Electrode Fracture and Low Energy Nuclear Reactions within Batteries

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Several simple experiments are presented that clarify the low energy nuclear reaction processes thought to take place due to the electrodynamic interaction between condensed matter collective degrees of freedom and degrees of freedom internal to the nuclei. Of central importance is the neutron production that results from the fracture of brittle materials or the grinding of solid condensed matter into powders that then may appear as colloidal particles within electrolytes in chemical cells, i.e. batteries. Mentioned are the reliable direct measurements of neutrons emitted from fracturing rocks in a mechanical engineering laboratory as well as geophysical neutron production just prior to earthquakes previously detected in underground laboratories. Discussed in more detail are some new experiments wherein plasma glows are detected from the copper cathode of electrolytic cells. The low energy nuclear reactions are in part associated with such electrolyte plasmas. Also reported here is the case wherein the electrolyte is distilled water so there is not enough current through the tungsten cathode employed to generate a plasma. Even without plasma, a slow shredding of the electrodes for long periods of time but less than a day allows for the observation of colloidal electrolytic suspensions and low energy nuclear reactions. Finally, it is shown that melted liquid lithium in contact with room temperature water gives rise to a bright white plasma explosion that is clearly related to the explosions routinely observed in lithium ion batteries that often run smart telephones, laptop computers, electric and/or hybrid motor vehicles and also play a central role in modern aircraft engineering. It is likely that such lithium plasmas have a nuclear as well as a chemical component as do many other similar electrolyte plasmas.

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I. INTRODUCTION

Our purpose is to report several simple experiments in order to elucidate the nature of low energy nuclear reactions that occur because of quantum electrodynamic interactions between nuclear and condensed matter collective degrees of freedom[1, 2]. In particular, we shall report experiments that probe those possible low energy nuclear reactions that occur because of the fracture of brittle materials[3–5]. Low energy nuclear reactions should also occur if solid objects are ground into powders or if such powders appear as colloidal particles in an electrolyte.

The experimental situation regarding neutron production and other electro-weak and electro-strong low energy nuclear reactions has been recently reviewed[6]. Measurements have been made of neutron production and electrostrong dipole resonance nuclear transmutation found by fracturing rocks in a mechanical engineering laboratory. Geophysical fracturing of rocks in the earth's crust have been observed in some tragic earthquake situations. In such cases, there appears to be nuclear transmutation activity somewhat prior to a large earthquake[7, 8]. Also of a geophysical nature is the observation of neutron production from bolts of lightning[9, 10].

Of interest in the work which follows are the low en-

ergy nuclear reactions due to the fracture of the cathode in an electrolytic cell, i.e. in a battery. We discuss some simple experiments carried out by electrolysis fracture and shredding in both copper and tungsten cathode wires. In Sec.II such experiments are discussed. During the fracturing process, a bright plasma glow may be observed on the tip of the cathode, however the plasma is by no means a requirement for low energy nuclear reactions in the cell[11]. Many nuclear reactions have been observed by Mizuno[12][13][14][15] and by Cirillo[16] employing scanning electron microscope (SEM) and energy dispersive spectroscopy (EDX) techniques probing those product atoms left on the cathode. The final nuclear reaction products may often be described by reactions of the form

$$e^{-} + p \to n + \nu_e,$$

 $n + {}^{A}X_Z \to {}^{A+1}X_Z,$
 ${}^{A+1}X_Z \to {}^{A+1}X_{Z+1} + e^{-} + \bar{\nu}_e,$ (1)

together with other similar low energy nuclear reaction chains.

In Sec.II we discuss the low energy nuclear reactions associated with tungsten and copper cathode probes carrying electrons through the electrolyte to a stainless steel anode. The voltage across the chemical cell was four hundred volts when employing a copper as cathode and a



FIG. 1: Shown is a copper electrolyte plasma when the cathode is immersed in a bi-sodium carbonate solution.



FIG. 2: After a considerable number of minutes running the current through the battery and the shredding of the copper wire, the cathode is shorter and the resulting colloidal grains make the bi-sodium carbonate electrolyte appear cloudy.

bi-sodium carbonate or a lithium hydroxide electrolyte carrying a current of about four amperes depending on the state of disrepair of the cathode. The fractured shredding of the copper wire cathode was made manifest by the powdered grains that formed an almost opaque colloidal suspension within the electrolyte. After a few days, the colloidal grains drifted to the bottom of a storage bowl leaving the electrolyte clear. Low energy nuclear reactions were detected on the partially shredded copper cathode wires. A similar experiment starting with distilled water at the same high four hundred volt source yielded a small current of about four milliampere depending on the state of disrepair of the tungsten cathode. At such small currents there is no visible plasma near the tungsten tip. Nevertheless high voltage shredding of the tungsten occurred over a long time scale of more than seven hours.

II. COPPER AND TUNGSTEN CATHODES

A copper cathode and a stainless steel anode were lowered into a strong $(Na^+)_2CO_3^{--}$ electrolyte in water. An anode-cathode voltage of four hundred volts was applied yielding an anode current of approximately five ampere. In FIG.1, the resulting cathode plasma is shown. Initially, the electrolyte is clear. There are gas bubbles rising into the atmosphere at both the anode and cathode corresponding to the normal water electrolysis. Also, the



FIG. 3: When the cloudy electrolyte from the copper cathode electrolyte colloidal suspension is placed in a separate bowl for a few days, the colloidal particles sediment onto the sides and mostly onto the bottom of the bowl as shown. The remaining electrolyte is clear.



FIG. 4: Shown is an energy dispersive spectra (EDX) of our pure copper electrode wire before any electrolytic treatment or plasma. The wire surface contains some oxide and organic carbon impurities. But the spectra in the main is that of pure copper.

copper cathode shreds colloidal grains into the fluid. The colloidal electrolyte eventually turns cloudy as shown in FIG.2 wherein the plasma is still visible. The copper cathode is considerably shortened due to the shredding of particles that entered into the colloid. The colloidal electrolyte was later stored in a glass bowl for a few days. The colloidal particles sediment at the bottom of the bowl as shown in FIG.3.

A. Chemical States of a Copper Electrode

The "pure copper" blank electrode was analyzed for surface chemical contamination as shown in the above FIG.4. Apart from small oxide concentrations and organic carbon deposits on the surface, the purity of the copper blank is shown to be of satisfactory quality.

An energy dispersive spectra was taken near the copper electrode tip *after* being treated by the plasma in a lithium hydroxide electrolyte. In FIG.5 the region of the copper electrode that was analyzed is exhibited. The resulting energy dispersive spectra is exhibited in FIG.6.



FIG. 5: Shown is a scanning electron microscope picture of a region near the tip of a copper cathode after being in part shredded by a plasma in lithium hydroxide. A region was selected for an energy dispersion analysis as shown.



FIG. 6: Shown is an energy dispersive spectra of atoms in the region shown in FIG.5. Apart from the atoms observed in the pure blank electrode in FIG.4, one finds an anomaly induced by the plasma in the form of a very large peak that the EDX machine labels as beryllium. Filtering this large new peak, one finds that what is really present is a mixture of boron and beryllium as would be expected for a nuclear lithium chain started from the lithium in the electrolyte plasma.

Very worthy of note is an anomalously large peak labeled by the EDX machine as beryllium. Since the EDX spectra are almost always too small to be detected for lithium, boron and perhaps beryllium due to the very low atomic numbers and since the line shape of the spectra was also somewhat anomalous, filtering was applied that revealed both boron and beryllium. Since the plasma is white hot, we attribute the boron and beryllium mixture to be the product of a lithium cycle chain that had been predicted theoretically in previous work and appears in stellar nuclear physics work[1, 17].

To examine the energy dispersive structure for a copper cathode in a LiOH electrolyte plasma on a smaller spatial scale, we chose a region as shown in FIG.7. Here one detects grains on a small length scale of about ten microns which is perhaps a factor of ten smaller than in FIG.5. The energy dispersive spectra on this smaller scale is shown in FIG6. The small length scale energy structure of the grains indicates one new element apart from the boron and beryllium nuclear transmutations. Within the grains there is a strong sodium peak in the EDX spectra. The sodium peak can be explained via the



FIG. 7: Shown is a scanning electron microscope picture of a region near the tip of a copper cathode after being in part shredded by a plasma in a lithium hydroxide electrolyte. The spatial scale is smaller than that chosen in FIG5.



FIG. 8: The small grain structure has a peak labeled by the EDX machine as boron but which after filtering is shown to be a mixture of boron and beryllium. The new peak is due to sodium atoms within the grains. This is most easily explained by giant dipole resonant disintegration of the copper nuclei within the cathode surface.

collective giant dipole resonant disintegration[3–5] of the copper nuclei in an electrode that is being shredded.

B. Chemical States of a Tungsten Electrode

An ordinary electrolysis was performed employing a pure tungsten cathode and a stainless steel anode in a distilled water electrolyte. A SEM-EDX picture of the blank tungsten rod is shown in FIG.9. At a high voltage of perhaps half a kilovolt, the very low conductivity of the



FIG. 9: The SEM picture of the blank tungsten rod before electrolysis is shown along with the EDX spectrum indicating that the blank was pure tungsten to a sufficient degree of accuracy.



FIG. 10: SEM-EDX picture of a typical region of the tungsten electrode after ten hours of electrolysis starting from a distilled water electrolyte. A large variety of new chemical elements is present on the cathode due to the shredding of tungsten. The elements added to tungsten are copper, iron, calcium, magnesium and nickel. The amount of copper from nuclear transmutations is anomalously large.

electrolyte yielded a current of about five milli-amperes dependent on the state of disrepair of the cathode. The currents were much too low to produce an electrolyte plasma. Before the electrolyte turned yellow, at least in part due to tungsten oxides, the chemical cell was run for about ten hours. The resulting electrolyte plated out in part on the cathode and in part on the anode.

In spite of the lack of an electrolyte plasma, the chemical cell apparently produced a large variety of nuclear transmutations during the shredding process into electrolyte colloidal particles that, in part, floated on top of the fluid. The large variety of atoms detected on the tungsten cathode after ten hours of electrolysis depended in detail on which part of the cathode was observed. A typical picture is exhibited in FIG.10. In Eq.2 below are shown the atomic fractions of elements on the tungsten cathode therein *after* electrolysis for ten hours.

Element	Atomic $\%$	
Mg	6.35	
Ca	3.45	
Fe	12.42	(2)
Ni	6.65	
Cu	49.07	
W	22.05	

The nuclear transmutations into copper are particularly striking. The copper is in fact visible to the naked eye as a golden-red granular deposit on the cathode in almost all regions near the tungsten cathode tip.

III. LITHIUM ION BATTERY EXPLOSIONS

It is a well known feature of lithium ion batteries that from time to time they explode. These explosions occur in electronic devices whose size can vary greatly. Smart phones, tablets, laptop computers can burst into flames. The number of small electronic objects run on lithium ion batteries that can be carried on a plane by passengers is limited by international security rules in large part to avoid lithium ion battery explosions. Larger electronic devices, in particular electronic transportation vehicles



FIG. 11: Ten grains of Li metal were placed in a pyrex bowl that at the bottom was about seven centimeters in diameter. The temperature at the bottom of the grains was slightly above the melting temperature while at the top of the grains one could still discern the shapes of solid. The grains show a dispersion in size in the range of about two to four millimeters in diameter.

such as cars, trucks or planes that require lithium batteries are also known to explode into hot flames. Drowning the flames in water very often merely increase the heat of the explosion.

To study this phenomenon we needed a reliable way to produce lithium explosions in the laboratory. Exploding melted droplets of alkali metals have been studied in some detail[18, 19]. When liquid alkali metal droplets are dropped from a height of the order of meters into water they at first lose their electrons and then they coulomb explode. We produced liquid lithium explosions by putting some lithium in a pyrex glass dish and melted at least in large part the lithium. In FIG.11 the melting lithium grains are exhibited. Then cool water was poured over the lithium melt and a lithium explosion ensued. In FIG.12, the explosion is exhibited. There is the white hot plasma near where the lithium was as well as a "balled lightning white hot plasma" that here jumped out of the glass bowl and fell onto the table top. Above the plasma is fire and smoke which can result if the lithium grains are not fully melted. For water poured over solid grains there is no white hot plasma but merely smoke given off by the lithium. The reader must be warned that the smoke can trigger a building alarm which may bring some attention to this experiment from local police and fire departments. However, the experimental explosions are simple and entirely reproducible preferably with a gas path to blow the smoke through a safety duct. The balled lightning plasmas discussed in this work should produce neutrons and thereby nuclear transmutations as does ordinary lightning[9]. However we have not yet done a detailed chemical analysis on the rubble produced by these lithium explosions that would distinguish between electronic and nuclear chemistry.

IV. CONCLUSIONS

We have demonstrated several simple reproducible experiments which probe low energy collective nuclear



FIG. 12: When cool water was thrown over the grains within the glass bowl, a lithium explosion took place that lasted approximately three seconds. The photograph above is from a video shot at a frame rate of 240 Hz. The white hot lithium plasma is at the bottom of the explosion and pieces of plasma are blown out as coulomb explosion white hot fragments. The orange fire on top forms lithium oxide and/or hydride colloidal particles which then go up in smoke.

chemistry as distinguished from the more usual chemistry based entirely by electronic structure. The physics of the low energy nuclear reactions is based on the notion of shredding solids into powders yielding colloidal fluids

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in either liquid electrolyte and/or gaseous form. The evidence in mechanical engineering labs or in geophysical earth quakes of low energy nuclear physics being produced by fractured rocks is well founded. For the problem at hand in electrolytic cells, i.e. batteries, shredding electrodes may also produce low energy nuclear reactions. We have substantiated some nuclear transmutations associated with confined plasmas near the tip of metallic cathodes. We have also shown, starting from a deionized water electrolyte, that a variety of nuclear transmutations can be induced without the plasma so long as the very low current batteries are run for a sufficiently long time. The colloids from shredding cathodes do still appear. Lastly, it was shown that melted liquid lithium in contact with room temperature water gives rise to a bright white hot balled lightning plasma explosion that is simply related to routinely observed lithium ion battery explosions of recent great industrial interest. It is likely that such lithium plasmas have a nuclear component as do many other similar lightning plasmas. However, the chemical analysis of the lithium explosion products has not yet been carried out in sufficient detail.

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