Occurrence of Troilite

MINERALS described from the Daggafontein Gold Mine[1] were later made available to me for detailed study. They included typical brownish magnetic tabular pyrrhotite crystals 2·5 mm. wide by 0·5 mm. thick, showing steep pyramid, prism and basal pinacoid faces. Some were intimately associated with black nodules of a hydrocarbon and grey chlorite streaks in lumps of white, finely crystalline dickite.

One large and one smaller crystal identical in form with the majority were more like pyrite in colour and practically non-magnetic. These crystals contained 62·4 per cent of iron, which is nearer to troilite (usually only found in meteorites) than to pyrrhotite in the series pyrrhotite-troilite. The typical pyrrhotite contained 60·31 per cent of iron (kindly analysed by Mr. T. Steele). Troilite has been recorded from the Witwatersrand previously[2], but the occurrence of two distinct varieties of the pyrrhotite series together is worthy of note.

It is suggested that detailed studies of pyrrhotite crystals will prove terrestrial troilite to be more abundant than was hitherto considered.

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Minimum Perceptible Energy and Brownian Motion in Sensory Processes

FOR all sense-organs there exists a lower limit to the minimum perceptible energy, which is set by the Brownian motion in the sensory equipment itself. The minimum perceptible energy must be so large that only a small number of spontaneous excitations by thermal motion can occur. The quantitative relations have been estimated tentatively in certain cases.

(*a*) *Vision*. The minimum perceptible stimulus corresponds to the absorption of a single light quantum by a molecule of visual purple in each of several retinal rods—about five according to Hecht *et al.*[1], or two according to Van der Velden[2]. Suppose that one rod only need be excited. The number of spontaneous thermal excitations will be approximately $q = \frac{N}{\tau} \exp - E/kT$ per sec., where E is the energy necessary to decompose a visual purple molecule and $\exp - E/kT$ is the probability that the essential part of the molecule has a thermal energy greater than E at a given moment (at 37° C., $kT = 4{\cdot}3 \times 10^{-14}$ erg). τ is the mean life-time of a given distribution of the energy; every second we have $1/\tau$ 'new' distributions. For molecules, τ is about 10^{-13} or 10^{-14} sec. (see ref. 3). Finally, N is the number of sensitive molecules in one cell. For applications, we can write our formula as

$$E = 2{\cdot}30\, kT \log \left(\frac{1}{q}\frac{N}{\tau}\right). \quad . \quad . \quad . \quad (1)$$

For the visual process, the calculation of the energy E which is necessary in order to avoid spontaneous excitations can be made with fair accuracy. For the rods, N is 4×10^9 (ref. 4). Strictly speaking, this was found for a frog retina, but it follows from the high sensitivity of the human retina (see ref. 2) that the concentration in dark-adapted human rods cannot be lower than about 10^9 molecules per rod. Hence $N/\tau = 10^{23}$, and according to formula (1) E must be $2{\cdot}3 \times 23\, kT = 53\, kT$ in order to experience less than one excitation per second. Even if ten excitations a second are admitted, E is not materially changed.

For the visual process the limit of 53 kT does not offer anything new, because from the sensitivity curves of the receptors it follows already that E is probably more than 70 kT. Moreover, the spontaneous excitation of only one rod does not give rise to the *sensation* of light; two excitations which occur within about 0·05 sec. are necessary[1,2]. (S. Hecht *et al.* arrive at about five quanta, but since the two-quantum hypothesis, developed by v. d. Velden, was checked by other observations, this number seems more probable.) Of course, the number of spontaneous *sensations* will be greatly reduced in this way, and this may be a reason why this remarkable 'coincidence mechanism' is present in the eye.

(*b*) *Excitation of a Nerve*. For other processes a similar reasoning can be applied, if the various constants are properly defined. As an example, we will consider the excitation of a nerve. For E should be inserted the energy which is necessary for the depolarization of an area O which is large enough to propagate itself. A reasonable value[5] for the energy per cm.^{2} is about 4×10^{-4} erg, so that O should be 3×10^{-9} cm.^{2} to have $E = 30\, kT$. (This value for O will only be assumed as a first approximation.) τ is unknown; it cannot be more than 0·001 sec., since after excitation the normal configuration is restored in about 0·001 sec.[5]. For N, the number of units any of which can start an excitation we should insert the total area of a nerve, divided by O. For a nerve, length 30 cm., diameter 5μ, $N = 3 \times 10^7$. From these data we find that in this case E should be about 25 kT (or more). Then $O = 3 \times 10^{-9}$ cm.^{2} or 2×10^{-6} cm. of the nerve. It is not probable that an area of depolarization of 2×10^{-6} cm. of a nerve is sufficient to propagate itself. This means that the nerve considered is very stable with regard to thermal excitation, and that 25 kT does not suffice for excitation. If the mechanism of the nerve were known in more detail, it would be possible to give a more elaborate discussion. Since the probability of excitation depends largely on the energy E, however, we can safely assume that for the nerve and probably *several other processes* the limit will be at least 25 kT.

(*c*) *Hearing*. For the process of hearing the limit of about 25 kT for one sense cell, mentioned above, is more important. This will be discussed in more detail in the near future in a paper to be published in *Physica*, but the leading idea is as follows. The minimum audible energy is some 300 kT. According to the present views, this energy is distributed over at least 1·5 mm. of the basilar membrane, or 1,000 sense-cells, so that one cell only receives 0·3 kT. This is obviously much too far below the limit mentioned in this letter to be accounted for by experimental errors. From this discrepancy interesting conclusions about the mechanism of hearing can be drawn.

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