riods under endemic conditions, since the bite of infected mosquitoes would reinforce the vaccine-induced immunity.

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Solid Electrolyte Behavior of $NaMgF_3$: Geophysical Implications

Abstract. *In the solid state, $NaMgF_3$ transforms smoothly with temperature into a solid electrolyte phase; the conductivity is 130 siemens per meter just below the melting point. The isostructural compound $MgSiO_3$ should behave similarly under conditions obtaining in the earth's lower mantle, and so it is expected that the electrical conductivity in that region is ionic rather than electronic.*

It has been known for some years that many binary fluorides are good solid electrolytes ("superionic" conductors) with ionic conductivities in the solid state at high temperatures comparable to those of molten salts. The transition from the poorly conducting to the solid electrolyte state may be abrupt as in YF_3 and LuF_3 (*1*) or continuous as in PbF_2 and other salts with the fluorite (CaF_2) structure (*2*) and in salts with the tysonite (LaF_3) structure (*3*).

A number of regularities in the transition have been noted (*4*). The more important of these for the present discussion are as follows.

1) The occurrence of a solid electrolyte transition of a particular type is closely related to crystal structure. Without exception, it has been found that, if a material with a given structure type (for example, CaF_2 or LaF_3) undergoes a continuous transition, that is, is in class III (*4*), then so do all other crystals with the same structure.

2) The entropy increment associated with the transition, whether discontinuous or continuous (*5*), is comparable to the entropy of melting of the salt. This finding suggests the concept of "sublattice melting."

3) The ionic conductivity of the salt is typically 10^{-1} S m^{-1} just below the transition temperature and ~ 10^2 S m^{-1} in the solid electrolyte range. For normal salts (not solid electrolytes) these are the ionic conductivities typically found just below and above the melting temperature. Thus ionic conductivities in the range 10^{-1} to 10^2 S m^{-1} are to be associated with solid electrolytes of class III in the transition region.

It has also been shown recently (*6*) that the structures of YF_3 and LaF_3 are very closely related to that of the orthorhombic "perovskites" typified by $YFeO_3$ and $CaTiO_3$ (perovskite). It was thought likely therefore that perovskites of this type might prove also to be anion-conducting solid electrolytes. The oxides generally have high (> 2000°K) melting temperatures. Because high-temperature conductivity measurements are subject to considerable experimental difficulties and uncertainties (*7*), we have investigated first the ionic conductivity of $NaMgF_3$ (*8*) which has the same structure type (*9*) and is isoelectronic with $MgSiO_3$. The experimental techniques were the same as those described in (*1*).

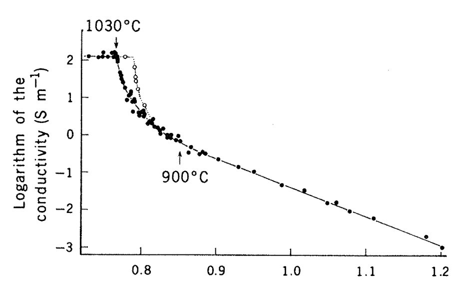

Fig. 1. The logarithm of the conductivity of $NaMgF_3$ as a function of reciprocal temperature. The arrow at 1030°C indicates the melting point, and the arrow at 900°C designates the temperature above which the salt becomes cubic. The closed circles represent four measurements (heating and cooling) on two different samples. The open circles and dotted line represent data obtained with a supercooled (~ 100°K/hour) melt.

The experimental results are displayed in Fig. 1. The conductivity of solid $NaMgF_3$ at high temperatures is in the solid electrolyte range (10^{-1} to 10^2 S m^{-1}), it is a continuous function of temperature, and it undergoes very little change at the melting temperature (1030°C). It is clear then that there is a continuous solid electrolyte transition in this compound that starts at about 900°C, the temperature at which the crystal becomes cubic (*9*).

Although of great interest in itself in establishing the occurrence of a solid electrolyte transition in a new structural type, this result also has geophysical implications of considerable consequence. It is a long-established principle in geophysics and geochemistry that fluorides can be used as model systems for isostructural oxides. We have discussed elsewhere (*10*) the correspondence between $NaMgF_3$ and the high-pressure perovskite form of $MgSiO_3$ (*11*), which is very likely a major constituent of the earth's lower mantle (that is, that region between 3500 and 5700 km from the center, the bulk of the earth) (*12*). Thus it is likely that perovskite $MgSiO_3$ is a high-temperature solid electrolyte and that the lower mantle is a solid electrolyte phase.

In connection with the above proposal, the following points are very relevant. (i) Heat flow considerations suggest very strongly that the material in the lower mantle is very close (within perhaps 10°K) to the melting temperature (*13*). (ii) The best estimates (*14*) of the electrical conductivity in this region place it in the range 10^{-1} to 10^2 S m^{-1}, that is, exactly in the "molten sublattice" or solid electrolyte range.

In short, the evidence is strong that the lower mantle consists of a solid electrolyte phase rather than an electronic conductor, as is usually assumed (*15*). As solid electrolytes differ in important ways from normal salts in many of their properties (thermodynamic, elastic, and rheological) (*16*), detailed models of the

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mantle that incorporate extrapolations to high temperatures and pressures based on the behavior of normal salts may well need to be revised.

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Determinants of Cognitive Performance in Warsaw

Firkowska *et al.* (*1*) investigated determinants of cognitive performance in Warsaw, where the variance in extrinsic determinants (such as the quality of schools, health care, and housing) was greatly reduced owing to social policy. A determinant that does not vary cannot explain variability in cognitive performance. Thus, Firkowska *et al.* observed stronger correlations between cognitive performance and certain intrinsic determinants (parents' education and occupation) than between cognitive performance and extrinsic determinants. They conclude that "an egalitarian social policy executed over a generation failed to override the association of social and family factors with cognitive development that is characteristic of more traditional industrial societies" (p 1358).

It could hardly have been otherwise. The egalitarian social policy could have eliminated individual differences in performance only under two unlikely sets of circumstances: if intrinsic factors did not affect cognitive performance, or if extrinsic factors were systematically and inversely correlated with intrinsic factors. Neither of these conditions is met in Warsaw nor, probably, in any other society.

Assessed extrinsic factors in the study by Firkowska *et al.* did not vary and therefore were not important in explaining the variability in cognitive performance in Warsaw. This does not mean that they may not be important in other populations where they do vary. Furthermore, although assessed extrinsic factors could not explain variability of cognitive performance in Warsaw, they may have been an important determinant of performance. Nutrition cannot explain any of the variability in height of a uniformly well-nourished population, but it is certainly an important determinant of height. The same may be true of extrinsic determinants in Warsaw and elsewhere.

The study by Firkowska *et al.* has mainly emphasized a statistical fact: reducing the variability of only one determinant of a multiply determined capability can only reduce the portion of the variance which that determinant explains.

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On the specific subject of the ability of our study to explain the contribution of extrinsic factors to cognitive performance, Lasky seems not to be aware that he is in agreement with us. We make the same point more than once in our paper, for instance:

> . . . The range of variation among the extrinsic variables themselves is not great, however; such effects as they may have would be largely neutralized by their even distribution across districts.
>
> For this reason one cannot say from our study that extrinsic factors are not salient in mental performance, but only that they are not salient under the equalized conditions of habitation found in Warsaw. In other words, social policy may have removed the effects of extrinsic factors from the reach of measurement. . . .

On the general subject of our study of cognitive performance in Warsaw, Lasky seems to us to have missed its main point. Virtually everywhere (but not in Warsaw) "extrinsic" and "intrinsic" factors are systematically associated. Statistical analysis, however sophisticated, of their relations with cognitive performance is therefore subject to confounding. For instance, the children of the better-off go to "good" schools, the children of the poor to "poor" schools, and cases that depart from such a distribution are likely to be too few or too deviant to provide adequate statistical control. The contribution of our study as we see it is that in Warsaw the two sets of factors were unconfounded. Since social policy had neutralized the effect of extrinsic factors, the effects of intrinsic factors could be isolated and studied separately. We aimed precisely to exploit the objective results of a social experiment rather than a "statistical fact."

On one particular point Lasky is in error. It is not true that "reducing the variability of only one determinant of a multiply determined capability can only reduce the portion of the variance which that determinant explains." Quite apart from the untenable assumption of perfect knowledge of confounding on which the statement rests, Lasky leaves out of account the possibility of interaction among factors. In the real world, manifestations of interaction are protean, and can rarely be safely ignored.

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