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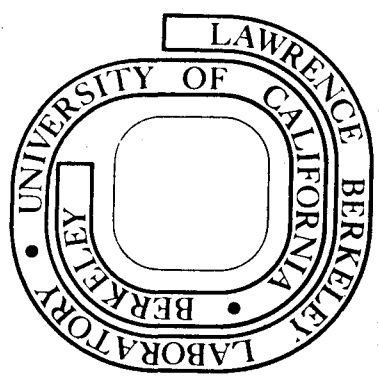
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A QUANTUM MECHANICAL TREATMENT OF
AN ELECTROMOTIVE FORCE OF FUSION

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An electromotive force has been measured between electrodes immersed in several different molten inorganic compounds near their melting temperatures when one of the electrodes is depositing crystals, or when crystals are melting. The maximum electromotive force (EMF) values measured at the onset of crystal formation correspond closely to reported heat of fusion values, $^1 H_f$, as shown in Table 1. The averages of measured values are listed where more than two values were obtained. In a few cases half energy values were measured indicating preferential crystallization of dimers or the transfer of two equivalents of electrons per mole of compound for these experiments. In several cases the measured EMFs clustered at intervals of one to two hundred cal/mole. Examples are shown in Table 1 for Na_2SO_4 . This may indicate crystallization modes that result in differences in initial and final states.

The experiment is usually started with both electrodes immersed in the molten liquid. This allows a check on extraneous junction or oxide layer potentials which might occur due to a difference in oxidation state or chemistry of the electrodes. Also, any initial strain or polarization EMFs are easily measured. Such EMFs have been observed to build up to the order of 1 or 2 volts (23.06 kcal per volt) when the whole melt crystallizes.

Variations in temperature of the order of 20 to 30° K gave no observable variation in the observed EMFs. The experiments were performed over a Fisher burner with air and gas inlets. The burner was turned down or off during EMF measurements.

The measured values were obtained with several sets of platinum wire electrodes which varied in size. Iridium electrodes were also used with comparable results. Most experiments were performed by establishing slight temperature gradients in order to favor crystallization or dissolution at one electrode, or, one electrode was repeatedly dipped into slowly cooling liquid while recording temperature and the EMF. In several cases constant EMF of fusion values were obtained for prolonged periods by keeping one electrode in the melt while the other barely touched the surface.

In the present experiments, the crystal was denser than the molten liquid, and the crystal forming electrode acted as a cathode, giving electrons to the molten liquid. The observed EMF is due to a difference in chemical potential between the forming crystal or surface and the molten liquid, which is also the difference in Fermi level energy, E_0 , for the electrons.² For non-equilibrium or equilibrium processes the chemical potential, μ_e for electrons, is defined by the Einstein-Josephson relationship given by Anderson³

$$\mu_e = -eV + \frac{h}{4\pi} \left(\frac{d\phi}{dt} \right) \quad (1)$$

where eV is in electron volts and is the direct current component of the energy (EMF), $h/4\pi \frac{d\phi}{dt}$ is the time, t , varying component of energy, ϕ is the phase difference for electron-pair "wave functions", and h is

Planck's constant. It is noteworthy that this relationship shows no temperature dependence at zero resistance in the absence of acceleration, $d\phi/dt$.³ This is in agreement with Gibbs' definition of the chemical potential and the Gibbs-Helmholtz relationship⁴

$$\mu_e = \left(\frac{\partial H}{\partial n_e} \right)_{S, P, n_j} \quad (2)$$

and

$$\mu_e = - \frac{\Delta S}{n_e \mathcal{F}} = -\mathcal{E} + T \frac{d\mathcal{E}}{dT} \quad (3)$$

or

$$\mu_e = -\mathcal{E} + T \frac{\Delta S}{n_e \mathcal{F}} \quad (4)$$

where $(\partial H / \partial n_e)_{S, P, n_j}$ is the change in enthalpy, H , with respect to the change in number of moles of electrons at constant entropy, S , pressure, P , and moles of other components, n_j , \mathcal{F} is the Faraday equivalent \mathcal{E} is the electromotive force, (EMF), and T is the temperature. Thus, equations (1) and (3) are equivalent when a common ground state chemical potential is established for one electrode in a Josephson junction experiment and one of the electrodes in an EMF of fusion experiment. When the maximum EMF is measured, $\Delta S = 0$, and

$$T \frac{d\mathcal{E}}{dT} = \frac{dE_o}{dT} = 0 \quad (5)$$

and if the maximum EMF is reduced by non-zero resistance or radiation losses (heat losses):

$$T \frac{d\mathcal{E}}{dT} = \frac{h}{4\pi} \frac{d\phi}{dt} = + eV \quad (6)$$

where the last two equalities are the Josephson equation.³ This is equivalent to saying that the non-equilibrium process of crystal formation will yield a maximum EMF or chemical potential difference in a superconducting mode (zero resistance) and that this maximum will be degraded by any acceleration of the supercurrent that acts as a back EMF and gives rise to radiative heat losses. The verity of this interpretation is supported by the one to two millivolt root mean square deviations in data shown in Table 1 for the experiments conducted at temperatures in excess of 1100 degrees Kelvin, where kT is of the order of 100 millivolts.

It is clear from Eqn. (1) and Eqn. (6) that acceleration of the supercurrent to $4\pi eV/h$ will result in a chemical potential of zero for the electrons. This will also hold for electrons at a constant gravitational potential. This is in agreement with a recent theory on gravitational symmetry⁵ where the relationship

$$G = \frac{32\pi}{\sinh(32)} \cdot \frac{1}{m^3 N} \cdot \left(\frac{hc}{2e} \right)^2 \quad (7)$$

has been obtained ab initio for the gravitational constant, G , where m is the proton mass, N is Avogadro's ratio, $hc/2e$ is one half of a quantum of magnetic flux per mole for a superconducting torus or ring, e is the charge, and c is the velocity of light.

When the chemical potential is zero, the change in free energy with respect to a change in charge is zero for any constant gravitational potential at constant T , P , n_j , and surface area. This explains beta decay in

accord with a theory on the magnetic moments of the neutron, the proton, and the electron.⁵

It is suggested that these experiments and this interpretation may help in understanding or formulating experiments in relation to some of the phenomena observed or postulated in studies of volcanism, crystallizing magmas, magnetic fields, strain energies, gravitation, and earthquakes.

The integral ratios observed for the EMF values of salts with common anions may be related to crystal symmetries.

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TABLE 1. EMF and Heat of Fusion (H_f) values

Compound	Number of Measurements	EMF (cal/mole)* Measured	H_f (cal/ g mole) Reference 2
LiF	6	2482 \pm 33	2360
Li ₂ SO ₄	15	3045 \pm 31	3040
K ₂ CO ₃	2	7764 7785	7800
	1	4001	
Na ₂ CO ₃	2	7663 6791	7000
	2	3996 3556	
NaF	3	7394 \pm 56	7000
Na ₂ SO ₄	23	5957 \pm 37	5830
	2	6232	
	9	6095	
	10	5835	
	2	5672	
	1	3113	

*EMF values are reported in cal/mole assuming 1 eV=23,060 cal/mole. Standard deviations are given where applicable.

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