carbon is undoubtedly of volcanic origin, being derived from magma.

A useful estimate of the amount of carbon that has been extracted from the atmosphere by various means has been made by Poole[2], who, however, has unnecessarily revived the theory that this has been all present at one time in gaseous combination in a 'primitive' atmosphere. Poole assumes that some of the fixed carbon has been derived from methane so present instead of from carbon dioxide—an assumption he has considered necessary because of an apparent over-supply of the by-product oxygen if carbon dioxide were the sole (or greatly predominant) source of carbon. When, however, oxidation of juvenile hydrogen throughout the long history of volcanic activity is taken into account, there is no longer any difficulty in accounting for the disposal of such an apparent surplus of atmospheric oxygen. A supply of oxygen for this purpose must indeed be found if there is anything of value in the theory of the volcanic furnace. It is permissible, and indeed necessary, therefore, to recalculate Poole's estimate of atmospheric methane as carbon dioxide, a more likely atmospheric gas.

When this is done, the total mass of carbon dioxide is $7{\cdot}02 \times 10^{16}$ metric tons; and to this must be added $0{\cdot}4 \times 10^{16}$ metric tons of nitrogen now in the atmosphere, and also $0{\cdot}18 \times 10^{16}$ metric tons of juvenile hydrogen which has combined with the surplus of oxygen liberated from carbon dioxide, giving a total of $7{\cdot}6 \times 10^{16}$ metric tons of gases in what must be regarded as the primitive atmosphere (itself perhaps very scanty) *together with the gases that have been emitted from volcanoes throughout the history of the earth.* This excludes juvenile water vapour, which it is impossible to estimate by this method; it has undoubtedly made a substantial contribution to the ocean, however. For comparison, the mass of the atmosphere at present, as given by Poole, is $0{\cdot}52 \times 10^{16}$ metric tons.

One great advantage of recognition of the juvenile (magmatic) origin of carbon, as compared with the 'primitive atmosphere' theory, is that it is in agreement with the geological doctrine of uniformitarianism. If one is to understand that doctrine in a forward-looking sense, a continuance of the supply of carbon from volcanoes will make possible the accumulation of further deposits of coal and limestone in the thousands of millions of years of future geological time; whereas in accordance with the 'primitive atmosphere' theory the supply of carbon for this purpose is exhausted, geological processes have worked themselves to a standstill, and we have arrived at the end of the world.

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[1] Chamberlin, T. C., and Salisbury, R. D., *Geology*, **2**, 90 (1906).
[2] Poole, J. H. J., *Sci. Proc. Roy. Dublin Soc.*, **22**, 345 (1941).

The Deflexion of Light and Relativity

IN a recent paper, E. F. Freundlich and W. Ledermann[1] have pointed out that "the question remains unsettled whether the light deflection at the sun's limb amounts to $1{\cdot}75''$ as predicted by the Theory of Relativity or whether it is substantially larger, namely, equal to $2{\cdot}2''$ as indicated by the findings of the Potsdam Expedition of 1929 and confirmed by a renewed discussion of previous observational material". The authors then proceed to discuss how an experiment can be planned to settle the question so that the standard deviation of the final result does not exceed $0{\cdot}1''$.

If m is the solar mass and R the radius in natural units, $4m/R$ is the predicted deflexion[2]. But $2{\cdot}2''$ means $5m/R$. As the deflexion provides a crucial test of the theory, the question that is often asked is whether relativity must be modified to give the result $5m/R$ instead of $4m/R$. It is well known that the Newtonian result, $2m/R$, is obtained from the usual equation,

$$\frac{d^2u}{d\varphi^2} + u = \frac{m}{h^2}; \qquad (1)$$

and the relativistic result from

$$\frac{d^2u}{d\varphi^2} + u = 3mu^2. \qquad (2)$$

For particles moving *almost* with the velocity of light, we have

$$\frac{d^2u}{d\varphi^2} + u = \frac{m}{h^2} + 3mu^2, \qquad (3)$$

and the deflexion, small as it is, is

$$\frac{2m}{Rv_0^2} + \frac{4m}{R}, \qquad (4)$$

where v_0 is the velocity, $Rd\varphi/ds$, at the perihelion. For light $v_0 = \infty$. The range $1 \leqslant v_0 \leqslant \infty$ corresponds to the velocity $Rd\varphi/dt$ lying between $0{\cdot}70c$ and c. The deflexion is $5m/R$ for a particle for which $v_0 = \sqrt{2}$ and $Rd\varphi/dt$ is $0{\cdot}82c$. In the Newtonian theory there is no distinction between dt and ds, and hence $v_0 = 1$ for light, but the second term of (4), which is of relativistic origin, is absent.

If the deflexion is really $2{\cdot}2''$, one wonders if fast moving atomic particles, with velocities of the order of $0{\cdot}8c$, participate in the process leading to the observed result.

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Aug. 13.

[1] Freundlich, E. F., and Ledermann, W., *Mon. Not. Roy. Ast. Soc.*, **104**, 40 (1944).
[2] Eddington, Sir A. S., "The Mathematical Theory of Relativity", 90 (1924).

The Commutation of Annual Subscriptions

MOST learned societies allow future annual subscriptions to be commuted by single payments which range from five to twenty-five times the annual subscription with, in many cases, a reduction to members of long standing. Although this is usually advantageous to the younger members, it is too expensive at later ages when there is most interest in commutation. There has thus arisen a growing demand for commutation scales on an actuarial basis.

Some examples of such scales may be given. The Institute of Actuaries, with an annual subscription of 3 guineas ceasing at the age of seventy, requires a payment of 30 guineas at age forty-five, with 1 guinea less for each additional year of age up to sixty and then by steps of $1\frac{1}{2}$ guineas to a minimum of $7\frac{1}{2}$ guineas at sixty-five and over. The actuarial basis of this scale is not stated, but the amounts appear to be two thirds of those derived from a $3\frac{1}{2}$ per cent annuity table.

The Royal Society now permits commutation on payment of the amount which the fellow would have to pay for a Government annuity on his own life