes as well as any other the dramatic and striking phases of one side of human activity. Its domain is modern because all science is modern as a recognized pursuit and one which is of good repute. It is treated in many forms which vary from the fascinating stories of Jules Verne and H. G. Wells to the lurid and generally inaccurate articles in the Sunday Press. In between, we have many an essay or address which emphasizes the picturesque features of the search for the secrets of nature. But it is new for a poet of the first rank amongst those living to recognize its claims to be classed with love, war, and the more obvious forms of nature's works and human activities for expression in verse. In one respect Mr. Noyes, who follows the great poets of the past in taking a single theme, differs from them. Homer tells of the struggle of man against man, Virgil of man against nature, Milton of man against the unseen powers; it is always warfare or struggle in which one side or the other is to conquer. Here there is no victory and no defeat. The Torch-bearers are striving to learn not by defeating nature but by cooperating with her, and the achievements of nature are of less importance than the methods by which she works. He who learns hands on his knowledge; the torch is passed, not extinguished.

From the preface we learn that the "Watchers of the Sky" is the astronomical portion of a trilogy the title of which "The Torch-bearers" describes the main idea of the treatment. There is no pretence at completeness—the poem is a story not a history—but the torch is followed with some degree of consecutiveness as it passes from the hands of Copernicus through those of Tycho, Kepler, Galileo, until Newton held it high for all the world to see. Later glimpses show William Herschel putting out his hand to take it and Sir John bearing it for a time. The setting of the whole poem places the first and last word on the summit of Mount Wilson

[1] By Alfred Noyes. Published by the Frederick A. Stokes Company.