## Letters to the Editor.

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### Rock-lead, Ore-lead, and the Age of the Earth.

In 1921 Prof. H. N. Russell attempted to fix an upper limit to the age of the earth on the basis of an assumption that all the lead in igneous rocks was of radioactive origin (*Proc. Roy. Soc.*, A, vol. 99, p. 84). He took the proportion of lead as $22 \times 10^{-6}$ (gr. per gm.) and obtained in consequence a very high maximum age. This proportion appears to be based largely on analyses of rocks from the neighbourhood of galena veins, and is therefore probably not a fair average for igneous rocks as a whole. An estimate more applicable to the problem is provided by an analysis for lead of 329 igneous rocks, made in 1914 by F. W. Clarke and G. Steiger (*Journ. Wash. Acad. Sci.*, vol. 4, p. 58). They found a proportion of only $7{\cdot}5 \times 10^{-6}$. The present proportions of uranium and thorium in average igneous rocks are respectively $6 \times 10^{-6}$ and $15 \times 10^{-6}$, the lead-generating equivalent in terms of uranium alone ($U + 0{\cdot}37$ Th) being $11{\cdot}5 \times 10^{-6}$.

If all rock-lead has been derived from the radioactive elements, then the equivalent amount of uranium must have been $8{\cdot}6 \times 10^{-6}$, giving an original total of equivalent uranium of $20{\cdot}1 \times 10^{-6}$. The time required for this original amount to disintegrate into $7{\cdot}5 \times 10^{-6}$ parts of lead and the corresponding quantity of helium, leaving the existing amounts of uranium and thorium, is approximately 3200 million years.

On the above figures, or on the data for any individual type of rock, granitic, basaltic, or peridotitic, the atomic weight of rock-lead should be a little less than 207. The lead of commerce, which is ore-lead derived almost entirely from the common vein mineral galena, is 207·2; and no significant deviation from this standard figure has been detected. Whatever the age or locality of galena may be, the atomic weight of its lead appears to be in all cases substantially higher than 207. It is therefore certain that ordinary lead cannot have been wholly derived from the radioactive elements during their terrestrial history, and this conclusion leads to two remarkable deductions.

Since an unknown amount of the lead in igneous rocks may be ordinary lead, it is clear that the earth —as a radioactive container—cannot have existed for so long as 3200 million years. This is in accordance with the evidence of radioactive minerals. Uraninites and other minerals from the Middle Pre-Cambrian rocks of Norway, Sweden, Ontario, Texas, Colorado, India, and Mozambique all give ages between 1000 and 1100 million years. The greatest age yet determined is that of a pitchblende from the Black Hills of South Dakota. I am indebted to Prof. A. C. Lane for an analysis of this mineral recently made by Mr. C. U. Davis, of the United States Bureau of Mines. It indicates an age of 1525 million years, and the atomic weight of the lead separated from it has been determined by Mr. L. P. Hall as 206·07. The frequently quoted figure for the age of the earth, 1600 million years, thus appears to be of the right order, provided that the method, as I believe it to be, is sound in principle.

Accepting this provisional estimate, it follows that roughly half the lead of igneous rocks is of radioactive origin. It also follows that the ore-lead of mineral veins cannot be a concentration of the lead of igneous rocks, as is usually supposed. At least the greater part of the lead of ore-deposits must have been already in existence when uranium and thorium began to generate lead in the crustal rocks. Consequently, unless one assumes that ordinary lead can have been formed within the earth by some other unknown process, it seems safe to conclude that ore-lead must have originated either in the ancestral sun or during the events that attended the birth of the solar system. In the former case it may have been of radioactive origin, but if so it must have been generated during a period over which the average ratio of uranium to thorium was 6 : 16·2, in order that the resulting mixture of isotopes should have an atomic weight of 207·2. The terrestrial ratio is not less than 6 : 15, and if this is a guide to the solar ratio, the latter must in former ages have been greater than 6 : 15 instead of less, because the half-period of uranium is much shorter than that of thorium. On the other hand, if ore-lead is not of radioactive origin, as the argument suggests, then uranium and thorium must either have originated or have become radioactive at about the time of the birth of the solar system.

From the point of view of ore-genesis, the distinction drawn between ore-lead and rock-lead is of fundamental importance. It implies that the ore-bodies in which galena occurs are not derivatives from the igneous rocks visibly associated with them in time and place. J. E. Spurr has already concluded from the distribution of ores that the "magmas" of the latter are not residual fluids expelled from igneous rocks during their crystallisation, but that they are magmas of a special type developed in a zone that is locally a rich storehouse of certain metals.

It is clear that if the atomic weight of rock-lead could be determined, the result, whatever it may be, would throw a searching light on many baffling problems. To separate sufficient lead for the purpose from a representative collection of the world's igneous rocks would be a herculean task, but the value of the result would justify the labour, and I have penned this letter partly in the hope that some great research association, such as those of the United States, may be persuaded to undertake it.

Arthur Holmes.

The University, Durham,
March 10.

### Miller's Ether Drift Experiment and Stellar Motions.

In connexion with Dr. Miller's recent announcement (*Science*, 63, 105, 1926) of his results in measuring the 'ether drift,' the writer wishes to direct attention to a few points which may be worthy of interest.

If we suppose that Miller's results are real, and if we try to interpret them as a partial drag of the ether, it is difficult to avoid conflict with known facts about first order ($v/c$) effects. The constant of aberration and the Michelson-Gale experiment for determining the earth's rotation by optical means give, within the errors of measurement, the full effect expected from theory, whereas Miller's experiment seems to give a greatly reduced effect of an ether drift. But if we interpret his results in terms of what they really are, second order effects ($v^2c^2$), most of the difficulties disappear.

The displacements measured by Miller correspond to a change in the length of his interferometer of the order $10^{-9}$, and his final errors are about 5 per cent. of this quantity. There are probably several explanations for this change in length of his interferometer or in the velocity of light, but if a contraction in the Lorentz-Fitzgerald sense (that is, one due to 'absolute' motion in a stationary medium) exists, it is *only* by experiments of this type that we have as yet been able to determine whether the supposed change in the velocity of light in different directions is *exactly* compensated by the contraction within quantities of this order of magnitude. If this compensation is not exact, the expression for the Lorentz-Fitzgerald contraction, and the fundamental formulæ in the special theory of relativity, require a small but important modification of such a form that the 'absolute' motion enters explicitly into the final expressions. A corresponding modification must also be introduced into the space-time transformations of the general theory, but as these modifications are of the order of only 5 per cent., or more probably 3 per cent., no conflict need arise with the observed facts as regards the tests of the general theory of relativity. But in this case we are obliged to admit the existence of a fundamental reference frame which plays an active rôle in determining physical phenomena.

If the 'absolute' motion does not completely vanish in the case of contraction of matter, it is likely that the expression for the change of mass of an electron requires a corresponding modification, so that the absolute motion enters explicitly. Our ordinary conception of electro-magnetic mass is connected with the way in which the 'field' reacts on the motion of a charged body, and if the mass of an electron is a function of its absolute motion, we may expect a resultant momentum opposing the absolute motion of an atom, but noticeable only when the electron connected with the atom has a velocity approaching the velocity of light. Inside the atoms of the heavier elements, and even more in radioactive processes, electronic velocities occur which approach the velocity of light. As this reaction presumably is exceedingly small, it is difficult to detect. The most promising objects to study are the stars, for which the impulses have opportunity to accumulate for a very long time without being modified by collisions. For a system of stars like our local star system, for which we can assume a community of origin, that is, small initial relative velocities, we may thus expect an asymmetry in the distribution of stellar motions. The motions of the stars in our local system actually show such an asymmetrical distribution and of just such a type as is to be expected from a velocity restriction in a fundamental reference frame in which the globular star clusters and the spiral nebulæ are statistically at rest (*Astrophysical Journal*, 61, 363, 1925). The sun's velocity relative to this 'world-frame' is about 300 km/sec. in the direction $\alpha = 307°$, $\delta = +56°$. Miller claims that his observations indicate a translation of the sun of at least 200 km./sec. in the direction $\alpha = 255°$, $\delta = +65°$, which point is about 23° from the apex as derived from the asymmetrical distribution and from the globular clusters. As the earth's orbital motion is too small to be detected, there is no way, however, of deciding between two opposite directions.

Even apart from a possible positive effect in the Michelson-Morley experiment, there is another reason for suspecting the existence of a fundamental stationary reference frame. The velocities of the stars are in general less than 500 km./sec., and this is ordinarily explained as a result of the fact that the stars have formerly been more intimately connected than they are now, and that objects of excessive velocities have escaped. But astronomers during the last decade have gone far outside our local star-system, and still we find velocities in general less than 1500 km./sec. The assumption of a selective effect or of an exchange of momenta between *all* cosmical systems may be unnecessary; distant systems may even, in a sense, have an independent origin and still have comparatively small initial velocities, if they are 'born' out of a fundamental medium, the metrical properties of which are the same everywhere. Such a medium and a velocity-restriction would also account for the rigidity of the inertial frame and its coincidence, so far as rotation is concerned, with the stellar frame even for the most distant objects observable. The uniformity in Nature is then due to the uniformity of this medium.

There are, however, several difficulties with regard to the possible interpretations of Miller's experiment. Among these difficulties is the predominant westerly deflexion of the 'ether-drift.' Unless unknown disturbing effects are present, the algebraic sum of the east-west components of the drift during a sidereal day must be zero. Among disturbing effects, besides those due to temperature changes, the effect of a magneto-striction ought to be carefully investigated.

GUSTAF STRÖMBERG.
Mount Wilson Observatory,
January 22.

### Nitrogen in the Sun and Stars.

IN a letter in NATURE of February 20, p. 268, under the title "Nitrogen in the Sun," Prof. Saha, in his discussion, refers to the occurrence of nitrogen lines in stellar spectra. He says: "The only nitrogen line which can be identified without ambiguity in the stellar sequence is λ3995. This, however, does not occur in the sun; it occurs, according to [Miss] Payne, first in the Ao class, and Fowler assigns it to $N^+$." The correction of inaccuracies in these statements may prove of assistance to Prof. Saha in his valuable theoretical deductions appertaining to spectra.

In 1910 the present writer gave ("Researches on the Chemical Origins of various lines in Solar and Stellar Spectra." Publication of the Solar Physics Committee) a list of twenty-nine lines of nitrogen which had been traced in spectra of various subdivisions of the B class. Five of these were, in the stellar spectra, probably blended with lines of other elements, but the remainder were quite free from ambiguity, though a few were weak lines which could not be traced through so long a range in the stellar sequence as the stronger nitrogen lines. Such well-known lines as λλ3995·3, 4447·2, 4630·7 and its four companions on the more refrangible side, are all quite free from blending, the first and third being traced through almost the whole of the B group (B8 to Bo) and in ι Orionis of the Oe type, while the remainder were detected only in the shorter range B2 to Bo. In addition to occurring in the ordinary stellar sequence, they were observed as absorption lines at certain stages of the spectra of Nova Geminorum by Mr. Stratton, and of Nova Aquilæ by the writer, but in each of these spectra they were enormously displaced to the violet of their normal positions. All the nitrogen lines just mentioned belong to the singly-ionised group designated by Fowler as $N^+$.

Of the doubly-ionised lines of Fowler's $N^{++}$ class, there is no ambiguity in stellar spectra with such lines as λλ4097·5, 4379·3, 4634·3, and 4640·8. Of these 4097·5 occurs as a weak line at B2 (γ Orionis), is much stronger at Bo (ε Orionis), and apparently attains its maximum intensity in a star of Oe type (29 Canis Majoris), where it is almost as strong as $H_\delta$. This is, however, probably a 'freak' intensity in a star placed, from other considerations, in the Oe class. In other stars of the same named type the line is much less intense. Line 4379·3 is never very