$$U_1 + U_2 < 3{\cdot}9 \pm 0{\cdot}3 \text{ eV} \qquad (2)$$

We will call $U_p/3$ the effective bond energy, U_e. This represents the energy absorbed when one lattice bond between two atoms is broken and converted into two partial bonds.

The activation energy for the motion of a vacancy is $U_m = 3{\cdot}15 \pm 0{\cdot}55$ eV (ref. 1). This involves the counter-motion of a lattice atom. In its rest position this atom has two lattice bonds. We assume that at the mid-point of its jump, these are both broken (each absorbing $2U_s/3$) and each half of each bond forms a partial bond with adjacent lattice atoms, each partial bond emitting energy U_3. Thus $U_m = 4U_s/3 - 4U_3$ or:

$$U_3 = 1{\cdot}71 \pm 0{\cdot}16 \text{ eV} \qquad (3)$$

The values of U_1, U_2 and U_3 are probably close to each other. For present purposes we will take them to be equal and estimate their mean value U_0. Equations (1), (2) and (3) then lead to $U_0 = 1{\cdot}5 \pm 0{\cdot}4$ eV. The stored energy of a vacancy-interstitial pair, U_p, is therefore $6{\cdot}0 \pm 2{\cdot}4$ eV. Half of this is to be associated with the interstitial and half with the vacancy. Experimentally the saturation value of the stored energy in graphite at reactor temperatures is about 600 cal/g (ref. 4) or 0·3 eV per lattice atom. If the damage configuration consists of single vacancies plus clustered interstitials, then the stored energy will be due principally to the bonds around the vacancies, and the saturation vacancy concentration is of order $0{\cdot}3/3{\cdot}0 = 1/10$. This is a very reasonable value[5].

We may estimate the activation energy, U_c, to evaporate interstitial clusters in graphite. The most firmly bound atoms on the edge of the cluster are attached to the edge of the cluster by two lattice bonds. U_c is thus the energy to convert these two bonds to partials (which is also the activation energy U_m for vacancy diffusion) plus the activation energy for diffusion of interstitial atoms, U_i. This latter is at least 0·4 eV (ref. 6), and is less than the 1·2 eV observed for annealing processes at higher temperatures[4], so we will put $U_i = 0{\cdot}8 \pm 0{\cdot}4$ eV.

Thus $U_c = 3{\cdot}95 \pm 0{\cdot}95$ eV. The disappearance of an interstitial cluster as the temperature is raised will thus be due first to erosion by any vacancies initially present in the lattice (U_m), followed closely by the evaporation of the interstitials remaining in the cluster (U_c). If the atoms on the edge of the cluster each evaporate in 10 sec, the value 3·95 eV corresponds to a temperature of about 1,200° C. If no vacancy clusters, dislocations or other suitable sinks are present, these interstitial atoms will condense into fresh clusters on cooling. This mechanism may contribute to the large cluster motion observed at 1,200° C (ref. 6).

The activation energy for the diffusion of a singly bonded interstitial atom along the edge of a cluster will similarly be of the order of $U_e + U_i$ or $2{\cdot}8 \pm 1{\cdot}2$ eV, which on the basis of 10^{-7} jumps per sec corresponds to a temperature of $450 \pm 300°$ C. This implies that at the lowest power-reactor temperatures, the clusters will contain a significant number of vacant (interstitial) sites due to imperfect filling, while at sufficiently higher temperatures the atom-density in the cluster will be normal.

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GEOPHYSICS

Annual Change in the Declination ('Variation') in Western Scandinavia and the North Sea

WITH reference to the letter in *Nature*[1] from Guro Gjellestad and Helge Dalseide it should be noted that the last published British Admiralty chart of declination (epoch 1960.0) does show a decrease in the annual change over the area in question, when compared with the previous chart. The isopors (lines of equal annual change) shown on the 1960 chart are given in Fig. 1 (full) together with those found for 1958 by Gjellestad and Dalseide (dotted).

Isopors appearing upon a declination chart are of necessity compiled in advance of publication of the chart. from data extending backwards and seldom fully up to date. The information deduced from these data are extrapolated values of the annual change which must be used for correcting the chart values of the declination for a period of several years subsequent to the epoch of the chart. No extrapolation formula has yet been devised to cope with the vagaries of secular change, and experience has shown that, even in the best-determined regions. extrapolation over a matter of several years is liable to errors of 1 or 2 min per year in the predicted annual change.

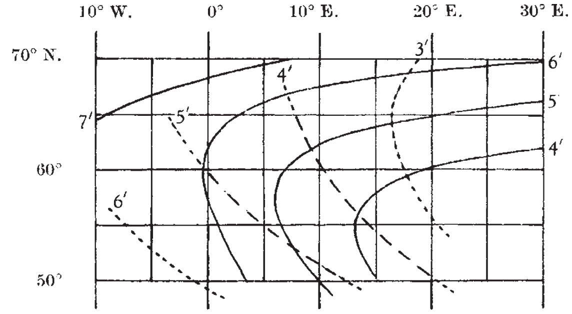

Fig. 1. Annual change (east) in the magnetic declination. ——, British Admiralty Chart, 1960; – – –, Gjellestad and Dalseide, 1958

Moreover, small variations in the adopted values at different observatories can alter materially the pattern of the lines, while the ends of lines deduced from the study of a limited region may differ in position and direction materially from a set of lines drawn up on the basis of world-wide coverage and thus influenced by the results from neighbouring regions.

The purpose of this communication is to point out that the decrease in the annual change discussed by Gjellestad and Dalseide is in fact shown in the last Admiralty world charts, and that the differences of the two sets of isopors should be treated with reserve.

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WE were not referring in our communication to the last published British Admiralty chart (1960.0) which we did not know about, but to several Scandinavian charts and to other sea maps apparently using information from older charts from the Admiralty. We fully agree with Finch in his remarks. It is unfortunate that no theory of the secular variation has been developed that might be generally accepted, and that no empirical formula is known for extrapolating for the secular variation.

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