A revolution in lithium-sulphur battery technology?

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Abstract

This article was motivated by a discovery, which could revolutionize battery technology. The so-called γ-sulphur is a phase of sulphur that stops the degradation of lithium-sulphur batteries and this could give electric vehicles a range of thousands of kilometers. In this article a proposal for the mechanism explaining the stability of γ-sulphur in lithium batteries is proposed.

A basic mystery of electrolysis is that the electric field between electrodes is quite too weak to explain the ionization, A TGD based model based on the TGD view of Pollack effect and its generalization explains why the ionization can happen in electrolyte. The implications of the Pollack effect for "cold fusion", nuclear physics and prestellar evolution are discussed. Cell membrane and DNA are negatively charged and also here Pollack effect and its possible generalization would play a key role.

Contents

1 Introduction

The last weeks have been full of surprises. The most recent surprise was the popular article published in Big Think (rebrand.ly/wootoqn), which told about an accidental discovery [D2] (rebrand.ly/ye9nt4g), which could revolutionize battery technology. The so-called γ-sulphur is a phase of sulphur stops the degradation of lithium-sulphur batteries and this could give electric vehicles a range of thousands of kilometers.

1.1 The discovery

It is good to start from the problems of lithium batteries.

1. Also other materials than lithium, which is a very light material, such as cobalt are needed in lithium batteries but their mining is very environmentally very damaging. There are also humanitarian problems: the working conditions are bad and even child labor is used.

2. Lithium batteries quickly lose their capacity and charging times are long. lithium batteries also suffer degradation.

3. The energy density is low so that the lithium batteries tend to be very heavy, which limits their commercial use in electric planes and ships.

4. Damaged cells can spontaneously catch on fire.

Lithium-sulphur batteries might provide a cure of all these problems but there is a new very serious problem. Polysulfides Li-S-...-S-Li are formed in the dielectric between the Li and sulphur containing capacitor platers and this reduces the number of charge cycles by one half from about 2000 cycles.

The completely unexpected discovery was that somehow the presence of γ-sulphur as a phase of sulphur, unstable at room temperature but stabilized in presence of Li, prevents the formation of polysulphides Li-S-...S-Li. γ-S crystals are produced by dropping hot sulphur to water at temperatures above 95 degrees Celsius. They are smooth elastic and resemble rubber.

1.2 Some questions with possible answers

The findings raise some questions.

1. What in their structure prevents the formation of considerable amounts of polysulfides L-S-....-S-Li with more than one S? Could the presence of γ-S crystals prevent the formation of S-S bonds or are they formed but split very rapidly? Why is γ-S stabilized in the presence of Li?

2. One thing to notice is the chemical analogy with water: H$\leftrightarrow$Li and O$\leftrightarrow$ S. Could this help? What prevents the formation of H-O-...-O-H sequences in water and one has only H-O-H? Could this be a good question?

Let us try to answer these questions.

1. The first thing to notice is that γ-S is not stable at room temperature. Somehow the presence of Li must stabilize it. The γ-S crystals should grow by addition of S to compensate for the spontaneous decay occurring at room temperature. This could give rise to flow equilibrium.

2. Could it be that the presence of γ-S crystals competes with the formation of Li-S-...S-Li sequences. Could S prefer to join to a γ-S crystal rather than to add to the sequences of S:s in Li-S-...S-Li? The formation of sequences would stop at Li_2-S. This does not yet explain the stability of γ-S at room temperature: differs from that in the absence of Li only in that Li competes with γ-S crystal for S atoms. The mechanism must be more delicate.

3. Li-S....-S-Li polysulphides must be produced at a considerable rate but they provide the S:s for the crystal growth of new γ-S. Li atoms are like servants carrying the food S at plate to γ-S, which eats it. There is a flow equilibrium and the total amount of Li-S...-S-Li stays very small although Li-S....-S-Li is produced with a high rate!

2 TGD view of the situation

I have not yet said anything about TGD and quantum but in the presence of γ-S Li_2-S is a chemical analog of water.

2.1 Basic questions

One must start from fundamentals and ask what batteries really are.

1. What causes the ionization in the electrolyte? In fact, almost 40 years ago I had discussions with a researcher studying batteries and realized that electrolysis is not actually understood in standard chemistry! Ionization is the mystery. It requires large energies measured in electron volts. The electric voltage between the batteries is low and generates extremely weak electric fields so that it should have no effects in the atomic length scales. I have discussed this problem in an article about "cold fusion" [K5].

2. If ionization occurs, electric field makes possible charge separation. But what makes this charge separation and therefore batteries so stable? They are of course not completely stable since the voltage decreases gradually. An analog of metabolic energy feed is necessary.

2.2 Could Pollack effect make batteries possible?

Ionization is necessary for the formation of batteries. I have discussed the problem of ionization in an article about "cold fusion" [K5].

1. The hint comes from the fact that electric voltages involved are measured in electron volts as are measured also the voltages associated with the molecular bonds associated with the salts of electrolytes used.

2. TGD view forces us to ask whether a phase transition in which ordinary particles, say positive ions of a salt, could become dark in the sense that the effective Planck constant h_{eff} characterizing it becomes very large.

   Could the length of the valence bond or hydrogen bond, or more generally, molecular bonds generalizing hydrogen bond to say Li bond between two Li_2-S molecules, become so long that the voltage along it is measured in electron volts so that it can lead to a genuine or effective ionization.

3. Before continuing, one must clarify what meanings the darkness can have. A dark proton associated with a dark very long hydrogen bond could be formed in the charge separation giving rise to batteries. The hydrogen bonds would be U-shaped and connect to the magnetic body (MB) of the positively charged electrode. After loading the flux tube pairs could split and become U-shaped flux tubes again and the positive would remain at the monopole flux tubes. If hydrogen bonds generalize to say lithium bonds, the notion of positive dark ion formed from a salt would generalize. Needless to say, this would mean generalization of chemistry.

   Also dark atoms in the sense that an unpaired valence electron becomes dark as it is transferred to a magnetic flux tube with large value of h_{eff} are possible. Also valence bonds can be dark and I have proposed that ordinary valence bonds are dark and have relatively small $h_{eff} > h$ [L6]. The mysterious disappearance of unpaired valence electrons from rare earth metals under heating [L7] could be an example of this phenomenon [L7].

Could the formation of dark protons correspond to Pollack effect [I2, L2, I4, I3] taking place in presence of gel phase and energy feed, by say IR radiation. Pollack effect is discussed from the TGD point of view in [L2, L12, L13, L17].

1. The TGD based proposal is that in the Pollack effect ordinary protons associated with hydrogen bonds would transform to dark protons at monopole magnetic flux tubes. The U-shaped dark hydrogen bonds would be very long and could reconnect with a second similar bond to form a pair of flux tubes forming a connection to a MB outside the exclusion zone. Dark protons could be transferred to the MB. The formation and splitting of a flux tube pair is the basic mechanism in the TGD inspired model of biocatalysis.

2. If the Pollack effect generalizes to biologically important positive alkali ions, it could serve as a general mechanism giving rise to the storage of energy as electrostatic energy and cell membranes could be seen as analogs of batteries. Hydrogen bond or its generalization as a monopole flux tube is necessary for this.

3. Why is the presence of the gel phase needed? The simplest explanation is that it also involves an exclusion zone as $H_{1.5}O$ phase and is accompanied by a MB carrying dark proton sequences. These dark proton flux tubes could serve as a seed for the formation of dark protons sequences outside the exclusion zone.

4. In the case of batteries, external voltage during the loading of the battery causes charge separation by providing the needed energy to induce ionization and to drive the ions to the oppositely charged electrodes of the battery.

What makes possible a metastable charge separation in the case of the Pollack effect in biology? The molecular binding energy of hydrogen in water molecules is measured in eVs and should be compensated.

1. IR photons with energies below eV scale are needed to generate Pollack effect but is their energy too small?

2. Could the Coulomb binding energy between the exclusion zone and the magnetic flux tubes compensate for the binding energy? How could one achieve a stable situation preventing the collapse of the flux tubes if only Coulomb energy is involved? The Coulomb repulsion between dark protons at the monopole flux tubes is a further serious problem.

3. Dark proton sequences are analogous to atomic nuclei. Could the analog of nuclear binding energy compensate for the molecular binding energy? If the dark protons, or more generally, positively charged dark ions, form analogs of dark nuclei bound together by bonds between nucleons in the TGD inspired nuclear string model, they could be stable and their formation would be also energetically favored if the binding energy scale correspond to that for atoms. These bonds could be analogs of mesons consisting of color quark and antiquark forming a color singlet.

   A large value of h_{eff} could make possible scaling of the bond length L as $L \propto h_{eff}$ or even $L \propto h_{eff}^2$ is might be the case for dark valence bonds. If the nuclear binding energy assignable to the bond scales as $1/L$ as function of bond length L, the scale could correspond to a nanometer scale in biology. One would have a scaled up version of nuclear physics or rather, and perhaps even its generalization obtained by replacing dark protons with dark variants of dark nuclei appearing in salts.

   Note that the spontaneous decay of dark proton nuclei to ordinary nuclei would liberate almost all nuclear binding energy and explain "cold fusion". In TGD framework, the large value of h_{eff} for weak bosons would scale up their Compton length to biological length scales, and in length scales shorter than Compton length they would behave as massless particles and weak interactions would be as strong as electromagnetism making possible weak interactions transforming dark protons to dark neutrons. The same scaling up applies also to color interactions.

4. What guarantees the stability of the charge separation? There are situations in which the charge separation has lasted such a long time [L4] that it is very difficult to understand in the framework of standard chemistry. Batteries must be loaded, that is energized, now and then and cell membranes as their biological analogs require a continual metabolic energy feed. This suggests that thermal non-equilibrium systems require a metabolic energy feed.

5. The energy transfer is the first step of photosynthesis. In the TGD based model it would take place by pairs of holes and dark valence electrons. This raises the question whether it is convenient to talk about a pair of a proton hole and dark proton assignable to the hydrogen bond and even a generalization of this notion.

2.3 Li-S batteries and generalized Pollack effect

Could the counterpart of the Pollack effect be involved with lithium-sulphur batteries?

1. Water is the dominating element of living systems. The MB of the water gives water its very special properties and makes it very special at physiological temperatures at which Pollack effect in presence of say IR radiation and gel phase gives rise to the formation of negatively charged exclusion zones by driving protons to Li_2S is the chemical analogue of water.

   One can use this as an analogue in an attempt to understand Li-S batteries in terms of a generalized Pollack effect. If the notions of Li-bond and Li-bonded Li_2S molecule clusters make sense, the model for the Pollack effect as a way to generate a metastable charge separation might work.

2. Note that the formation of H-O-O-...-H is not a problem in the ordinary Pollack effect and the role of the γ-S would be only to make possible stable exclusion zones and magnetic flux tubes. Without it the dark Li-ions at flux tubes would transform to ordinary Li-atoms forming fingers, Li-S-...-S-Li sequences would form and the battery would degrade also otherwise. This can be understood in terms of reduction of h_{eff} inducing the reduction of complexity and scale of quantum coherence at the positive electrode.

3. The counterpart of the exclusion zone with an effective stoichiometry $H_{1.5}O$ and negative charge would be negative electrode with effective stoichiometry $Li_{1.5}O$. Dark Li^+ ion would take the role of dark proton. Every fourth Li^+ would go as dark ion to the magnetic flux tube and end up to the positively charged electrode or its MB. It would create the same voltage along the space-time sheet associated with the electrolyte as along possibly still existing flux tubes connecting it to the negatively charged electrode.

2.4 Pollack effect, cold fusion and protostars

"Cold fusion" (for the recent situation see `rebrand.ly/ui7xoig`) is an anomaly, whose existence very many colleagues still find difficult to accept. "Cold fusion" also involves dielectric plates and the proposed TGD based model [L3, L5, L10] involves dark proton currents at magnetic flux tubes.

"Cold fusion", or more precisely dark fusion in the TGD framework, can be initiated at rather low temperatures and involves the formation of dark proton sequences at monopole flux tubes. Dark nuclei are essentially scaled up variants of nuclei but much smaller binding energy and can be generated in the Pollack effect, which plays a key role in the TGD inspired quantum biology. Dark nuclei can spontaneously decay to the ordinary nuclei and also protons can transform to neutrons. This liberates essentially all nuclear binding energy.

For instance, in the case of heavy water D_2S, the dark protons would be replaced by Deuterons and $H_{1.5}O$ would be replaced by $D_{1.5}O$. Dark proton sequences would correspond to dark D^+ sequences as dark nuclei. They would spontaneously decay to ^4He and deuteron nuclei in consistency with the observations.

There is also evidence for biotransmutations [C1, C2, C3] occurring in living systems discussed from TGD point of view in [K6, K4]. For instance, Kervran found that hens are able to produce Ca needed in egg shells. These findings might allow interpretation in terms of dark fusion based on the Pollack effect or its generalization.

Dark fusion would generate protostars [L8, L9, L5] in which there is no ordinary fusion yet. The temperature increases because essentially nuclear binding energy is liberated when the dark nuclei transform to ordinary nuclei and eventually ordinary fusion is ignited. It is quite possible that all nuclei heavier than Fe are generated in this way outside stellar cores rather than in supernova explosions. Also many anomalous abundances of lighter nuclei could be understood.

2.5 Pollack effect, DNA and cell membrane

Capacitors involve both negatively and positively charged plates. Pollack effect is central in the TGD view of living matter and generates negatively charged entities such as cell interior and DNA double strand. Pollack effect would make the cell membrane a capacitor and battery able to store metabolic energy electrostatically.

2.5.1 Pollack effect and DNA

Pollack effect is central in the TGD view of living matter and generates negatively charged entities such as cell interior and DNA double strand. In the case of DNA, Pollack effect would mean that negatively charged phosphates giving constant charge of -1 units per nucleotide act as negative electrode and screen the positive dark proton charge per DNA strand inside the fundamental region of icosa-tetrahedral tessellation [L16] having size scale given by the p-adic length scale $P_p = L(151) = 10$ nm, $p = M_{151} = 2^k - 1$, $k = 151$. It would contain 10 DNA codons and correspond to 3 full turns for DNA double strand. This picture differs from the original one in which dark DNA strands were assumed to reside outside the double strand.

What could be the detailed mechanism?

1. Has the O-H group of phosphate have lost dark proton into the interior of the fundamental region where it belongs to dark proton triplet defining genetic codon. One would have $P-O^-$ phosphate ions at the negative electrode.

2. Does the O-H group of phosphate have a hydrogen bond with the water molecule of the cell exterior and has the flux tube transformed to dark flux tube extending to the interior of the fundamental region? Has it lost its dark proton to the interior of the fundamental region via a reconnection process?

3. The answer to the question comes from the consistency with the realization of the dark genetic codons as dark proton triplets considered in [L16]. The dark protons of the codon should be associated with the vertices of triangular tetrahedral or icosahedral faces of the fundamental region of the icosa-tetrahedral tessellation.

   This would suggest that the monopole flux tubes representing hydrogen bonds have (de-)reconnected and left the dark proton to the vertices of the triangular face. The small closed flux tube produced in the de-reconnection would naturally correspond to the required closed flux tubes connecting icosahedron, tetrahedron, and octahedron assignable to a given dark proton of the codon. The magnetic field for the flux tube would determine the cyclotron frequency and cyclotron frequency triplet would characterize the codon and provide the icosa-tetrahedral realization of the genetic code [L1, L11].

2.5.2 Pollack effect and cell membrane

In the model of the cell membrane as a battery, the rough first picture could be as follows. The original model involved the Pollack effect for protons but the generalization of the effect to biologically important positive ions is suggestive and involved with the cell membrane.

1. In the simplest model, dark positively charged alkali ions reside always outside the cell membrane at monopole flux tubes. The negative ions resulting from the transfer of positive ions to the U-shaped monopole flux tubes defining analogs of hydrogen bonds would reside inside the cell membrane.

   The connections between exterior and exterior by pairs of flux tubes from U-shaped flux tubes could be permanent but one can also consider the possibility of U-shaped flux tubes extending to the exterior with delocalized ions at them.

   The transfer of dark ions permanently to the exterior would involve a (de-)reconnection generating a transfer of dark ions to the exterior and subsequent reconnection isolating splitting the flux tube pair and isolating exterior from the interior. Reconnections could control the transfer of dark ions between interior and exterior.

   Membrane resting potential would be controlled by the transfer of dark ions to the exterior generating a hyperpolarization. This would suggest permanent flux tube connections.

2. Gel phase would be a natural candidate for the analog for the negatively charged $H_{1.5}O$ involving corresponding phases for various ions. In gel-to-sol transition this phase would transform to ordinary water and the battery charge would decay. Metabolic energy feed is needed to prevent this since the value of h_{eff} increases with energy and tends to be spontaneously reduced.

It is unclear whether one could understand the nerve pulse in terms of the gel-to-sol phase transition in which ohmic currents would be generated leading to the reduction and change of the sign of the membrane potential. That Hodkin-Huxley model works satisfactorily suggests that ohmic currents are present during the nerve pulse.

3. In the Josephson junction model of the cell membrane [K1, K3, K2], there is a permanent Sine-Gordon soliton sequence based on the phase difference $\Delta\Phi$ for superconducting phases residing at monopole flux tubes at the two sides of the membrane.

   One has $d\Delta\Phi/dt \equiv \Omega = E/\hbar_{eff}$, where E is the sum of the ordinary Josephson energy ZeV and difference of cyclotron energies over the junction. Very large value of $\hbar_{eff}$ is required to give Josephson frequency in EEG range and gravitational Planck constant $\hbar_{gr}$, introduced first by Nottale [E1], central in TGD view of quantum gravitation [L15, L14, L18, L19, L20], is highly suggestive.

   The cyclotron frequencies are associated with the flux tubes parallel to the cell membrane. If there are no flux tubes in the interior, the corresponding cyclotron frequency vanishes. Josephson junctions are associated with the membrane proteins. Josephson junctions could correspond to pairs of flux tubes between interior and exterior so that bosonic dark ions or Cooper pairs of fermionic ions would give rise to Josephson currents between interior and exterior.

   The system is mathematically equivalent to a sequence of rotating gravitational penduli assignable to various ions. The simplest model assumes that all bosonic dark ions are at the magnetic flux tubes in the exterior of the cell membrane and parallel to it.

4. What about the nerve pulse in the simplest picture? The nerve pulse could be induced by a propagation of a perturbation changing the sign of the local rotation direction of some fictitious gravitational penduli at the point in which the sine of the phase vanishes so that also Josephson current vanishes. Formally this corresponds to a change of the arrow of time and could correspond to a pair of "big" state function reductions (BSFRs). Could this change of the arrow of time induce reduction of the voltage and ordinary Ohmic currents changing the sign of the membrane potential temporarily?

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