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ELECTRON TRANSITIONS ON DEEP DIRAC LEVELS II.

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ABSTRACT
In our previous paper (1), we suggested that both the relativistic Schroedinger and Dirac equations allow the existence of so called "Deep Dirac Levels" (DDL) in all atoms of the Periodic Table.

In this paper we give an estimate of the size of the DDL atoms and we propose a physics explanation how to excite the DDL transitions. We suggest possible secondary nuclear reactions of the atoms on the DDL levels and we present our own preliminary experimental results. We searched for some direct experimental evidence supporting the proposed DDL model. So far, in the electrolytic experiments, only the calorimetric evidence was found.
1. INTRODUCTION

In our previous paper (1) we stated that in both equations (relativistic Schroedinger and Dirac equations) the entire class of solutions was rejected in the early stages of a quantum mechanics development. This statement was made based on the fact that these solutions have a pole at r=0, which was not compatible with the model of point-like nucleus. We know now that the nucleus is not point-like and that the Coulomb potential inside the nucleus is finite at r=0. The solution which has a pole at r=0 is completely valid and can be normalized in the entire region outside the nucleus (2). This solution should be matched with the solution inside the nucleus.

The rejected energy levels were calculated in (1) for electrons in hydrogen-like atoms. It was found that besides the known atomic levels, each atom should also have Deep Dirac Levels (DDL), which have binding energies close to ~300-500 keV. The electron transitions from the normal levels to such DDL levels would produce large amounts of atomic energy.

Paper (1) also presented calculations for atoms formed of particle-antiparticle pairs, such as positronium. In the case of positronium, the leptons size is nearly point-like (at a level of ~10^{-18} m), and our theory may provide an explanation how the electron-positron pair collapses towards the DDL levels, where the pair annihilates because of the large overlap of two wave-functions.

Paper (1) also suggested a possible impact on Astronomy, especially in the area of the dark matter. The hydrogen atoms with electrons on the DDL level could be a key to explaining the missing dark matter in the Universe. The atoms which have collapsed to very small electron orbits could also play an important role in the dynamics of a star collapse.

In the present paper we estimate the size of the DDL atoms and we try to propose an explanation for how the DDL transitions can be excited. We suggest possible secondary nuclear reactions with the atoms on the DDL levels and we present our own preliminary experimental results.

2. SIZE OF ATOMS WITH ELECTRONS ON THE DDL LEVELS

This theory will be described in more detail in reference (2). Since a detailed calculation would be quite lengthy, here we will only briefly outline the main points. To calculate the electron density distribution inside and outside the nucleus we use the known techniques for solving the appropriate Dirac radial differential equations (3).

The starting radial differential equations are (see Fluegge (3), eq. 201.9, page 194): 

\[ g' + g (k + 1) / r - i (E - V(r) - m c^2) / \hbar c = 0 \]
\[ f' - f (k - 1) / r - i (E - V(r) + m c^2) / \hbar c = 0 \]  \hspace{1cm} (1)

where \( V(r) \) is a potential inside or outside the nucleus, \( m \) or \( e \) is the mass or charge of the electron, \( E \) is the energy of the electron (assumed the same inside and outside), \( c \) is the velocity of light, \( k = j + 1/2 \) contains quantum numbers \( k \) and \( j \).

The electron density outside the nucleus is solved by choosing the central-force potential \( V(r) = -Ze^2/r \). This theory applies to hydrogen-like atoms with one electron only. The solution of (1) outside the nucleus is sought in the form (3):

\[ g = C r^{s-1} e^{-r/a} G_0(r), \quad f = \frac{i}{\mu} C r^{s-1} e^{-r/a} F_0(r) \]  \hspace{1cm} (2)

where
\[ a = \frac{1}{\alpha} = \frac{1}{137.036}, \quad \mu = \sqrt{(m c^2 - E) / (m c^2 + E)} , \quad \beta = \frac{Ze^2}{\hbar c} \]  \hspace{1cm} (3)

If (2) is inserted into (1) we obtain the condition which yields the value of parameter \( s \) for the limit \( r \to 0 \):

\[ s = \pm \sqrt{k^2 - \beta^2} \]  \hspace{1cm} (4)

Following a full derivation of the problem in reference (3), one can show that the solution of the equations (1) is in the following form (Fluegge (3), equation 202.15, page 197):

\[ g = \frac{1}{2} C \frac{r^{s-1}}{a} \left[ \frac{1}{2} F_1(s + p, 2s + 1; 2r/a) ight] 
- \frac{(s + p)}{(k + q)} \left[ \frac{1}{2} F_1(s + p + 1, 2s + 1; 2r/a) \right] \]  \hspace{1cm} (5)

\[ f = -\frac{i}{2\mu} C \frac{r^{s-1}}{a} \left[ \frac{1}{2} F_1(s + p, 2s + 1; 2r/a) 
- \frac{(s + p)}{(k + q)} \left[ \frac{1}{2} F_1(s + p + 1, 2s + 1; 2r/a) \right] \right] \]  \hspace{1cm} (6)

where the solution \( F_1(b, c; z) \) has the form of a confluent hypergeometric power series (2) with \( z = \frac{2r}{a} \), \( p = \frac{\beta}{2} (\mu - \frac{1}{\mu}) \) and \( q = \frac{\beta}{2} (\mu + \frac{1}{\mu}) \). Both confluent series must terminate with only a few terms, for a finite solution at \( r= \infty \). This is achieved by setting:

\[ s+p = -n' \quad \text{with} \quad n' = 0,1,2,3,4,... \]
\[ k = 1,2,3,... \quad \text{or} \quad -1,-2,-3,... \]
\[ n = n' + |k| \quad \text{main quantum number}. \]  \hspace{1cm} (7)
For $s$ with $+$ sign in equation (4) the wave functions in (5), (6) and (7) with $s>0$ are valid, which describe the normal ($+$) levels of hydrogen-like atoms with known $E(+)$ values. For $s$ with $-$ sign in equation (4) the new wave functions in (5), (6) with $s<0$ are valid (the constant $C$ in this case contains $(2/a)^2$).

The equation describing the energy levels is given by (see Fluegge (3), equation 202.17, page 198):

$$E = mc^2 \left[ 1 + \beta^2 \right]^{1/2} \left[ (s + n')^2 \right]^{1/2}$$

where $s$ is defined in equation (4). The plus sign in (4) corresponds to normal energy levels of hydrogen-like atoms. The minus sign in equation (4) corresponds to the neglected solutions by all previous authors. This was pointed out in detail in reference (1) where we showed that some of the solutions with a negative sign in $s$ give rise to the DDL energy levels with a binding energy close to 500 keV.

We calculate the electron density outside the nucleus according to the equation:

$$E_\text{el} d = 4 \pi r^2 (g^2 + f^2)$$

where $g(r)$ and $f(r)$ are defined in formulas (5), (6) and (7).

The Coulomb potential inside the nucleus is not $Ze^2/r$, but it is finite. For example, we have chosen the following potential inside the nucleus:

$$V(r) = -\frac{Ze^2}{\hbar c} \left( \frac{3}{2} - \frac{r^2}{2R_0^2} \right) + V(A) \frac{\hbar c}{\hbar c} = (-\beta_1 + \beta_2 r^2 + \beta_3)$$

The solution of equation (1) with the potential of equation (10) gives functions $g_i(r)$ and $f_i(r)$. Equation (1) with the potential (10) inside the nucleus is solved with solutions in the form (see (2)):

$$g_i = A r^{s_i - 1} G_2(r), \quad f_i = i B r^{s_i - 1} F_2(r)$$

where $G_2(r)$ and $F_2(r)$ have a form of power series:

$$G_2(r) = a_1 r + a_2 r^2 + a_3 r^3 + \ldots, \quad F_2(r) = b_1 r + b_2 r^2 + b_3 r^3 + \ldots$$

Inserting (11) with form (12) into (1) leads finally to the recurrent formulas for the coefficient calculation (see (2)):

$$a_{n+1}(s_i + k + 1 + n) = B / A (b_n K_1 + b_{n-2} \beta_2)$$

$$b_{n+1}(s_i - k + 1 + n) = A / B (a_n K_2 + a_{n-2} \beta_2)$$
where
\[ K_1 = \left[ \mu a + (\beta_0 - \beta_1) \right], \quad K_2 = \left[ 1 / (\mu a) - (\beta_0 - \beta_1) \right] \] (14)

\[ a_0 = a_{-1} = a_{-2} = b_0 = b_{-1} = b_{-2} = 0. \]

The recurrent formulas (13) lead to some coefficients for \( k < 0 \):

\[ a_1 \neq 0, \quad s_i = -k - 1 \geq 0, \quad b_1 = 0 \] (15)

and for \( k > 0 \):

\[ b_1 \neq 0, \quad s_i = k - 1 \geq 0, \quad a_1 = 0 \] (16)

with arbitrary \( a_1 \neq 0, \quad b_1 \neq 0 \) and \( B/A \) (needed in normalization). The other coefficients \( a_2, a_3, a_4, a_5 \) and \( b_2, b_3, b_4, b_5 \) can be calculated with formula (13) for \( k > 0 \) and \( k < 0 \) (see (2)). These coefficients were used in the normalization integrals. The series (12) were terminated with \( a_5 r^5 \) or \( b_5 r^5 \) term, due to a very small \( r \) inside the nucleus (higher order terms were neglected).

One can show (2) that both solutions (one inside and one outside the nucleus) can be numerically normalized and matched to each other at the nucleus radius \( R_0 \). The normalization constant \( A_0 \) was obtained using a formula:

\[ A_0 \cdot 4 \pi \left[ \int_0^{R_0} r^2 (g_i^2 + f_i^2) dr + \int_{R_0}^{\infty} r^2 (g^2 + f^2) dr \right] = 1 \] (17)

The matched curves were normalized to the density of one electron by multiplication of their electron density \( E_{ld} \) with the proper value of \( A_0 \). Fig. 1a shows an example of the electron density distribution for the hydrogen atom with the electron on the normal level in the 1s(+) state (+ sign corresponds to \( s > 0 \) in equation(4)). The peak of the curve is at 52,900 Fermi, which is the Bohr radius (as one expects). Figure 1b shows the electron density distribution for the hydrogen atom with the electron on the normal level in 2s(+) and 2p(+) states. Figure 2 shows the electron density distribution for the hydrogen atom with the electron on the DDL level in the 2s(-) state, corresponding to an energy level of -509.133 keV (- sign corresponds to \( s < 0 \) in equation(4)), and for the hydrogen-like lithium atom with one electron on the DDL level in the 2s(-) state, corresponding to an energy level of -505.405 keV. The peak of the distribution corresponds to the radius of the nucleus. One can define a "size" of the hydrogen-like atom with an electron on the DDL level using the equation:
\[ \bar{r} = \infty \int_0^\infty \rho \text{Eld} \, dr \] (18)

The value of the \( \bar{r} \) for the 2s(-) hydrogen atom state is 5.2 fm. A "naive" calculation using the Bohr model presented in ref.(1) gave about 1.45 fm. The \( \bar{r} \) for the lithium atom in the 2s(-) state is 9.3 fm. The Bohr atom estimate gives 2.34 fm. Fig.3 shows the electron density distribution for the potassium and cesium atoms with one electron on the DDL level in the 2s(-) state.

To illustrate the calculation of the Coulomb repulsion radius in the normal hydrogen atom we use Figure 1, which shows the 1s(+) electron density distribution. Note that the curve drops to 1/10 of its peak at the radius of about 178 000 fm = 1.78 \( \text{A}^0 \). One can calculate the Coulomb repulsion radius for H from the density of liquid H\(_2\). This density is 0.070 g/cm\(^3\), which gives the volume \( V = 47.5 (\text{A}^0)^3 \) for one molecule of H\(_2\). We can assume that the same molecular volume V is occupied by a parallelepiped with (2R) base and the length \( L = (2R + 0.74) \text{A}^0 \) (i.e. \( V = L \times (2R) \times (2R) \)), where 0.74 \( \text{A}^0 \) is the inter atomic distance of two bound H atoms inside the H\(_2\) molecule. In this case the radius \( R \) is 1.695 \( \text{A}^0 \). The Eld distribution in Figure 1 drops to 1/8 of its peak at about 1.695 \( \text{A}^0 \). This indicates that the Coulomb repulsion radius of the normal atom is at the position of about 1/8 to 1/10 of the peak in the Eld distribution.

To calculate the repulsive radius for the DDL hydrogen atom one might attempt to use Figure 2 and the same argument as above. From Figure 2 we can see that the Eld drops to 1/10 of the peak value at about 4 fm. However, more detailed analysis of this particular problem (2), which includes a proper matching of derivatives of the wave functions on the nucleus surface, reveals that the repulsive radius is less than 4 fm only for high orbital numbers \( \ell > 10 \). In other words, only orbitally excited DDL atoms could participate in the secondary nuclear reactions (It is well known that the short range nuclear forces are acting within a distance of 3-5 fm).

The main point of this chapter is that the size of atoms with all electrons on the DDL levels can be very small. Under certain conditions (\( \ell > 10 \)), such atoms with all electrons on the DDL levels might participate in the secondary nuclear reactions (see chapter 4).
3. PROPOSED MECHANISM OF ATOMIC TRANSITIONS TO THE DDL LEVELS

We suggest the following model to explain a gain in energy in the electrolytic (4,5) or gaseous experiments (6): the power gain is caused by the release of photonic energy during an injection of energetic "projectile" electrons into ions or atoms near cathode or anode surfaces, forming atoms with electrons captured on the DDL levels. This photonic energy could be released in X-ray, UV or IR wavelength regions.

3.1. "ELECTRON ACCELERATOR" ON THE CATHODE OR ANODE SURFACES

This effect is controlled by the cathode and anode surface effects. We describe the cathode effects first. During the electrolysis, the positive ions will attach themselves on the very first layer of the cathode atoms. This creates a layer of atomic H or D, or hydrides such as LiH or LiD on the surface of the cathode (all of these are insulators). The thickness of atomic H or D could be a few Å. The thickness of a hydride could be up to 1 µm or more, depending on the anode-cathode current.

We can illustrate this effect by the following example: we consider an electrolytic reactor with an anode and a cathode area $A = 10 \text{ cm} \times 10 \text{ cm}$, and an anode-cathode gap $L_{\text{liq}} = 5 \text{ mm}$, and we assume that the cathode is covered with $L_{\text{cath}} = 0.1 \mu \text{m}$ thick layer of an insulator with a volume resistivity $\rho_{\text{cath}} = 10^7 \text{ Ohm.cm}$. The corresponding resistivity of this layer is $R_{\text{cath}} = \frac{\rho_{\text{cath}} \cdot L_{\text{cath}}}{A} = 1 \text{ Ohm}$. For an electrolyte of $L_{\text{liq}} = 5 \text{ mm}$ with a volume resistivity of $\rho_{\text{liq}} = 1 \text{ Ohm.cm}$, the resistivity of the liquid $R_{\text{liq}} = \frac{\rho_{\text{liq}} \cdot L_{\text{liq}}}{A} = 0.005 \text{ Ohms}$ (very small value). This means that if we connect a 10 Volt battery, the electrolytic reactor with such parameters will draw a current of about 10 A. In addition, we also see that practically all power supply voltage is across the insulator layer. For a voltage drop of 10 Volts across the $100 \mu \text{m}$ thick insulator layer, one creates an electric field gradient of $10^7 \text{ V/cm}$. The surface of the cathode is highly irregular after a few minutes of electrolysis, and local bumps and voids could create local enhancements of the electric field. For example, a field $3 \times 10^7 \text{ V/cm}$ will accelerate a free electron from the cathode metal lattice to an energy $(30-W_0) \text{ eV}$ along the $100 \mu \text{m}$ path, where $W_0$ is a metal work function (typically 4-5 eV). The work function $W_0$ can be reduced either by heating (Nordheim thermionic emission), or under a strong applied electric field (Schottky emission: the new work function is $W_0' = W_0 - \frac{e^3}{2} \frac{E^{1/2}}{2}$, where $e$ is the electronic charge and $E$ is the applied electric field). An oxide on the electrode surface could also lower the work function. Only a small fraction of the electrons would actually be accelerated to energies calculated in this paragraph. The majority of electrons would tend to be thermalised by atomic collisions with a typical
mean free path of a few Å. Only those which suffer no collision over 50 to 100 Å distance, would get higher energy. We will call these accelerated electrons "projectile" electrons in the following text.

A typical process occurring at the cathode is a recombination of hydrogen positive ions:

\[
2 \left[ H^+ + e^- \right] \rightarrow 2 \, H \rightarrow H_2
\]

If the electron released by the cathode is thermal as it approaches the positive hydrogen ion, it would be captured by the normal atomic orbits. However, if the electron escaping the cathode has a larger energy than the hydrogen atom ionization potential 13.6 eV, it could continue to fall towards the nucleus, and it could be captured by the DDL orbit. The probability of such an event is related approximately to a geometrical ratio of the DDL radius and the Bohr radius of a normal atom (it is about \( \sim 1.5 \ \text{Fermi}/0.5 \ \text{Å} = 3 \times 10^{-5} \)). During a successful transition to the DDL level the "projectile" electron could radiate a broad spectrum of photons which could be a combination of the synchrotron, the bremsstrahlung, Cherenkov radiation (when the electron becomes relativistic in the last stages of its fall towards the DDL level), or a radiation associated with the electron capture (see chapter 4). A hydrogen atom with an electron on the DDL level would behave almost like a neutron, and it could participate in the secondary nuclear reactions.

As an example, we have used in our experiment a K₂CO₃ solution in normal water as an electrolyte (see chapter 7). In this case one deals with a recombination of K⁺ ions near the cathode. The recombination electron could enter the K⁺ ion and fall on the DDL level of the K atom.

On the anode one could form resistive oxides for some types of materials (or the resistive oxide layer could be deposited on the anode), which could create a similar voltage drop as discussed above, but this time near the anode surface. A negative ion approaching the anode surface could release its excess electron before the oxide layer, which could be accelerated by the voltage gradient present in the resistive layer. Such "projectile" electrons could participate in the DDL transitions if they strike atoms of the anode material. A typical process occurring at the anode is a release of oxygen:

\[
2 \ \text{OH}^- \rightarrow O + H_2O + e^- 
\]

In this case the extracted electron from the negative ion OH⁻ could enter an atom of the anode material (such as carbon, oxygen, etc.) at relatively high energy.
As mentioned in chapter 7, we were dealing with two types of materials during our experimentation. In one case we used carbon electrodes. With carbon electrodes the anode does not have a tendency to form a resistive oxide layer, and one would expect that all DDL processes would tend to occur near the cathode surface. In the second example, we used stainless steel electrodes. With stainless steel electrodes one can form a resistive oxide layer on the anode and some DDL processes could also be expected to occur at the anode.

Thus the metal surface may act as a small accelerator of relatively high energy "projectile" electrons. This effect can occur both on the cathode or anode depending upon what the distribution of resistance is in the electrolyte and both respective cathode and anode surfaces.

A similar mechanism could occur in the gaseous "cold fusion" experiments. Again we assume that one creates a very thin insulating layer of a high volume resistivity on the cathode, for instance. This can occur either deliberately by forming an oxide or accidentally by some contamination. The positive ions, created in a plasma-like condition between the anode and the cathode, land on the surface of the resistive layer, thus creating a capacitor-like field. If the volume resistivity is sufficiently high, there will be a build up of a field across the insulator. Therefore, the cathode surface can emit the electrons. Such "projectile" electrons can then enter an ion and initiate a transition to the DDL level.

The cathode or anode surfaces are sensitive to various contamination problems, to time dependency in forming oxide layers, and to temperature (a formation of bubbles on the cathode surface near the boiling point), etc. This all may contribute to inconsistencies and a certain lack of repeatability in the so called "cold fusion" experiments.

3.2. SUGGESTED OUTLINE OF A THEORY OF PHOTONIC EMISSION DURING THE ELECTRON FALL TO DDL LEVELS

From the observed stability of the world around us, it is obvious, that the rate of transitions to the DDL levels is either very small or zero. In the early Universe, during the period of atom formations, the slow electrons were attached to normal energy levels primarily because their cross section is much larger compared to the electron attachment to the DDL levels (using simple geometrical arguments). In the normal atomic transitions the electron orbit sizes are comparable and large. This is not the case for transitions between the normal level and the DDL level. For example, compare the radius and half width of the electron density peaks for (+) and (-) levels in Figures 1a,
1b, 2 and 3. In addition, the transitions to the DDL levels is a relativistic problem, and therefore one does not expect to follow a classical atomic transition with only one quantum emission. A complete theory of such transitions will still have to be developed.

We suggest that a possible theory of photon emission during the "projectile" electron fall towards the DDL level of a hydrogen atom, could be similar to that of the synchrotron radiation, the bremsstrahlung, or the electron capture by a nucleus. The energy per unit solid angle and per unit frequency interval radiated by the accelerating spiraling electron near the nucleus can be calculated generally as follows (see Jackson for a classical calculation (7), equation 14.66, page 670. The quantum mechanical treatment is found in (8,9)):

\[
\frac{d^2I}{d\omega d\Omega} = \frac{e^2}{4\pi^2c} \int \frac{\hat{n} \times [(\hat{n} - \hat{\beta}) \times \hat{\beta}]}{(1 - \hat{\beta} \cdot \hat{n})^2} e^{i\omega(t - \hat{n} \cdot \mathbf{r}(t) / c)} \ dt
\]

where \( I \) is the radiated photonic energy, \( \omega \) is its frequency, \( \hat{n} \) is the direction of observation (it is a constant in time since the observation point is far away from the region of space where the acceleration occurs), \( c \) is the velocity of light, \( \mathbf{r}(t) \) is the electron trajectory description, \( \hat{\beta}(t) \) is the electron velocity divided by \( c \), \( \hat{\beta}(t) = \frac{d\hat{\beta}(t)}{dt} \) is the electron acceleration divided by \( c \). For a given electron motion \( \mathbf{r}(t), \hat{\beta}(t) \), a quantity \( \hat{\beta}(t) \) can be calculated and the integral can be evaluated as a function of \( \omega \) and the direction \( \hat{n} \). Radiated photonic energy in all three above mentioned processes could be calculated based on equation (19). In the final phases of the "DDL fall" the electron becomes relativistic and can collectively excite nearby atoms via its electric field interaction with their atomic electron shells (for example, producing ionization, excitation and Cherenkov radiation). Generally, in the electrolytic experiment we expect multi-photon emissions for each DDL transition.

A solution of equation (19) will be generally different whether we are dealing with the electrolytic experiment, or, for example, processes near the black hole in the Universe. In the electrolytic experiments the "projectile" electrons are very soft. However, near the black hole all particles are extremely energetic and moving in a large magnetic field. In the second case, both electron and proton trajectories could be "parallel" to each other and the electron's fall towards the proton could be a "straight" line. In this case a single \( \sim 510 \) keV photon could be released in a hydrogen DDL transition. It would be interesting if such photonic transitions are indeed observed near the black holes in the Universe. A strong flux of 511 keV photons radiating from the center of the Milky Way was observed.
by the Compton Gamma Ray Observatory (Scientific American, December 1993, page 76). It is difficult to explain such signal based on the annihilation of electrons and positrons since there is little of antimatter (positrons) in the Universe. Our model provides an interesting alternative for the observed signal.

3.3. DEFORMATION OF ATOMS BY THE EXTERNAL ELECTRIC FIELD

The ions waiting for recombination near the cathode or anode form a capacitor where a dielectricum is formed of neutral atoms created after a charge recombination. The neutral atoms placed in such a field will deform in proportion to the external field and the polarizability of the atom itself. For example, alkali atoms have a very large polarizability and their distortion will be 1-2 orders of magnitude larger than the distortion of noble gases in a given electric field. Table I shows an example of the deformation of neutral atoms which are placed in the electric field of a capacitor formed by ions near the cathode and electrons on the cathode (taking as an example $E = 1\text{Volt per } 10\text{ A}^0 = 10^7 \text{ V/cm}$). Note that a deformation of the Li atom is 365 times larger than that of the H atom, and 1200 times larger than that of the He atom, which makes Li a good choice for having electrons trapped on the DDL level.

The electrons in the deformed atoms may fall to the DDL levels when they are "kicked" out of the normal atomic level, obtaining energy from the electromagnetic interaction with the "projectile" electrons moving nearby. This hypothesis is based on the assumption that the electron orbits in highly deformed atoms are less stable. If such a process is possible it would increase the probability transfer on the DDL.

4. NUCLEAR AND CHEMICAL BEHAVIOR OF THE DDL ATOMS

There has not yet been any evidence found for a high rate of the nuclear reactions in the electrolytic experiments. However, the "collapsed" atoms of H and Li with all their electrons on the DDL could behave almost as neutral particles with a substantially reduced Coulomb barrier, and they could participate at some level in the nuclear reactions. At present, we do not know how to calculate the nuclear reaction rate. We can only suggest what could be examples of such reactions. Candidates for the nuclear reactions could be atoms with a small number of electrons such as H, D, T, He, Li or Be, because the probability is extremely small that all electrons of a larger atom will fall on the DDL. We illustrate this possibility by several examples. In the case of atomic hydrogen $^1\text{H}^1$[with one electron on DDL level], it will behave almost as a neutral particle. If it approaches another $^1\text{H}^1$[with one electron on the normal level(NL)],
located in a H₂O molecule to a distance of about 4 Fermi, it could react according to the following reaction:

1. \[[H^1, \text{e}^- \text{on DDL}] + [H^1, \text{e}^- \text{on NL}] \rightarrow \[D^2, \text{e}^- \text{on NL}], \quad Q = -1.4422 \text{ MeV}\]
   \[
   7.289 \quad + \quad 7.289 \quad = \quad 13.1358 \text{ MeV}
   \]

Similarly, in reactions with heavy water D₂O:

2. \[[H^1, \text{e}^- \text{on DDL}] + [D^2, \text{e}^- \text{on NL}] \rightarrow \[He^3, \text{e}^- \text{on DDL} \text{and e}^- \text{on NL}], Q = -5.4935 \text{ MeV}\]
   \[
   7.289 \quad + \quad 13.1358 \quad = \quad 14.9313 \text{ MeV}
   \]

3. \[[D^2, \text{e}^- \text{on DDL}] + [D^2, \text{e}^- \text{on NL}] \rightarrow \[He^4, \text{e}^- \text{on DDL} \text{and e}^- \text{on NL}], Q = -23.846 \text{ MeV}\]
   \[
   13.1358 \quad + \quad 13.1358 \quad = \quad 2.4249 \text{ MeV}
   \]

The D² or H¹ [each with one e⁻ on DDL] could approach Li⁶ or Li⁷, present in the solution, to a distance of 3-5 Fermi and react according to the following reaction:

4. \[[D^2, \text{e}^- \text{on DDL}] + [Li^6, \text{e}^- 's on NL] \rightarrow \[Be^8, \text{e}^- \text{on DDL}, \text{3e}^- \text{on NL}] \rightarrow \[Be^8, \text{e}^- \text{on DDL}, \text{3e}^- \text{on NL} \rightarrow \[2He^4, Q_1 \rightarrow \[2He^4, Q_2 \rightarrow\]
   \[
   13.1358 \quad + \quad 14.0874 \quad = \quad 4.94176 \quad = \quad 2 \times 2.42494 \text{ MeV},
   \]
   giving \(Q_1 = -22.2814 \) and \(Q_2 = -0.09188 \text{ MeV}\).

5. \[[H^1, \text{e}^- \text{on DDL}] + [Li^7, \text{e}^- 's on NL] \rightarrow \[Be^8, \text{e}^- \text{on DDL}, \text{3e}^- \text{on NL}] \rightarrow \[Be^8, \text{e}^- \text{on DDL}, \text{3e}^- \text{on NL} \rightarrow \[2He^4, Q_1 \rightarrow \[2He^4, Q_2 \rightarrow\]
   \[
   7.289 \quad + \quad 14.9082 \quad = \quad 4.94176 \quad = \quad 2 \times 2.42494 \text{ MeV},
   \]
   giving \(Q_1 = -17.2554 \) and \(Q_2 = -0.09188 \text{ MeV}\).

Further reactions could be observed in electrolysis of K₂CO₃, Rb₂CO₃ or Cs₂CO₃ (only one isotope shown as an example):

6. \[[H^1, \text{e}^- \text{on DDL}] + [K^39, \text{e}^- 's on NL] \rightarrow \[Ca^{40}, \text{one e}^- \text{on DDL}], Q = -8.3296 \text{ MeV}\]
   \[
   7.289 \quad - \quad 33.8062 \quad = \quad -34.8468 \text{ MeV}
   \]

7. \[[H^1, \text{e}^- \text{on DDL}] + [Rb^85, \text{e}^- 's on NL] \rightarrow \[Sr^{86}, \text{one e}^- \text{on DDL}], Q = -9.6423 \text{ MeV}\]
   \[
   7.289 \quad - \quad 82.1588 \quad = \quad -84.5121 \text{ MeV}
   \]

8. \[[H^1, \text{e}^- \text{on DDL}] + [Cs^{133}, \text{e}^- 's on NL] \rightarrow \[Ba^{134}, \text{one e}^- \text{on DDL}], Q = -9.6414 \text{ MeV}\]
   \[
   7.289 \quad - \quad 88.0898 \quad = \quad -88.9688 \text{ MeV}
   \]
Many more secondary reactions similar to those mentioned above are possible, including those with the cathode or anode metals. The reactions of p or d with Pd isotopes were proposed in (10) to explain the observation of a change of isotopic composition in the Pd electrode after electrolysis. Similarly, the reaction of p with $^{19}$K$^{39}$ was proposed in (11) and (12) to explain the observed growth of Ca in the solution after electrolysis of K$_2$O$_3$. All such explanations are not expected by conventional nuclear reaction theory, due to the enormous Coulomb barrier (several MeV) for reactions of p or d with K or Pd isotopes. Our reactions 6.,7. and 8., which use $^1$H$^1$ with e$^-$ on the DDL level, can explain all such experimental observations, without contradicting existing nuclear reaction theory. Our theory predicts that $^1$H$^1$ or $^1$D$^2$ with their e$^-$ on the DDL level could react with any nucleus from the Periodic System to which it approaches within a distance of about 4 fm. Note also in reactions 2-8 that the reaction product contains a bound e$^-$ on the DDL level and a large Q < 0 at the same time, indicating an exothermic nuclear reaction. It is possible that part of this Q would be used for an ejection of e$^-$ from the DDL level (about 500 keV from Q is needed). The ejected electron could carry away most of the Q energy as kinetic energy. As a result, one could observe a formation of energetic electrons in the above reactions.

The electrons descending to the DDL levels could also be captured by a nucleus if the energy conservation permits. For example, in the case of a hydrogen atom, a DDL electron has a total energy of about 1.022 MeV ~ EDDL+m_ec$^2$. To make a transition from proton to neutron (m_n$^2$ = 1.293 MeV) energetically possible, one still needs about dE = 1.293 - 1.022 = 0.271 MeV. Such nuclear capture is not energetically possible during the electrolytic experiment (the "projectile" electrons have an energy of only a few tens of eV at most).

There are many atoms where electron captures are possible (see TABLE II for only a few examples (using ref.(b) for atomic masses)). In the electrolytic experiments involving K atoms, one could expect the following electron capture reaction:

9. $[^{19}$K$^{40}$, e$^-$ on DDL, and 18 e$^-$ on NL] $\rightarrow$ $[^{18}$Ar$^{40}$, 18 e$^-$ on NL], Q = -1.505 MeV.

-33.53526 = -35.04027 MeV

In the nuclear electron capture process, the photon emission is accompanied with a neutrino emission from the nucleus which would carry the balance of energy, and which would not be observed in an ordinary experimental setup.

Chemically, an atom (A,Z) with one electron bound on the DDL level will have one of its nuclear charges screened by this electron and will behave like a (A,Z-1) element, i.e. like a lighter element with Z-1 electrons, which is its neighbor in the Periodic Table. The alkali metal atoms with one electron on the DDL level, created in
electrolysis, will behave like their lighter neighbors, noble gases, and should escape with the electrolytic gases. These "alkali-noble gases" could be determined by GC-MS analysis.

5. OUR PRELIMINARY EXPERIMENTAL RESULTS

We have also performed experiments based on the electrolytic technique. Our main objective in the tests was to see if the excess heat could be explained by a major photonic (or electron emission) activity. We were not instrumented to see small effects due to the secondary nuclear processes mentioned in chapter 4. We have concentrated on the following points during the experimental work: (a) calorimetry, (b) detection of X-rays, UV light, visible light, and charged particles (electrons).

The measurements were performed with many different types of electrolytic reactors implementing various electrode materials, geometries, different electrolytes and different concentrations of the electrolyte. Not all results gave a positive power yield. In fact a variability is not yet understood, and may be connected with the above mentioned delicate electrode surface conditions (see chapter 3). More detailed description of these tests will be given in ref. (13).

In this paper we describe the results from only one reactor. We will describe the calorimetric portion of the experiment only briefly. Following reference (14), we decided to use a 0.001 mole/l solution of K₂CO₃ in normal distilled water. This reactor was open at the top, which made the photonic detection experiments easier. The reactor consists of 7 glass cells, each cell having carbon electrodes for both the anode and the cathode. The size of each carbon electrode was 2.5 cm x 15 cm x 0.6 cm and the anode-cathode gap was about 7 mm. Each cell had a calibration resistive wire. Electrically, seven cells were connected in parallel.

In the calorimetric problem we considered the evaporation losses, water decomposition by the electrolysis and the heat losses through the sides of the reactor. During all photonic tests, the net input power was typically 5.5 W, the total input power 8.5 W, the electrolytic current about 2 A and dc voltage across the electrodes about 4.25 V. We observed a power gain of about 1.75 times (with a ~10% error), compared to the net input power. The net input power is defined as the total input power minus the power necessary to decompose water (~1.5 Volts x electrolytic current). Although there is an indication of overall positive calorimetric power gain (especially if one would catch oxygen and hydrogen and utilize that portion of energy ~ 3W), we concentrated mainly on the photonic detection, because it is motivated by our DDL model. If the DDL model is correct, there is about ~4 W released in this test in some form of photon radiation. This
would represent more than \( \sim 5 \times 10^{13} \) photons/sec, if we assume one photon per \( \sim 500 \) keV DDL transition (and higher photon yield if we are dealing with multi-photon emission per one DDL transition). That would appear as an easily detectable effect, if the generated photons are in our detection sensitivity window. We have investigated the following photon detection techniques:

(a) Fast photographic films (Polaroid #57 (speed 3000 ASA) and Kodak dental film):
As a calibration, we could see a Fe\(^{55}\) source (about 5 mC; 5 mm dia.) emitting 5.9 keV X-rays very clearly, if the source was placed on the surface of the film for only five seconds. This means that the film's detection sensitivity limit is about \( 1-2 \times 10^8 \) of 5.9 keV X-rays per 5 mm diameter area. However, even a 2 day exposure of the film placed 10 cm above the electrolyser did not reveal any evidence of the radiation.

(b) Phototube (RCA8850):
Two tests were performed. In the first test, we placed the phototube simply above the electrolyser and surrounded the entire arrangement with a lightproof tent. This test would detect light only if it is emitted from the electrolyte surface. This phototube's sensitivity is between 260 and 650 nm. It is sensitive to single photons. The detection was observed on the oscilloscope. No difference in the phototube rate (< 1kHz) was observed switching the electrolyser on and off (typically, the off time would be 10-30 seconds). In the second test we have connected one end of the UV quartz fiber to the same phototube. The other end was placed into the electrolyte next to the cathode or anode surfaces deep inside the electrolyte. Although the quartz fiber would transmit a light starting from 175 nm, the transmission window is defined by the phototube's response. Again, no signal above the noise rate was observed.

(c) Phototube with BGO crystal (Hamamatsu E974):
A small BGO crystal (0.5 inch diameter, 0.25 inch thick) was placed on the face of the phototube (~1 inch diameter). This arrangement should be sensitive to \( \sim 0.5 \) MeV gammas. As a calibration we used the Fe\(^{55}\) source, i.e. 5.9 keV X-rays. The phototube was placed directly into the opening of the electrolyser cell a few mm above the liquid. No difference in the phototube pulse rate or pulse height was observed by switching the electrolyser current on and off.

(d) Geiger counter (Model TBM-3S):
As a calibration, the Geiger counter could detect the Fe\textsuperscript{55} source very clearly. However, there was no evidence that any radiation escapes the electrolyser. The rate was consistent with a cosmic ray background (20-40 counts/min.). We have found no evidence of an electrode surface activation after all our electrolyzers were taken apart. The Geiger counter would also have detected the charged particles (electrons). The electron energy detection threshold was 20-30 keV.

(e) A visual inspection with a fluorescent dye:

To prove that the DDL reactions might occur deep inside the electrolytic bath, in the middle of tests we have also added a small amount of UV excitable fluorescent dye which is soluble in water (Sodium fluoresceine made by Pylam Co.). We did not observe any "glow" visually in darkness around the electrodes, with or without the dye. No detailed study was performed on how the dye affects the calorimetric portion of the experiment. However, a similar amount of excess heat was produced with or without the dye.

We have not detected a significant photonic activity consistent with the observed heat excess in the electrolysis. This means that either there are no DDL formations in the electrolytic process, or they do exist, but the experiment is insensitive to photons generated in the DDL process. Our techniques were not able to detect the photonic activity if the DDL mechanism is generating infrared photons (> 650 nm), or very hard UV photons (5-100 eV) or very soft X-rays (0.1-5 keV). In addition, only hard X-rays (> 15 keV) will emerge from a depth of the electrolyte. Softer X-rays would be observed only if they are created near the surface of the liquid.

Perhaps, the best way to detect the photonic activity is in gaseous experiments performed at low pressure. The peaking at an energy of about 100 keV was observed (6), with a tail extending to hundreds of keV. Their observed intensity ratios of the gamma quanta, neutrons, charged particles and X-rays indicate \( I_\gamma : I_\text{n} : I_\text{c.p.} : I_\text{x} = 1: (10^{-5}-10^{-2}) : (10^{-1}-10^{2}) : (10-10^{2}) \). However, the authors point out that the observed charged particle yield is still 3-4 orders of magnitude short to explain their heat yield. Similarly, in the cold fusion reactions induced by sparking in hydrogen isotopes (15), there appears to be an emission of low energy radiation (consistent with ~50keV electrons). However, we conclude that in the experiments where the power gain was observed, it is not accompanied by major photonic activity. One may investigate whether the DDL transitions radiate in the infrared wavelength region because the main observed effect is heat. It could be still possible that the collective thermal excitation of
nearby atoms by the electric field of the spiraling electron falling towards the DDL level is a dominant radiation during the DDL transition.

CONCLUSIONS
We have estimated the size of the DDL atoms by calculating an electron density on the DDL levels. Our paper also suggested possible secondary nuclear reactions of the atoms with electrons on the DDL levels. A model of transition from normal atomic energy levels to the DDL levels was also presented. We suggest that the given model would manifest itself as photonic emissions near the cathode or anode surfaces.

Experimentally, although we have measured a calorimetric power gain in the electrolytic experiment in terms of heat, we have not yet measured any evidence supporting the major photonic emissions at the same time. We have specified a wavelength window of our sensitivity during the tests: 260-650 nm and > 5 keV X-rays. We were sensitive to ~ 0.5 MeV gammas. We realize that it is difficult to measure UV photons and soft X-rays in the electrolytic environments. Perhaps, the same measurements should be repeated in the gaseous experiments. Another way to prove the model would be to use the GC-MS analysis and identify a mass 39 among the Ar isotopes (the $^{19}$K$^{39}$ with one e$^-$ on the DDL level). One could then investigate whether the DDL transitions radiate in the infrared wavelength region.

ACKNOWLEDGMENTS
We are grateful to Catherine Maly, for editing this paper.
REFERENCES
(2) J.A. MALY and J. VA'VRA, "Electron Transitions on Deep Dirac Levels III.", To be published.
FOOTNOTES

(a) HANDBOOK OF CHEMISTRY AND PHYSICS, Published by the Chemical Rubber Co., Cleveland, Ohio, 1991.

(b) TABLES OF ISOTOPES; Edited by C.M. LEDEER, V.S. SHIRLEY, Seventh Edition, John Willey & Sons, 1978.; The values in MeV are amounts relative to the AMU units (931.5 MeV), and one should also note that the atom masses contain masses of atomic electrons.

Table I - Displacement calculated for field \( E = 10^7 \) V/cm

<table>
<thead>
<tr>
<th>Atom</th>
<th>H</th>
<th>He</th>
<th>Li</th>
<th>Ne</th>
<th>Na</th>
<th>Ar</th>
<th>K</th>
<th>Rb</th>
<th>Cs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarizability</td>
<td>0.667</td>
<td>0.205</td>
<td>24.3</td>
<td>0.396</td>
<td>23.6</td>
<td>1.64</td>
<td>43.4</td>
<td>47.3</td>
<td>59.6</td>
</tr>
<tr>
<td>Displacement</td>
<td>0.46</td>
<td>0.14</td>
<td>168</td>
<td>0.28</td>
<td>16.4</td>
<td>1.14</td>
<td>30</td>
<td>33</td>
<td>41.3</td>
</tr>
</tbody>
</table>

Table II - Examples of energetically possible electron capture reactions.

<table>
<thead>
<tr>
<th>Starting atom (with e(^-) on DDL)</th>
<th>Intermediate atom (after e(^-) capture from DDL)</th>
<th>( T_{1/2} )</th>
<th>Final state</th>
</tr>
</thead>
<tbody>
<tr>
<td>( ^{7}\text{N}^{14} )</td>
<td>( ^{6}\text{C}^{14} ) (emits ( \beta^- ))</td>
<td>5730 y</td>
<td>( ^{7}\text{N}^{14} )</td>
</tr>
<tr>
<td>( ^{17}\text{Cl}^{35} )</td>
<td>( ^{16}\text{S}^{35} ) (( \beta^- ))</td>
<td>87.4 d</td>
<td>( ^{17}\text{Cl}^{35} )</td>
</tr>
<tr>
<td>( ^{29}\text{Cu}^{63} )</td>
<td>( ^{28}\text{Ni}^{63} ) (( \beta^- ))</td>
<td>0.05 s</td>
<td>( ^{29}\text{Cu}^{63} )</td>
</tr>
<tr>
<td>( ^{19}\text{K}^{40} )</td>
<td>( ^{18}\text{Ar}^{40} ) (e.c.)</td>
<td>stable</td>
<td>( ^{18}\text{Ar}^{40} )</td>
</tr>
<tr>
<td>( ^{28}\text{Ni}^{58} )</td>
<td>( ^{27}\text{Co}^{58} ) (e.c.)</td>
<td>70.8 d</td>
<td>( ^{26}\text{Fe}^{58} )</td>
</tr>
<tr>
<td>( ^{42}\text{Mo}^{92} )</td>
<td>( ^{41}\text{Nb}^{92} )</td>
<td>3.2x10(^7) y</td>
<td>( ^{40}\text{Zr}^{92} )</td>
</tr>
<tr>
<td>( ^{44}\text{Ru}^{96} )</td>
<td>( ^{43}\text{Tc}^{96} ) (( \beta^+ ))</td>
<td>4.3 d</td>
<td>( ^{42}\text{Mo}^{96} )</td>
</tr>
<tr>
<td>( ^{46}\text{Pd}^{102} )</td>
<td>( ^{45}\text{Rh}^{102} ) (e.c.)</td>
<td>2.9 y</td>
<td>( ^{44}\text{Ru}^{102} )</td>
</tr>
<tr>
<td>( ^{47}\text{Ag}^{107} )</td>
<td>( ^{47}\text{Pd}^{107} ) (( \beta^- ))</td>
<td>6.5x10(^6) y</td>
<td>( ^{47}\text{Ag}^{107} )</td>
</tr>
<tr>
<td>( ^{55}\text{Cs}^{133} )</td>
<td>( ^{54}\text{Xe}^{133} ) (( \beta^- ))</td>
<td>5.25 d</td>
<td>( ^{55}\text{Cs}^{133} )</td>
</tr>
</tbody>
</table>
Figure 1. The electron density distribution for the hydrogen atom with its electron on the normal level in (a) : $1s(+) \text{ state (+ sign corresponds to } s > 0 \text{ in equation(4))}$, (b) : in the normal states $2s(+) \text{ and } 2p(+)$. 
Figure 2. The electron density distribution for the hydrogen atom with its electron on the DDL level in 2s(-) state, corresponding to an energy level of -509.133 keV (- sign corresponds to $s < 0$ in equation(4)), and the same for the lithium atom with one electron only, which is on the DDL level in 2s(-) state, corresponding to an energy level of -505.405 keV.
Figure 3. The electron density distribution for the potassium atom with one electron only, which is on the DDL level in 2s(-) state, corresponding to an energy level of -475.488 keV, and the same for the cesium atom with one electron only, which is on the DDL level in 2s(-) state, corresponding to an energy level of -406.227 keV.