The average number of red blood cells in the blood fluid of an adult human in good health is about 5 million per c.mm. [1]; thus the total number of red blood cells is obtained from this number and the total volume of blood fluid, which is about 6 litres. The total number of red blood cells is therefore

$$5 \times 10^6 \times 10^3 \times 10^3 \times 6 = 3 \times 10^{13}.$$

In the condition of pernicious anæmia in relapse, the number of red blood cells may fall to half this number or even less.

If the number of molecules in an effective dose of vitamin $B_{12}$ is compared with the total number of red blood cells, it is apparent that there is more than enough vitamin $B_{12}$ for a one-to-one correspondence, and there is available an excess for a depot storage in the liver. The close accord of these numbers is very suggestive and the smallness of the therapeutic doses no longer appears surprising, nor does vitamin $B_{12}$ appear to be behaving as a catalyst. Since the effect of injecting vitamin $B_{12}$ is rapidly to raise the number of reticulocytes, the precursors of the erythrocytes, it appears probable that at least one vitamin $B_{12}$ molecule interacts, at an earlier stage of the normoblast process, with one blood cell. Thus it seems likely that the vitamin $B_{12}$ molecule provides in some manner an essential unit for each *individual* blood cell in an early stage of its development. If this hypothesis is valid, then it opens up possibilities for further investigations.

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[1] Whitby and Britton, "Disorders of the Blood" (Churchill, 1946–49).

## Minimum and Maximum Limits of Photon-Energy

Milne[1] has recently suggested that Planck's 'constant' $h$ may vary with time, the variation being significant for the interpretation of the spectra of distant galaxies. According to Milne's discussion, $h$ varies linearly with $t$, the present value of the latter being of the order of $2 \times 10^9$ years. This possibility has the particular merit of reconciling the observed red-shifts with the principle of conservation of energy. It is the object of the present letter to point out some other significant consequences of Milne's law.

First, we note that this law has an important bearing on the physical dimensions of Planck's constant. For, if $h$ varies linearly with $t$, then $h/t$ must be a fundamental constant of energy which, unlike $h$, will be a secular invariant. Hence, the fundamental constant will now be a natural unit of energy, the value of $h$ at any cosmic epoch being obtained by multiplying this unit by that epoch.

Secondly, we consider the possible identification of this new unit. Taking $h \sim 6 \times 10^{-27}$ erg-sec. and $t \sim 6 \times 10^{16}$ sec., we find that

$$\frac{h}{t} \sim 10^{-43} \text{ ergs.} \qquad (1)$$

This is equal to the inertial energy of a rest-mass,

$$\frac{h}{c^2 t} \sim 10^{-64} \text{ gm.} \sim \frac{m}{\sqrt{N}}, \qquad (2)$$

where $m$ is the mass of the proton and $N$ is Eddington's number $10^{79}$. (This number indicates the order of magnitude of the equivalent number of protons in a universe of mass $10^{55}$ gm., a numerical value which arises in many otherwise widely different theories of world-structure[2].) Substituting $r\sqrt{N}$ for $ct$ in equation (2), we can immediately isolate the well-known fundamental unit of length,

$$r \sim \frac{h}{mc}. \qquad (3)$$

This unit, of course, is comparable with the radius of the proton ($\sim 10^{-13}$ cm.). The length $ct$, on the other hand, is equivalent to the 'radius of the universe', both in Milne's theory and in Eddington's.

It is natural to ask: What are the minimum and maximum theoretical limits of photon-energy? Since, in standard notation, $E = h\nu = hc/\lambda$, it follows that the minimum $E$ will be given by maximum $\lambda$, and it is reasonable to assume that this is comparable with $ct$. The corresponding $E_{\text{min.}}$ is, therefore, $h/t$, that is, the fundamental unit of energy already isolated. On the other hand, if we assume that minimum $\lambda$ is comparable with the fundamental unit of length $r$, given by (3), the corresponding $E_{\text{max.}}$ is given by

$$E_{\text{max.}} \sim \frac{hc}{r} \sim mc^2, \qquad (4)$$

and so is comparable with the inertial energy of the proton.

These simple calculations suggest further questions: in particular, if $m$, the mass of the proton, is the largest possible rest-mass for an 'elementary particle', is $m/\sqrt{N} \sim 10^{-64}$ gm. the smallest possible rest-mass, and if so, are there material particles far less massive than any so far observed? If the rest-mass of the neutrino, for example, were of this order of magnitude, its energy and momentum could be significant experimentally provided its velocity were sufficiently close to $c$.

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[1] Milne, E. A., "Kinematic Relativity", chap. 8 (Oxford, 1948).
[2] Whitrow, G. J., *Nature*, 158, 165 (1946).

## Schumann–Runge Absorption Bands in Heated Oxygen

The development in emission of the Schumann–Runge system of $O_2$, throughout the greater part of the ultra-violet transmitted by quartz, was recently reported by one of us[1,2]. In the region below 2500 A. the necessity of using fast coarse-grain plates resulted in impaired definition, and accurate measurement was not possible. At the same time, well-resolved rotational structure was desirable in this region; first for the continuation of the rotational analysis which has now been performed for most of the new bands lying above 2500 A.[3]; secondly, since an accurate wave-length list of the band lines in this region seems likely to be an important requirement in the near future, consequent upon the extension of the ultra-violet solar spectrum beyond the ozone limit. The latter point is emphasized by Babcock's identification in the solar spectrum of part of the Schumann–Runge system in the 3000–4000 A. region[4].