Professor Paul Engelking Debunks I_E Crystals

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Mark–

I don't want to get too deep in this. There are several ways of expressing what is wrong with the theory in several places. Let me just name two problems with one of Lo's basic calculations.

E&M:

First, Lo assumes that the electric field flux (E) is conserved in a polarizable medium. The correct Gauss's law–one of the four Maxwell's equations–states that the displacement flux (D) is conserved in a polarizable medium.

To support his claims, Lo does a back of the envelope calculation of the field surrounding a charge in water. However, he denies that the dipole moments of the nearby water molecules, when oriented in the field surrounding the charge, will reduce the field strength.

Normally this effect of polarization is summarized in the macroscopic dielectric constant, which is about 80 for water. This is the amount by which the electric field E is reduced in the bulk liquid from that of the electric displacement D, so it is not a negligable effect. For water, generally $E = D/80$. (*Note*: I'm rationalizing units here so that the polarizability of free space is 1, or $D = E$ in a vacuum. If you want SI units, multiply all D's by an ϵ_0.). When Lo calculates the field around a charge, he neglects this contribution to the field E by the polarization of water.

To calculate the field in a polarizable medium, one uses Maxwell's result that the displacement flux, represented by D, is conserved. This is represented by Maxwell's first equation:

$$\mathbf{div}\, D = \text{(charge density)}$$

The spherically symmetric solution gives $|D| = Q/(4\pi r^2)$ where Q is the charge and r is the distance to the charge. Or, in terms of E, using $E = D/80$, $|E| = Q/(4\pi 80 r^2)$.

In integral form, Maxwell's first equation is also known as Gauss's law, or

$$\oint D\,ds = Q$$

where the integral is taken over a surface enclosing the total charge Q.

Lo makes an argument that would modify this first law of electromagnetism. He first calculates E correctly, based upon the expression $|E| = Q/(4\pi 80 r^2)$. But then he argues that this E is a factor of 80 too small, justifying his revision by stating an incorrect expression for Gauss's law in a polarizable medium,

$$\oint E\,ds = Q$$

This expresses (incorrectly) the conservation of the flux of E, rather than (correctly) the conservation of the flux of D in a polarizable medium. If Lo's statement of Gauss's law would be true, it would be true only in a vacuum; it is incorrect in a polarizable medium, such as water, here. Thus, Lo argues himself into neglecting the polarizability of water when he calculates the electric field, and gets a field E that is almost two orders of magnitude too large in the water surrounding an ion.

Thermodynamics:

A second point of inconsistency with standard physics comes from Lo's neglect of any entropy effects.

In one sense, Lo is correct that oriented water molecules would have a lower electrostatic energy than do disordered water molecules. But so do water molecules in ice, even above the melting point temperature of ice.

One reason Lo's I_E crystals don't spontaneously form is the same reason that water at room temperature doesn't sponaneously freeze: although energetically allowed, the process is entropically forbidden. The entropy of the world would have to spontaneously decrease, violating the second law of thermodynamics.

Ordinary ice has water molecules hydrogen bonded in a regular hexagonal array. When ice melts, this regular network of hydrogen bonds is partially disrupted at random. Thus, liquid water has higher entropy: it is more disordered. In thermodynamics, the exchange rate for energy and entropy is temperature. The temperature at which the higher energy liquid form of water is favored over the lower energy solid form is given by $T = dE/dS$, where dE and dS are the energy and entropy changes accompanying the phase change.

In addition to estimating the lowering of the energy of formation of I_E crystals, one must also estimate the entropic effects, too, of a thermodynamic material. Lo doesn't do this.

But a simple calculation suggests that these effects can't be negligible. To orient water molecules the way that Lo want to do, he must virtually stop their free rotations. Say that their dipoles are contrained to within 0.1 steradians of the orienting field. Normally able to move about 4π steradians, this is a constraint of about 1/125 of free motion of the water dipoles. Even making no other assumption about the pointing angle of the hydrogens, this is still an entropic factor of $-k\ln(125)$ for each molecule, or loss of about $40J/(mol \cdot K)$ of entropy on a mole scale. At room temperature, liquid water has only about $70J/(mol \cdot K)$ entropy, total, so this would correspond to reducing the entropy of water by about half! Or to put it in energetic terms, at room temperature, orienting the molecules this much would correspond to about $12kJ/mol$ increase in free energy for the I_E form. For a spontaneous phase change to occur, this would have to be made up by an even greater decrease in the internal energy. This is twice the heat of fusion of ordinary ice/water at 0°C ($6kJ/mol$). By any estimate, the entropic costs of orienting great numbers of water molecules are very large.

In thermodynamics, the lowest energy state is not necessarily the most stable state. Whenever one has a substance in equilibrium at finite temperature, thermodynamics, including the second law of thermodynamics, applies.

Lo didn't attempt to consider the severe entropy penalty that would be assessed. He never checked the second law of thermodynamics.

I hope this clarifies just two points.

–Paul Engelking