over glass surfaces provide further evidence for lateral mobility. Such evidence as is available at present suggests that lateral mobility of physically adsorbed molecules, but not of the chemi-sorbed species, can occur within the range of temperature at which the catalytic reactions occur. We cannot, however, eliminate the possibility of some mobility even in the chemi-sorbed species.

Several hypotheses concerning surface catalysis involve the concept of two-dimensional gas reactions. The experimental evidence available suggests that in surface reactions chemi-sorbed reactants, and not physically adsorbed reactants, are involved; thus the question of mobility becomes one of great importance. Apart from the fact that this mobility for the chemi-sorbed species appears to be non-existent or extremely limited, we must note that the adatoms have dipole moments, and as a result strong repulsive fields exist between them. It is interesting to compare this repulsive or spreading pressure of a film of adatoms where the pressure is due to a free two-dimensional gas, that is, one which obeys the formal relationship

$$F = \sigma KT,$$

where σ is the surface density of adatoms, with the pressure due to a free two-dimensional array of dipoles, that is,

$$F^1 = 4{\cdot}51\ \mu^2\ \sigma^{5/2},$$

where μ is the dipole moment. At values of $\sigma = 0{\cdot}8 \times 10^{14}/\text{cm.}^2$ and $4{\cdot}6 \times 10^{14}/\text{cm.}^2$, the values of F and F^1 are for formic acid on mercury 14 and 52 dynes/cm. for F, and for potassium on tungsten 26·0 and 307 dynes/cm. for F^1 respectively. The value of the dipole moment μ likewise changes as we alter the surface density of the film, due to mutual interaction.

Examination of the heats of adsorption gives us some indication as to the extent of mutual interaction which is repulsive in the chemi-sorbed layer, as well as on the mobility of the film. It is interesting to note that, in the physically adsorbed layer, below the critical temperatures attractive forces appear to predominate; for example, in the condensation of metallic and other vapours on glass.

In the chemi-sorption of a diatomic gas such as hydrogen on the surface of a metallic lattice, the molecule undergoes dissociation to form a pair of metallic hydride molecules. If the film be immobile during the process of filling up the lattice, some eight per cent of the lattice points will be left isolated as singlets. These singlets may play an important part in heterogeneous catalysis. Two of the simplest cases of heterogeneous catalysis are the ortho-para conversion of hydrogen or deuterium and the exchange reaction between hydrogen and deuterium at the surface of non-paramagnetic metals. The reactions proceed smoothly at quite low temperatures with small but definite energies of activation. In the cases which have been examined, the metal is covered with a chemi-sorbed layer of hydride broken only by the gaps already referred to. The formal kinetics of the reaction and reference to the corresponding homogeneous reactions preclude the possibility of the reaction proceeding by a two-dimensional bimolecular gas reaction in a mobile physically adsorbed phase on the top of the chemi-sorbed atomic or hydride layer. One of the current views is that the reaction proceeds by interaction of two neighbouring adsorbed hydrogen adatoms with subsequent evaporation of the newly formed molecule. In view of the repulsive forces which we have shown to be operative and the great heat of adsorption even in a closely packed film, it is clear that many difficulties have still to be overcome before this hypothesis as to the mode of action can be freely accepted.

An alternative proposal involving an interaction between a physically adsorbed molecule situated over one of the vacant sites, and a neighbouring chemi-sorbed adatom to form a transition complex, presents us with a mechanism involving exchange of valence forces rather than rupture of any primary bonds, and goes far to overcome the difficulties associated with the other two proposed mechanisms. Many of the heterogeneous catalytic reactions can be readily interpreted by means of such a mode of action, but experimental re-examination of some of the catalytic exchange reactions is necessary before an unequivocable decision is possible.

The mechanism proposed, it will be seen, involves what is, in fact, the half-hydrogenated state which in the catalytic chemistry of the hydrocarbons has proved such a useful concept. The hypothesis of vacant sites inaccessible to particular reactants suggests their accessibility to other species, and provides us with an explanation of the broken linear character of the curves connecting poisoning with catalytic activity, an explanation alternative to a series of patches of different activity. Dissociation in chemi-sorption involves not only an electron switch, but also the problem of interatomic spacing; the relation of both these factors to the energetics of surface action provides yet another field of inquiry as yet almost unexplored. Provisional theoretical examination of the effects of surface spacing on the activation energy have not taken the electron distribution in the substrate into consideration; while attempts to evaluate energies of activation by examination of metals which form a continuous series of solid solutions and thus provide a gradual change in the mean lattice spacing, require a more detailed examination of the composition of the Gibbs surface layer and its dimensions before we can draw justifiable conclusions.

THE MAIN GEOMAGNETIC FIELD

THE main geomagnetic field and its secular variation were the subject of a Geophysical Discussion held at the Royal Astronomical Society on February 27. The largely attended meeting, at which the Astronomer Royal was chairman, was addressed by Dr. E. C. Bullard, of the Department of Geodesy and Geophysics, Cambridge (who is shortly to take up the post of head of the Department of Physics in the University of Toronto), Dr. J. McG. Bruckshaw, in charge of the sub-department of applied geophysics at the Imperial College of Science and Technology, London, Mr. D. W. Bishopp, director of the Geological Survey of Eire, and Mr. S. K. Runcorn, of the Physics Department in the University of Manchester.

Dr. Bullard outlined a new theory of the secular magnetic variation. He first recalled the main character of this variation, as exemplified by the longest series of observations, for London, which suggests a cycle of change of magnetic direction, of which about three-quarters has been completed in four centuries. Other places, however, show variations that suggest shorter periods. The accumulated data discredit the hypothesis, formerly advanced, that these changes are due to a rotation of the geomagnetic axis about the geographical axis. Bartels has shown that the secular variation is regional in character, differing from the main field itself, which is planetary. The secular variation studies made by Fleming and Fisk, and more recently by Vestine and his collaborators, at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, show that at any one epoch the secular variation is most active in certain limited regions, but that such activity may die away in the course of a few decades, new centres of activity appearing elsewhere. These characteristics are substantiated by the occasional rather rapid changes of rate and direction of the secular variation at magnetic observatories, where the field is most accurately determined.

This time scale of the secular magnetic variation is one of its most remarkable features. Cycles of change of a few centuries in duration, and still more the observed changes during a few decades, are very rapid for a phenomenon that undoubtedly originates within the body of the earth; ordinary geological changes require millennia or even millions of years for their evolution. The rapidity of the secular magnetic variation excludes any theory based on motions or thermal changes in the solid outer portion of the earth. A deeper source must be sought, in the liquid core, the existence of which is inferred from the failure of transverse seismic waves to pass through or near the earth's centre.

Dr. Bullard discussed particularly the rapid secular variation in and near South Africa during recent decades. The isoporic charts, which show the lines of equal rate of secular change, are somewhat complicated; a clearer conception of the variation over this region is obtained by plotting the rate-of-change vectors for the horizontal component, and indicating beside them the positive or negative rate of change of the vertical component. It is still better to draw the (inclined) rate-of-change vectors of the secular variation (vertical as well as horizontal) in the median vertical plane through the region, in the direction of the horizontal change—roughly the north-west to south-east direction. Taking the region to extend over 25° or 30° in this direction (over which range the curvature of the earth is, of course, important), the vectors at the north-west end slope upward, those at the south-east end slope downward, while intermediately they are nearly horizontal.

Dr. Bullard finds that these vectors for surface points correspond approximately, in magnitude and direction, to the field of a nearly horizontal magnetic dipole situated near the surface of the earth's liquid core, below the centre of the region. The estimated moment of the dipole for the change in one year is $3{\cdot}5 \times 10^{22}$ gauss (Γ) cm.^{3}. If the change continued for a century, the equivalent dipole moment would be $3{\cdot}5 \times 10^{24}$ Γ cm.^{3}—about 4 per cent of the moment (8×10^{25}) of the earth's main field. The dipole of the secular variation may not attain this value; it may die away again within a century from the commencement of secular activity in this region, a possibility to be confirmed or negatived only by future observation in this region.

The origin of the secularly evolving magnetic dipole is attributed by Dr. Bullard to an electric current circuit, flowing in the mass of an eddy near the surface of the core; the current is supposed to be produced by electromagnetic induction by the circulatory motion in the eddy, in the presence of the permanent magnetic field. Dr. Bullard is inclined to infer that at that depth the magnetic vector is more nearly vertical than at the surface point directly overhead. He has considered, to a degree of detail not possible to reproduce here, various numerical values pertaining to the dipole mechanism; a few of his illustrative estimates may be cited. If the radius of the eddy is 300 km., the electric current intensity must be of the order 4×10^{-5} amp./cm.^{2}, the total current being about 3×10^{11} amp. The time of circulation in the eddy may be of the order $0{\cdot}3$ year. Under the conditions supposed to prevail at the surface of the core, where the electrical conductivity can be roughly estimated, these would be a possible set of values. The Reynolds number is estimated as 5×10^{11}; Dr. Bullard suggests that the eddy would disappear by break-up rather than by frictional decay. He considers that developing dipole fields of eddies more than a few hundred kilometres below the surface of the core would be shielded by currents induced in the upper part of the core, so that the observed secular variation at the earth's surface will be due to the uppermost core eddies.

This fascinating theoretical discussion was followed by Dr. J. M. Bruckshaw's account of some observations of great theoretical interest on the magnetic anomalies associated with the main tholeiite dykes of the north of England, a system of volcanic dykes extending from the Isle of Mull to the north-east coast of England. This work was done in conjunction with E. I. Robertson, a New Zealand research student, aided by a team of student observers. The dykes are tertiary igneous intrusions, perhaps fifty million years old; they are nearly vertical, and only 10–25 yards thick. Since their formation they have remained undistorted by any major earth movements, though displaced slightly here and there by local faults.

The vertical magnetic intensity (V) was measured at points along sixty-five traverses across the dyke; pronounced anomalies were observed, of amounts up to 2,500 γ. Each traverse gave a graph of the variations of V. Rock specimens were also taken, their orientations *in situ* being carefully noted; laboratory measurements of their susceptibility and permanent intensity of magnetization (I) thus enabled the magnitude and direction of the resultant I for the dykes to be determined. The observed anomalies in V agree well with those calculated from the size, form, position and magnetization of the dyke at various places along it. The outstanding feature disclosed by the investigation is that the dyke is magnetized in a direction nearly opposite to that of the present geomagnetic field in the locality.

Observations in volcanic regions to-day show that the magnetic lavas that well upwards as a molten magma become magnetized by induction in the earth's field as they cool through the Curie point. Mercanton, Thellier and others have shown that in many cases such rocks have great magnetic retentivity, and most of the rock specimens collected in this investigation show the same property, though in a few cases their magnetization declined appreciably within a few months. The simple interpretation of the observed data is that the earth's field in this region fifty million years ago was opposite in direction to that which now exists there. The poor retentivity of a minority of the rock specimens may explain the few cases in which the magnetization has the present direction of the field. In general, the observed anomalous I is two to eight times as intense as the present field would induce.

Such anomalous magnetization has previously been observed in Germany, in the Arctic (by Mercanton), in New Zealand, and (perhaps the most striking case) in the Pilansberg dykes in South Africa, which are palæozoic, perhaps two hundred to five hundred million years old. Mr. D. W. Bishopp, in his account of a recent survey of the vertical force (V) over Eire (from which two magnetic maps, not yet published, have been prepared), added further examples, also of tertiary intrusions, showing the 'wrong' sign of magnetization.

The Pilansberg dykes are not too far from the equator to exclude the possibility of explanation, in their case, by the hypothesis that in the course of the secular variation the *magnetic* equator has passed across this region, corresponding to a reversal of the local value of V. But this explanation could not be applied to regions so far north as the Border or as Eire. It is difficult also to see how Dr. Bullard's explanation of the secular variation could account for a local reversal of the field. Geologists present at the discussion remarked that in tertiary times the molten layers seem to have come unusually near the surface; but it is not clear how this could help to explain a reversal of the field. A very extensive continental drift carrying great land masses across the equator is another possible but unattractive hypothesis that would obviate the conclusion that the earth's field as a whole was once of opposite polarity. This conclusion would, of course, be quite inconsistent with any 'fundamental' theory associating magnetization with rotation in the case of large rotating masses, such as Prof. P. M. S. Blackett has advocated.

The fourth contribution to the discussion, by Mr. S. K. Runcorn, bore on this hypothesis. When Prof. Blackett in May last read his paper on the 'fundamental' theory of magnetization by rotation, Dr. Bullard pointed out that the variation of the magnetic intensity with depth within the earth should provide a crucial test between such a theory, and the usual 'core' theories which assign the source of the earth's field to some cause within an inner core of the earth. Any core theory, which regards the overlying portion of the earth as non-magnetic, implies that V and H both vary as $1/r^3$ at distance r from the earth's centre, outside the core. On the fundamental theory, in which every element of mass contributes in some way to the field, the intensity might be expected to decrease downwards. The depth-variation of intensity on the fundamental theory, for different distributions of density within the earth, has since been calculated by Mr. Runcorn and also by Chapman; it appears that near the surface V varies as $1/r^3$ whatever the density distribution (assumed spherically symmetrical), so that measurements of the depth variation of V cannot distinguish between the fundamental and the core theories. The 'fundamental' depth-variation of H, however, is a downward decrease, depending on the density distribution; this therefore, as Dr. Bullard suggested, offers a possibility of deciding between the two theories.

Observations of H in South Africa at an effective depth of 4,800 ft. in a Witwatersrand mine have recently been reported in *Nature* (**160**, 746; 1947); they show a decrease, favouring the fundamental theory; but there is great need of further measurements in regions less disturbed magnetically than the Witwatersrand. Mr. Runcorn gave a preliminary account of such measures in a coal-mine at Leigh, in Lancashire, in a region apparently devoid of any appreciable magnetic anomalies. He, Mr. A. C. Benson and Mr. S. Goldsack, of the University of Manchester, have measured both V and H at a depth of 4,000 ft., in a disused working, well removed from any iron or steel mining structures. Comparison with V and H measured at the surface show the expected downward increase of V, and a *decrease* in H; $\Delta H = -45\gamma$ approximately, as against $\Delta H = +13\gamma$ as expected on the core theory. An intensity of magnetization of $0\cdot08\ \Gamma/\text{cm.}^2$ in the top layer 4,000 ft. deep would be needed to account for this value of ΔH, and this layer is certainly not so magnetized (and if it were, V would also be affected by it).

Prof. Blackett pointed out the great importance of such observations, which if verified would indicate a hitherto unrecognized property of matter which is not magnetic in the ordinary sense of the word. Prof. T. G. Cowling remarked on the indefiniteness of the concept of angular momentum in connexion with fundamental theories of magnetization by rotation, and Prof. Blackett agreed that such theories must at present be regarded only as provisional.

The whole discussion showed that this relatively old science of geomagnetism remains lively and vigorous, and the new contributions made by Prof. Blackett and Dr. Bullard will undoubtedly provide much stimulus to further observations and their interpretation.

S. CHAPMAN

STRUCTURE OF AN ANIMAL VIRUS

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BECAUSE of their crystallinity, a great deal is known about the ultimate chemical structure of the plant viruses, whereas little or no corresponding information is available for the animal viruses. Efforts to obtain X-ray diffraction patterns have not been successful, and attention has been turned in recent years towards the electron microscope as the tool most likely to solve the problem. For obvious reasons attention in the first instance has been directed to the larger animal viruses, but with the exceptions of nuclei-like bodies in the Rickettsiæ[1] and less definite internal bodies in the pox group[2,3], this technique has also proved disappointing. It is clear on the practical side that the size and density of the infective particles is such that 100-kV. electrons can only just penetrate them, and any internal differences in electron density which may exist must be of a low order—probably less than 20 per cent.

In the pox group of viruses, outlines of a central body were first seen by Green *et al.*[2], with vaguer indications of the presence of four satellite bodies occupying the corners of the brick-shaped particles. The viruses of this group are all purified by differential centrifugation from dilute buffer suspensions, and it is a common experience[4,5], especially with vaccinia, to find structureless material present in the background of the electron micrographs—sometimes linking neighbouring particles as if by gelatinous bridges—which persists after repeated differential centrifuga-