LETTERS TO THE EDITORS

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Variation of Geomagnetic Intensity with Depth

IN a recent letter[1], A. L. Hales and D. I. Gough compared their measurements of H_d, the horizontal magnetic intensity (H) at depth d, made in the Witwatersrand at $d = 4,800$ ft., with the formula

$$H_d/H_0 = 1 - 2 (5\rho_1/\rho + 1) d/a \qquad (1)$$

obtained by S. K. Runcorn from Blackett's theory[2]. In (1), H_0 denotes the value of H at the overlying point on the surface $(d = 0)$, a denotes the earth's radius, ρ_1 the mean density of the rocks down to depth d, and ρ the overall mean density of the earth. The observations were compared also with the formula

$$H_d/H_0 = a^3/(a-d)^3 = 1 + 3d/a \text{ (approximately)}, \qquad (2)$$

corresponding to any 'core' theory which places the source of the field wholly below the depth d.

It is clear that (1) cannot be correct, because it should agree with (2) if $\rho_1 = 0$, whereas in fact it gives $H_d/H_0 = 1 - 2d/a$ in that case. The correct formula, which can be derived from a vector potential or otherwise, is

$$H_d/H_0 = 1 - 3(5\rho_1/k\rho - 1)d/a, \qquad (3)$$

where k denotes I/I_0, and I signifies the moment of inertia of the earth and I_0 that of a uniformly dense sphere of the same size and mass. The proof of this and allied and more general formulæ will be communicated to the Physical Society.

Taking $\rho = 5\cdot5$, $\rho_1 = 2\cdot8$, $k = 0\cdot88$, the factor of d/a in (1) is $-7\cdot1$, and in (3) is $-5\cdot7$. Hence $\Delta H \equiv (H_d - H_0)$, which for comparison with the Witwatersrand observations was calculated[1] as $-26\,\gamma$ from (1), should be $-21\,\gamma$ according to (3), whereas (2) gives $+11\,\gamma$. The mean observed value, after making various alternative possible corrections for the effects of local magnetic matter, was given as lying between -10 ± 4 and $-20 \pm 4\,\gamma$. These are not in accord with (2); but to what extent ΔH agrees with (3) must remain uncertain until a more unambiguous determination is obtained.

SYDNEY CHAPMAN

Queen's College,
Oxford.

[1] Hales, A. L., and Gough, D. I., *Nature*, **160**, 746 (1947).
[2] Blackett, P. M. S., *Nature*, **159**, 658 (1947).

THE formula giving the variation of the earth's horizontal field with depth quoted in the letter of Hales and Gough involves an approximation concerning densities which is only applicable to spheres the density distribution of which is only slightly different from a uniform one, such as is roughly true for the earth. Thus it is not to be expected that the formula should give the dipole variation law when $\rho_1 = 0$, but I am grateful to Prof. Chapman for pointing out a more general formula. It should be noted, however, that in the present state of the theory of Blackett's formula, $P = \beta \dfrac{G^{1/2}}{2c} U$, the treatment of densities must remain ambiguous, various assumptions leading to slightly different values of the predicted variation

with depth. This point will be dealt with in detail elsewhere.

S. K. RUNCORN

Physical Laboratories, University,
Manchester 13.

Beta-quinol: an Example of the Firm Union of Molecules Without the Formation of Chemical Bonds Between Them

THE substance formerly called 'β-quinol' and obtained by crystallization of quinol from methanol has been shown[1] to be a compound of three molecules of quinol with one molecule of methanol. It is one of a series of solid compounds of very similar crystalline structure[2], which consists of two interpenetrating giant molecules of hydrogen-bonded quinol units together enclosing small molecules, such as that of methanol, in cavities that are left when these two giant molecules are fitted together as closely as possible. Compounds of this general type in which one component imprisons the other without necessarily having any strong attractive interaction with it have been named clathrate compounds[3]. When crystallized, for example, from ethanol in conditions such that molecules of suitable size are not available for enclosure in this way, quinol forms a more densely packed structure, α-quinol, by a different arrangement of quinol units which has not yet been completely determined.

In the clathrate compounds of quinol the presence of the enclosed molecules exerts a stabilizing effect on the double cagework quinol structure which, although it represents a simple way of satisfying the directional requirements of the hydrogen bonds linking the quinol units, is clearly of a very open character since it provides space for the second component. However, since some of the compounds are found to exist with a large proportion of the cavities unoccupied[4], it seemed possible that the completely empty structure might be capable of existence. Single crystals of quinol have now been obtained in this form. This crystalline form is given the name 'β-quinol', which should no longer be used for the methanol compound. It differs in unit-cell dimensions, refractive indices and density from α-quinol, and a preliminary Fourier electron-density synthesis shows that the structure is very similar to those already determined for the clathrate compounds '3 quinol.M', where M is SO_2, MeOH or a variety of other small molecules, with the essential difference that the spaces occupied in the compounds by molecules of the second component are here vacant. This may be seen in a comparison of the accompanying electron density maps for (a) 3 quinol.SO_2, (b) the empty β-quinol structure. Both show the projected electron density on the (0001) face of the crystal. Whereas the compound shows in the centre a high circular peak, corresponding to the (rotating) sulphur dioxide molecule, and the six surrounding quinol molecules which form its cage, the β-quinol projection shows similar quinol molecules with an empty space at the centre. In both projections the benzene rings are considerably out of the plane of the projection and consequently they appear distorted from their true regular hexagonal shape.

It may be shown from the unit-cell dimensions and from the number and dimensions of the cavities contained within it that in β-quinol about $7\frac{1}{2}$ per cent of the total volume is empty space that could be