ABSTRACT

Applications of Quantum Mechanics: Black Light Power and the Widom-Larsen Theory of LENR [open pdf - 4MB]

This document consists of a set of slides on the topic of Low Energy Nuclear Reactions (LENR) "theoretical modeling" and "experimental observations". It also discusses efforts to: "Catalogue opponent/proponent views on LENR theories and experiments", "Review data on element transmutation", "Prepare assessment and recommendations", and "Critically examine past and new claims by Black Light Power Inc [...] power generation using a newly discovered field of hydrogen-based chemistry". Note: This document has been added to the Homeland Security Digital Library in agreement with the Project on Advanced Systems and Concepts for Countering WMD (PASCC) as part of the PASCC collection. Permission to download and/or retrieve this resource has been obtained through PASCC.

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Applications of Quantum Mechanics:
Black Light Power
and
the Widom-Larsen Theory of LENR

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March 2010

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Applications of Quantum Mechanics

BlackLight Power

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31 March 2010

Fort Belvoir, VA

Tasking

- Determine the state of understanding of LENR theoretical modeling, experimental observations
  - Confer with selected Low Energy Nuclear Reactions (LENR) proponents
  - Survey and evaluate competing theories for the observed LENR results
- Catalogue opponent/proponent views on LENR theories and experiments
  - Conduct literature search
  - Seek consultations
- Review data on element transmutation
  - Present alternative explanations
- Prepare assessment and recommendations
  - Include pros & cons for potential DTRA support of LENR research

- Critically examine past and new claims by Black Light Power Inc: power generation using a newly discovered field of hydrogen-based chemistry
  - Investigate the theoretical basis for these claims
  - Assess compatibility with mainstream theories and other observed phenomena

Background

- BlackLight Power, Inc. formed as HydroCatalysis, Inc. - 1991
  - Dr. Randy Mills
  - Hydrino concept to explain cold fusion observations – postulates states of hydrogen below conventional ground state capable of yielding keV energies per atom
- Over $60M in venture capital to date
- Publications
  - Both pro and con
  - Mills' publications tend to be in speculative journals
- Previous OSD/DARPA interactions with Dr. Mills
- Meeting with BlackLight Power representatives February 2009
  - DTRA personnel - Bill Wilson, Dave Algert, and Chuck Allen (A&AS)
  - Mike Sabel, BLP business development - emphasis:
    - Need to be "up to speed" on Mill's theory – the basis of the BlackLight Power effort
    - BlackLight Power must have contractual relationship with DTRA before any substantive technical exchanges could be arranged including facilities inspection
- Latest edition of Mills book – The Grand Unified Theory of Classical Physics (June 2008 edition – released February 2010)
  - Review
  - Assessment

Strategy

- Focus on theory
  - Physics foundations
  - Mathematical credibility
- Use Mills' book and relevant publications
- Note:
  - Experimental evidence can trump theory – alternative explanations may be possible if data claims borne out

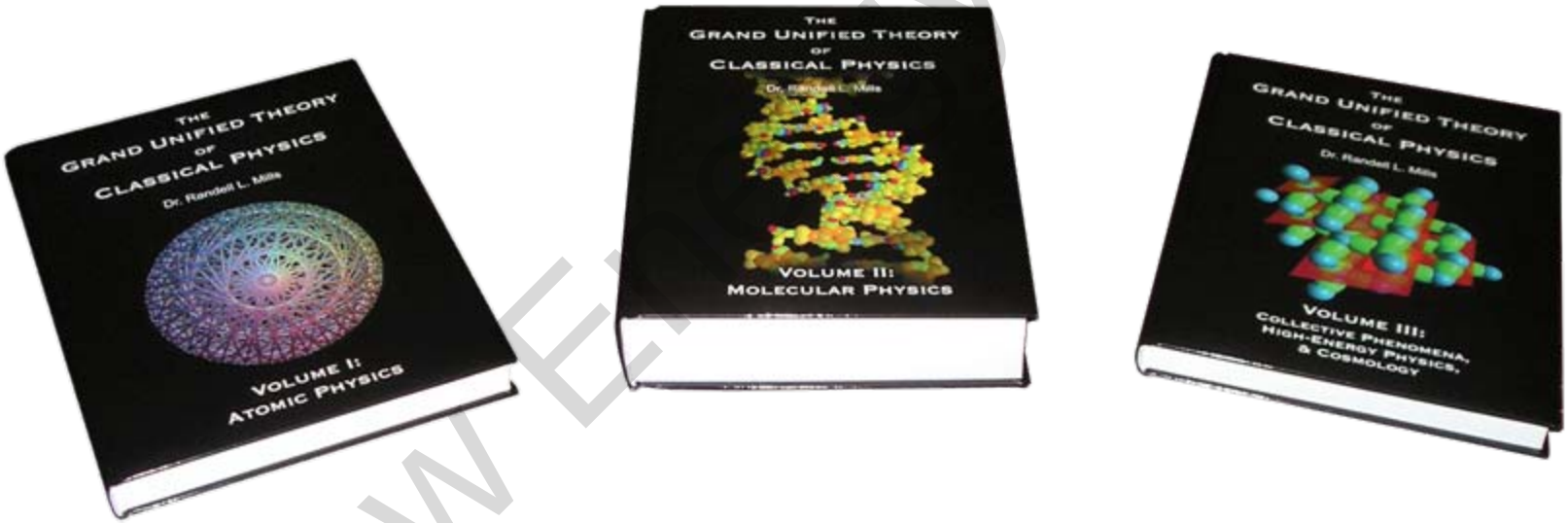
The Grand Unified Theory of Classical Physics

About the Author

Randell L. Mills received a Bachelor of Arts Degree in chemistry, summa cum laude and Phi Beta Kappa from Franklin & Marshall College in 1982 and a Doctor of Medicine Degree from Harvard Medical School in 1986 with a concentration on technology while also studying electrical engineering at the Massachusetts Institute of Technology. He is the Founder and President of BlackLight Power, Inc., based in the Princeton, New Jersey area that is developing technologies based on novel hydrogen chemistry. He has authored or co-authored over a hundred (100) articles and a book in this field. He is also active in a number of other areas of technology. He has received or filed patent applications in the following areas: (1) catalysis of hydrogen to lower-energy states; (2) computational chemical design technology; (3) magnetic resonance imaging; (4) Mossbauer cancer therapy; (5) Luminide class of drug delivery molecules; (6) genomic sequencing method, and (7) artificial intelligence. He is a member of the American Chemical Society.

The Grand Unified Theory of Classical Physics – Book

- Three volumes
- 1726 pages
- 6110 numbered equations



New Theories & Paradigm Shifts

- *"One of the principal objects of theoretical research in any department of knowledge is to find the point of view from which the subject appears in its greatest simplicity."* – Josiah Willard Gibbs, as quoted in *The Grand Unified Theory of Classical Physics*, p.xxi
- *"Extraordinary claims require extraordinary evidence."* – Carl Sagan, *Cosmos*, p.339.
- New theories emerge
  - To explain data & observations (e.g., Newtonian gravity, quantum mechanics)
  - Resolve philosophical/epistemological conflicts (e.g, relativity)
- Mills' theory offers applications from quarks to universe (85 orders of magnitude in scale)
- *We address Mills' theory with respect to hydrino & energy implications*

Mills' Perspective on Quantum Mechanics

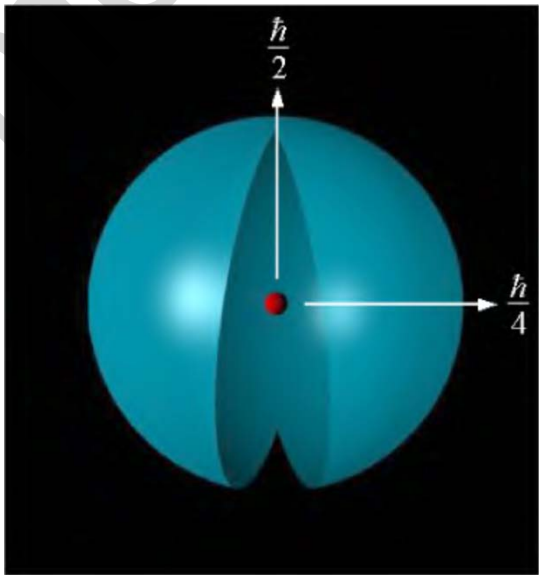
Quantum Mechanics	Perspective
Schrödinger's equation	• Not Lorentz invariant • Violates first principles, including special relativity & Maxwell's equations • Gives no basis why excited states are radiative and 13.6eV state is stable • Predicts the ground state electron has zero angular energy and angular momentum • Equation is not wave equation • Fails to predict electron spin, leads to negative energy states in a vacuum, infinities, negative kinetic energy, stability of atomic hydrogen state n = 1 • Predicts non-causality, non-locality, spooky actions at a distance
Wave function solution for Hydrogen	• Electron has probability of being in nucleus - impossible
Nature of fundamental particles	• "Particles have zero volume but are everywhere" – is nonsensical
Heisenberg Uncertainty Principle	• Defines the limitations of the existence of physical reality

- **Mills proposes Classical Physics (CP) theory as foundational replacement of Quantum Mechanics (QM)**
- **These perspectives (and many others) reveal lack of appreciation/ understanding of QM**

CP Theory & Quantum Electrodynamics (QED)

- QED perhaps the most successful theory in human history
  - Photo-electric effect – instantaneous ejection of electrons from metals upon illumination/ intensity governs number of electrons ejected – not kinetic energy
  - Laser – stimulated emission
  - Thermonuclear process – quantum tunneling
  - Electron microscope – wave nature of leptons
  - Superconductivity/fluidity – collective particle motions
  - Teleportation – jump of quantum states across time and space
- CP theory
  - Replaces QM foundation with pure classical concepts such as
    - Restores absolute space, absolute time
    - Retains Newtonian physics at micro-scale
  - Offers predictions of atomic & molecular properties with precision using only fundamental constants
  - Implies new states of hydrogen atom → *hydrino*

CP Core



- CP core
  - Entirely classical physics construct
  - Electron in hydrogen atom is represented by *orbitsphere*
    - Infinitely thin mass and charge spherical shell surrounding the nucleus
    - All infinitesimal surface elements move with same v, r, and ω so that $v = \omega r$, with v determined by nucleus attraction force
    - Surface element trajectories are great circles
    - Serves as resonant cavity for standing waves (photons)
    - Surface charge/currents provide boundary conditions
- Fourier decomposition of general exterior solution for electromagnetic field
  - Constrains surface charge kinematics & distribution for non-radiating solutions
  - Provides characterization route for excited state transitions

Fourier Characterization of Non-Radiating Solutions

$$\mathbf{E}_{\perp}(\mathbf{r},\omega)\frac{d\omega}{2\pi} = \frac{c}{2\pi}\int\int \rho(\omega,\Omega)\,d\omega d\Omega \sqrt{\frac{\mu_0}{\varepsilon_0}}\mathbf{n}\times\left[\mathbf{n}\times\mathbf{J}\left(\frac{\omega}{c}\mathbf{n},\omega\right)\right]e^{i(\omega/c)\mathbf{n}\cdot\mathbf{r}}$$

- Fourier component of radiating electric field
- Fourier coefficient of arbitrary charge distribution
- Unit vector in radiation direction
- Fourier coefficient of source current density

- Concept originated with Haus†
  - Far-field radiation electric field directly associated with presence of Fourier component of (perpendicular) source current traveling at speed of light ($\mathbf{k} = (\omega/c)\mathbf{n}$)
- Origin of arcane phraseology:

The reason for the radiation of an accelerated charge is that the Fourier decomposition of the current acquires components that are synchronous with the light velocity.

†Haus, H.A., On the Radiation from Point Charges, Am. J. Phys. 54 (12), December 1986, p.1126

Non-Radiating Orbitsphere

- CP equivalent for orbitsphere:

$$\mathbf{J}_{\perp}(s,\Theta,\Phi,\omega) \propto \frac{\sin(2sr_n)}{2sr_n}\left[\delta(\omega-\omega_n)+\delta(\omega+\omega_n)\right]$$

Wavenumber

- Trapped photon: $\lambda_n = 2\pi r_n$
- But then: $s = 2\pi/\lambda_n = 1/r_n$
- Mills "relativistic argument": $\lambda_n = r_n$
- Then: $s = 2\pi/\lambda_n = 2\pi/r_n$
- And sine function vanishes

→ No radiating fields at infinity

Hydrino

- Orbitsphere
  - Classical object
  - Ground-state energy fixed by radius equal to Bohr radius
  - Energy levels ~ $1/n^2$, n = 1, 2, … (quantum numbers)
- Hydrino
  - Classical construct admits extension to fractional levels ~n = ½, 1/3, …
  - Fractional state changes through photon exchange
    - Prohibited by conservation laws
    - Facilitated by three-body interactions (“catalytic interactions”)
- Hydrino concept the basis for BlackLight Power investment to establish this as new, abundant energy source

Assessment

- Mills set-aside of established QM
  - Strawman strategy?
  - Fundamental misunderstanding of QM principles?
- CP theory attributes
  - Fully classical formulation – no adjustable constants
  - Orbitsphere charge shell has only charge and mass characteristics
  - Infinitesimal elements all move with same tangential speed along individual great circle orbits
  - Analogy to cometary Oort cloud – fine distribution of non-interacting elements gives rise to stationary shell with no net momentum or current
- Issues
  - Electron charge should be quantized for orbitsphere, but no mechanism to prohibit fractionization through collisions
  - Mills claims state stability based on absence of radiative fields – only establishes stationary behavior
  - Details of analysis sometimes opaque, yet key to conclusions (e.g., relativity scaling for establishing non-radiating behavior)
  - Mathematical "leaps of faith" & unjustified assumptions

Relevance for Power Claims

- Formal theories can be logically consistent but be ruled out for other reasons – e.g.
  - Herman Weyl's unification of gravity and electromagnetism (fatal flaw in that the state of atomic matter would depend on its history)
- Grandiosity in claims for full range of physics scales, misunderstandings in other branches of physics weakens credibility in QM realm
- Abundance of numerical results for atomic and molecular physics arrived at based only on CP assumptions and fundamental constants
  - Interesting but not compelling evidence for rejection of established QM in light of CP weaknesses
- Weaknesses in CP theory do not *a priori* rule out experimental results
  - Advertisements of BlackLight Power successes with calorimetry experiments claim excess power with particular catalysts – analogies exist with LENR experimental claims
  - Experimental evidence held for proprietary reasons – no other evidence offered of potential existence of hydrino-like matter in nature

Recommendations

- DTRA should be cautious in considering contractual relationships with BlackLight Power
  - Reviews & assessments performed throughout the BlackLight Power history have generally revealed serious deficiencies in the CP theory
  - Experimental claims have not enjoyed the benefit of doubt of even those in the LENR field
  - No substantive independent validations (BlackLight Power exercises proprietary constraints)
- DTRA should continue to be receptive to and an advocate for independent laboratory validation
  - Contractual support for participation in independent laboratory validation should be avoided – a full, "honest broker" stance is necessary should promising results emerge in a highly controversial field

Applications of Quantum Mechanics

Highlights of the Widom-Larsen Theory of LENR and Some of Its Implications

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The lack of testable theories for (LENRs) is a major impediment to acceptance of experimental claims … What is required for the evidence (presented) is either a testable theoretical model or an engineering demonstration of a self-powered system …

2004 DOE LENR Review Panel

31 March 2010

The Theoretical Dilemma posed by Cold Fusion

- On 23 March 1989 Pons and Fleischman revealed in a news conference that they had achieved thermonuclear fusion (D – D) in an electrochemical cell at standard pressure and temperature
- D – D reactions and their branching ratios
  - D + D⇒ ^{3}He (0.82 MeV) + n^{0} (2.45 MeV) (slightly less than 50% of the time)
  - D + D⇒ T (1.01 MeV) + n^{0} (3.02 MeV) (slightly less than 50% of the time)
  - D + D⇒ ^{4}He (0.08 MeV) + γ (23.77 MeV) (less than 1% of the time)
- But the Pons & Fleischman* results did not indicate neutron emissions at expected rates, nor show any evidence of γ emissions
- Subsequent experiments, while continuing to show convincing evidence for nuclear reactions, have largely dispelled thermonuclear fusion as the underlying responsible physical mechanism
- Some other Low Energy Nuclear Reaction (LENR) was likely in play

A new theory was needed to explain “LENR”

* Pons and Fleischman reported detecting He^{4} but subsequently retracted this claim as a flawed measurement.

Observations from LENR Experiments

- Macroscopic “excess heat” measured calorimetrically
  - Weakly repeatable and extremely contentious
  - Richard Garwin says, “Call me when you can boil a cup of tea*”
- Production of gaseous helium isotopes
  - Difficult to detect reliably and possibility of contamination
  - Observed by only a few researchers but most do not go to the expense of looking for helium
- Modest production of MeV alpha particles and protons
  - Reproducible and reported by a number of researchers
- Production of a broad spectrum of transmuted elements
  - More repeatable than excess heat but still arguments over possible contamination
  - Difficult to argue against competent mass spectoscopy

* Largest amount and duration of excess heat measured in an LENR experiment was 44 W for 24 days (90 MJ) in nickel-light hydrogen gas phase system.

Widom-Larsen Theory

- The Widom-Larsen (W-L) theory provides a self-consistent framework for addressing many long-standing issues about LENR
  - Overcoming the Coulomb barrier – the most significant stumbling block for thermonuclear "Cold Fusion" advocates
  - Absence of significant emissions of high-energy neutrons
  - Absence of large emissions of gamma rays
- The W-L theory does not postulate any new physics or invoke any ad hoc mechanisms to describe a wide body of LENR observations, including
  - Source of excess heat in light and heavy water electrochemical cells
  - Transmutation products typically seen in H and D LENR experimental setups
  - Variable fluxes of soft x-rays seen in some experiments
  - Small fluxes of high-energy alpha particles in certain LENR systems

W-L Theory – The Basics

- Electromagnetic radiation on a metallic hydride surface increases mass of surface plasmon electrons (e^-)
- Heavy-mass surface plasmon polariton (SPP) electrons react with surface protons (p^+) or deuterons (d^+) to produce ultra low momentum (ULM) neutrons and an electron neutrino (v)
- ULM neutrons are readily captured by nearby atomic nuclei (Z,A), resulting in an increase in the atomic mass (A) by 1 thereby creating a heavier mass isotope (Z,A+1) .
- If the new isotope is unstable it may undergo beta decay*, thereby increasing the atomic number by 1 and producing a new transmuted element (Z+1, A+1) along with a beta particle (e^-) and an anti-neutrino (v_e)
- The energy released during the beta decay is manifest as “excess heat”

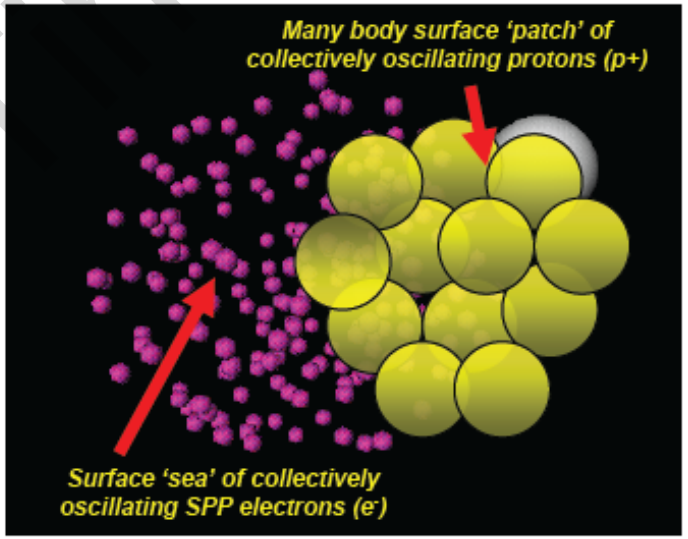
1. $\tilde{e}^- + p^+ \rightarrow n^0_{ulm} + v_e$
2. $\tilde{e}^- + d^+ \rightarrow 2n^0_{ulm} + v_e$
3. $n^0_{ulm} + (Z,A) \rightarrow (Z,A+1)$
4. $(Z,A+1) \rightarrow (Z+1,A+1) + e^- + \overline{v}_e$

*It could also undergo alpha decay or simply release a gamma ray, which in turn is converted to infrared energy

W-L Theory Invokes Many Body Effects

- Certain hydride forming elements, e.g., Pd, Ni, Ti, W, can be loaded with H, D, or T, which will ionize, donating their electrons to the sea of free electrons in the metal
- Once formed, ions of hydrogen isotopes migrate to specific interstitial structural sites in the bulk metallic lattice, assemble in many-body patches, and oscillate collectively and coherently (their QM wave functions are effectively entangled) setting the stage for a local breakdown in the Born-Oppenheimer approximation[1]
- This, in turn, enables the patches of hydrogenous ions to couple electromagnetically to the nearby sea of collectively oscillating SSP electrons
- The coupling creates strong local electric fields ($>10^{11}$ V/m) that can renormalize the mass of the SSPs above the threshold for ULM neutron production
- ULM neutrons have huge DeBroglie wavelengths[2] and extremely large capture cross sections with atomic nuclei compared even to thermal neutrons
  - Lattice Energy LLC has estimated the ULM neutron fission capture cross section on U^{235} to be ~ 1 million barns vs. ~586 barns for thermal neutrons

It's not just a two-body collision



[1] The Born-Oppenheimer approximation allows the wavefunction of molecule to be broken down into its electronic and nuclear (vibrational and rotational) components. In this case, the wavefunction must be constructed for the many body patch.

[2]The DeBroglie wavelength of ULM neutrons produced by a condensed matter collective system must be comparable to the spatial dimension of the many-proton surface patches in which they were produced.

W-L Theory Insights

Insight 1: Overcoming Coulomb energy barrier

- The primary LENR process is driven by nuclei absorbing ULM neutrons for which there is no Coulomb barrier

Insight 2: Suppression of gamma ray emmisions

- Compton scattering from heavy SSP electrons creates soft photons
- Creation of heavy SSP electron-hole pairs in LENR systems have energy spreads in the MeV range, compared to nominal spreads in the eV range for normal conditions in metals, thus enabling gamma ray absorption and conversion to heat

Insight 3: Origins of excess heat

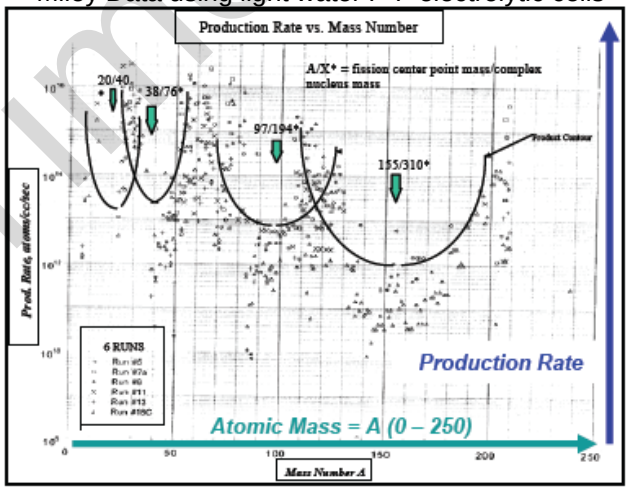
- ULM neutron capture process and subsequent nuclei relaxation through radioactive decay or gamma emission generates excess heat
  - Alpha and beta particles transfer kinetic energy to surrounding medium through scattering process
  - Gamma rays are converted to infrared photons which are absorbed by nearby matter

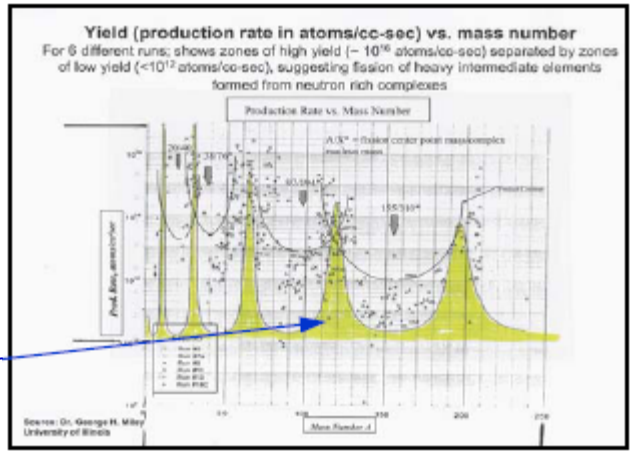
W-L Theory Insights Cont'd

Insight 4: Elemental transmutation

- Five-peak transmutation product mass spectra reported by several researchers
  - One researcher (Miley) hypothesized that these peaks were fission products of very neutron-rich compound nuclei with atomic masses of 40, 76, 194, and 310 (a conjectured superheavy element)
- According to W-L theory, successive rounds of ULM neutron production and capture will create higher atomic mass elements consistent with observations
  - The W-L neutron optical potential model of ULM neutron absorption by nuclei predicts abundance peaks very close to the observed data

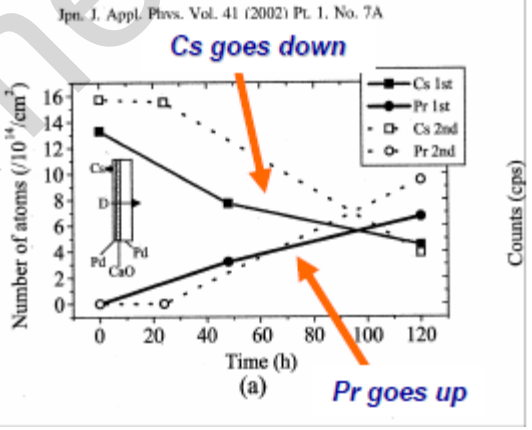
Miley Data using light water P-F electrolytic cells





W-L Theory Transmutation Pathways for Iwamura Experiments

- Transmutation data from Iwamura, Mitsubishi Heavy Industries
  - Experiments involved permeation of a D_2 gas through a Pd:Pd/CaO thin-film with Cs and Sr seed elements placed on the outermost surface
  - $_{55}Cs^{133}$ target transmuted to $_{59}Pr^{141}$; $_{38}Sr^{88}$ transmuted to $_{42}Mo^{96}$
  - In both cases* the nuclei grew by 8 nucleons
- W-L theory postulates the following plausible nucleosynthesis pathway



$^{133}_{55}Cs + 1\,ulm\,n \rightarrow {}^{134}_{55}Cs + \gamma$ (Q = 6.9 MeV; 2.1 yrs; $\sigma_{thermal}$ = 140b)

$^{134}_{55}Cs + 1\,ulm\,n \rightarrow {}^{135}_{55}Cs + \gamma$ (Q = 8.8 MeV; hl = 2.3 x 10^6 yrs; $\sigma_{thermal}$ = 8.9b)

$^{135}_{55}Cs + 1\,ulm\,n \rightarrow {}^{136}_{55}Cs + \gamma$ (Q = 6.8 MeV; hl = 13.2 days; $\sigma_{thermal}$ = ?)

$^{136}_{55}Cs + 1\,ulm\,n \rightarrow {}^{137}_{55}Cs + \gamma$ (Q = 8.3 MeV; hl = 30.1 yrs; $\sigma_{thermal}$ = 0.25b)

$^{137}_{55}Cs + 1\,ulm\,n \rightarrow {}^{138}_{55}Cs + \gamma$ (Q = 4.4 MeV; hl = 33.4 min; $\sigma_{thermal}$ = ?)

$^{138}_{55}Cs + 1\,ulm\,n \rightarrow {}^{139}_{55}Cs + \gamma$ (Q = 6.6 MeV; hl = 9.3 min; $\sigma_{thermal}$ = ?)

$^{139}_{55}Cs + 1\,ulm\,n \rightarrow {}^{140}_{55}Cs + \gamma$ (Q = 4.4 MeV; hl = 64 sec; $\sigma_{thermal}$ = ?)

$^{140}_{55}Cs + 1\,ulm\,n \rightarrow {}^{141}_{55}Cs + \gamma$ (Q = 5.5 MeV; hl = 25 sec; $\sigma_{thermal}$ = ?)

$^{141}_{55}Cs$ decays 100% via $\beta^- \rightarrow {}^{141}_{56}Ba + \gamma$ (Q = 5.3 MeV; hl = 18.3 min)

$^{141}_{56}Ba$ decays 100% via $\beta^- \rightarrow {}^{141}_{57}La + \gamma$ (Q = 3.2 MeV; hl = 3.9 hrs)

$^{141}_{57}La$ decays 100% via $\beta^- \rightarrow {}^{141}_{58}Ce + \gamma$ (Q = 2.5 MeV; hl = 32 days)

$^{141}_{58}Ce$ decays 100% via $\beta^- \rightarrow {}^{141}_{59}Pr$ + X-rays (Q = 580 keV; stable)

$^{88}_{38}Sr + 1\,ulm\,n \rightarrow {}^{89}_{38}Sr + \gamma$ (Q = 6.4 MeV; 50.5 days)

$^{89}_{38}Sr$ decays 100% via $\beta^- \rightarrow {}^{89}_{39}Y$ + X-rays (Q = 1.5 MeV; stable)

$^{89}_{39}Y + 1\,ulm\,n \rightarrow {}^{90}_{39}Y + \gamma$ (Q = 6.9 MeV; hl = 64hrs; $\sigma_{thermal}$ = 6.5b)

$^{90}_{39}Y + 1\,ulm\,n \rightarrow {}^{91}_{39}Y + \gamma$ (Q = 7.9 MeV; hl = 59 days; $\sigma_{thermal}$ = ?)

$^{91}_{39}Y + 1\,ulm\,n \rightarrow {}^{92}_{39}Y + \gamma$ (Q = 6.5 MeV; hl = 3.5 hrs; $\sigma_{thermal}$ = ?)

$^{92}_{39}Y + 1\,ulm\,n \rightarrow {}^{93}_{39}Y + \gamma$ (Q = 7.5 MeV; hl = 10.2 hrs; $\sigma_{thermal}$ = ?)

$^{93}_{39}Y$ decays 100% via $\beta^- \rightarrow {}^{93}_{40}Zr + \gamma$ (Q = 2.9 MeV; hl = 1.5 x 10^6 yrs; $\sigma_{thermal}$ = <4b)

$^{93}_{40}Zr + 1\,ulm\,n \rightarrow {}^{94}_{40}Zr + \gamma$ (Q = 8.2 MeV; stable; $\sigma_{thermal}$ = 0.05b)

$^{94}_{40}Zr + 1\,ulm\,n \rightarrow {}^{95}_{40}Zr + \gamma$ (Q = 6.5 MeV; hl = 64 days; $\sigma_{thermal}$ = ?)

$^{95}_{40}Zr$ decays 100% via $\beta^- \rightarrow {}^{95}_{41}Nb$ + X-rays (Q = 1.1 MeV; hl = 35 days; $\sigma_{thermal}$ = <7b)

$^{95}_{41}Nb + 1\,ulm\,n \rightarrow {}^{96}_{41}Nb + \gamma$ (Q = 6.9 MeV; hl = 23.4 hrs; $\sigma_{thermal}$ = ?)

$^{96}_{41}Nb$ decays 100% via $\beta^- \rightarrow {}^{96}_{42}Mo + \gamma$ (Q = 5.3 MeV; stable)

  - Neutron-rich isotopes build up via neutron captures interspersed with β-decay
  - Neutron capture on stable or unstable isotopes releases substantial nuclear binding energy, mostly in gamma emissions, which convert to IR

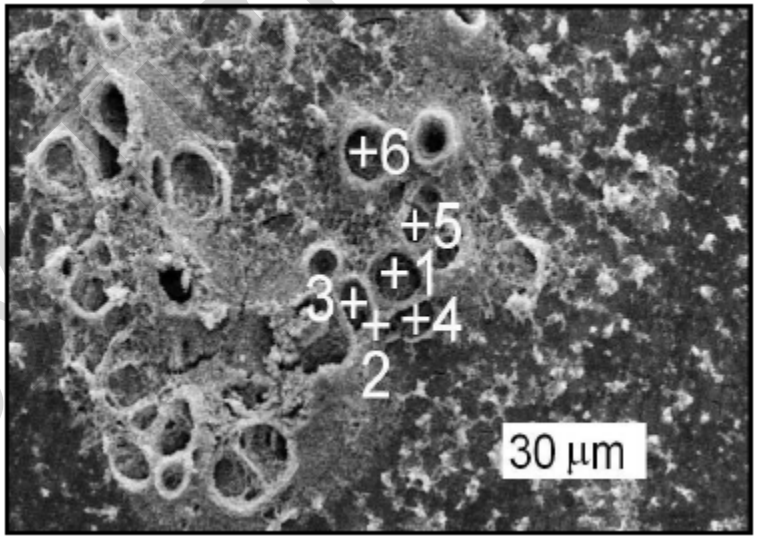
* Iwamura noted that it took longer to convert Sr into Mo than Cs into Pr. W-L argue that this is because the neutron cross section for Cs is vastly higher than for Sr

W-L Theory Insights Cont'd

Insight 5: Transmutation sites correlate with surface damage

- With Pd as the target element in an electrolytic cell, silver (Ag) is observed at the location of microcraters on the Pd cathode
- W-L theory suggest this is the result of ULM neutron captures on Pd with β-decays to Ag isotopes, resulting in locally high heat fluxes
- Feature size is consistent with theoretical scale of oscillating patches of protons, deuterons and tritons

Scanning electron microscope image of Pd cathode

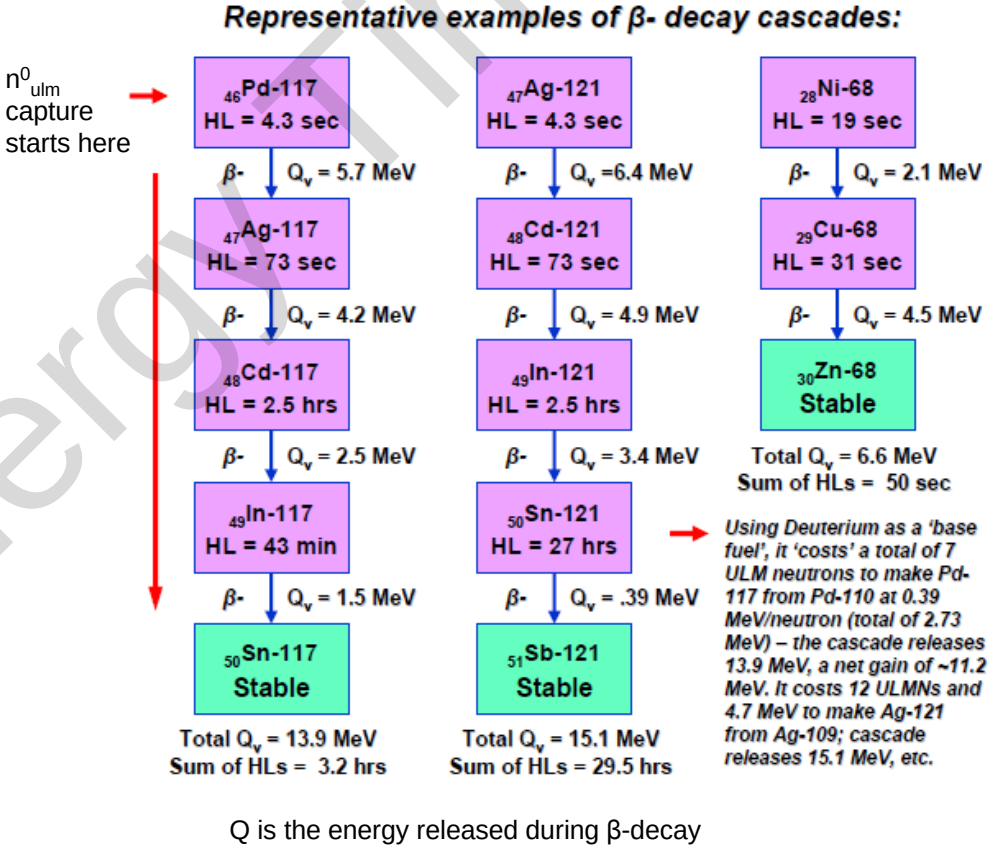


W. Zhang and J. Dash, "Excess heat reproducibility and evidence of anomalous elements after electrolysis in $Pd/D_2O + H_2SO_4$ electrolytic cells," 13th Intl. Conference on Condensed Nuclear Matter, Sochi, Russia 2007

W-L Theory Insights Cont'd

Insight 6: "Weak nuclear interactions"are not weak in terms of energy release

- Neutron-rich isotopes* will decay, mainly by a series of rapid β cascades
- β particles create heat by transferring kinetic energy to surrounding matter
- Energy released is comparable to D-D and D-T fusion reactions
- Decay cascades terminate in production of stable higher Z elements



Q is the energy released during β-decay

* In condensed matter LENRs, neutron-rich "halo" isotopes continue to absorb ULM neutrons as long as capture Q values remain favorable and as long as they are unable to decay or shed neutrons

W-L Theory Insights Cont'd

Insight 7: LENR experiments produce few long-lived radioactive isotopes

- In surface patches that experience large fluxes of ULM neutrons, populations of very neutron-rich "halo" nuclei will build up
- The half-lives of these nuclei are longer than they would be if isolated because they are unable to emit β electrons or shed neutrons into unoccupied states in the local continuum
- The cessation of ULM neutron production will trigger serial cascades of fast β-decays from neutron rich into stable isotopes
- Few long-lived radioisotopes remain after this process has run its course

W-L Theory Insights Cont'd

Insight 8: Production of Helium

- Several LENR researchers (e.g., McKubre, Miles, Arata and Zhang, Lipson, Karabut) have reported detectable levels of He-4 and He-3 in some of their experiments
- Considered by many to be a telling signature of the D-D nuclear fusion reaction, He^4 can be produced by other nuclear reactions, including minor alternative branches of neutron captures and various alpha particle decays (e.g., when using lithium* as the fuel)

$$Li^6 + n^0 \rightarrow Li^7$$
$$Li^7 + n^0 \rightarrow Li^8$$
$$Li^8 \rightarrow Be^8 + e^- + \nu_e$$
$$Be^8 \rightarrow He^4 + He^4$$

- Many isotopes have minor (n,α) decay channels with small cross sections that would result in at least one alpha (He^4) particle
- Unstable isotopes of elements with atomic number > 83 commonly decay via α-decay

* In a Pons and Fleischman-type electrolytic cell, any lithium present in the electrolyte will invariably accumulate in intimately alloyed admixtures with Pd on the surface of the cathode

Possible Pathway to He^4 Production using Palladium as Seed Nucleus

- Besides serving as the medium for producing ULM neutrons, Pd can also potentially capture ULM neutrons
  - All stable Pd isotopes have large ULM neutron capture cross sections
- ULM capture on PD isotopes can release significant amounts of binding energy
- Alpha decays of Pd isotopes have small cross section but positive Q values

$^{102}_{46}Pd$, $^{104}_{46}Pd$, $^{105}_{46}Pd$, $^{106}_{46}Pd$, $^{108}_{46}Pd$, $^{110}_{46}Pd$ are stable

$^{102}_{46}Pd + 1\ ulm\ n \rightarrow {}^{103}_{46}Pd + \gamma$ (Q =7.6 MeV; 17 days; Q_α = 5.3 MeV)

$^{103}_{46}Pd + 1\ ulm\ n \rightarrow {}^{104}_{46}Pd + \gamma$ (Q =10 MeV; stable; Q_α = 7.4 MeV)

$^{104}_{46}Pd + 1\ ulm\ n \rightarrow {}^{105}_{46}Pd + \gamma$ (Q =7.1 MeV; stable; Q_α = 4.2 MeV)

$^{105}_{46}Pd + 1\ ulm\ n \rightarrow {}^{106}_{46}Pd + \gamma$ (Q =9.6 MeV; stable; Q_α = 6.3 MeV)

$^{106}_{46}Pd + 1\ ulm\ n \rightarrow {}^{107}_{46}Pd + \gamma$ (Q =6.5 MeV; 6.5 x 10^6yrs; Q_α = 3 MeV)

$^{107}_{46}Pd + 1\ ulm\ n \rightarrow {}^{108}_{46}Pd + \gamma$ (Q =9.2 MeV; stable; Q_α = 5.4 MeV)

$^{108}_{46}Pd + 1\ ulm\ n \rightarrow {}^{109}_{46}Pd + \gamma$ (Q =6.2 MeV; 13.7 hrs; Q_α = 2.1 MeV)

$^{109}_{46}Pd + 1\ ulm\ n \rightarrow {}^{110}_{46}Pd + \gamma$ (Q =8.8 MeV; stable; Q_α = 4.4 MeV)

$^{110}_{46}Pd + 1\ ulm\ n \rightarrow {}^{111}_{46}Pd + \gamma$ (Q =5.7 MeV; 23.4 min; Q_α = 1.2 MeV)

$^{111}_{46}Pd + 1\ ulm\ n \rightarrow {}^{112}_{46}Pd + \gamma$ (Q =8.4 MeV; 21 hrs; Q_α = 3.3 MeV)

$^{112}_{46}Pd + 1\ ulm\ n \rightarrow {}^{113}_{46}Pd + \gamma$ (Q =5.4 MeV; 93 sec; Q_α = 161 keV)

$^{113}_{46}Pd + 1\ ulm\ n \rightarrow {}^{114}_{46}Pd + \gamma$ (Q =7.9 MeV; 2.4 min; Q_α = 1.9 MeV)

$^{114}_{46}Pd + 1\ ulm\ n \rightarrow {}^{115}_{46}Pd + \gamma$ (Q =5 MeV; 25 sec; Q_α = none)

$^{115}_{46}Pd + 1\ ulm\ n \rightarrow {}^{116}_{46}Pd + \gamma$ (Q =7.6 MeV; 12 sec; Q_α = 727 keV)

Note: neutron capture on $^{105}_{46}Pd$ has a measured Q_α cross-section of 0.5 μbarns for $^{106}_{46}Pd \rightarrow {}^{102}_{46}Ru + He^4$

β-Delayed Isotopic Decay Branches

- LENR systems exhibit a very dense occupation of local fermionic states which can delay the β-decay (a fermion) of neutron-rich intermediate isotopes compared to that of isolated nuclei
- This provides a much richer variety of decay channel possibilities, such as beta-delayed emissions of gammas, neutrons, alpha particles, tritons and deuterons
  - Production cross-sections for such emissions are typically small, but certain isotopes have substantial β-delayed branches e.g., 12% of N^{18} decays emit alphas
  - Over 100 isotopes are known to exhibit β-delayed decay pathways
- Depending on the LENR nucleosynthetic pathways, target seed nuclei may produce significant quantities of He^4 without any lithium present or the need to invoke D-D “cold fusion” processes

ULM Neutron Catalyzed LENR Network

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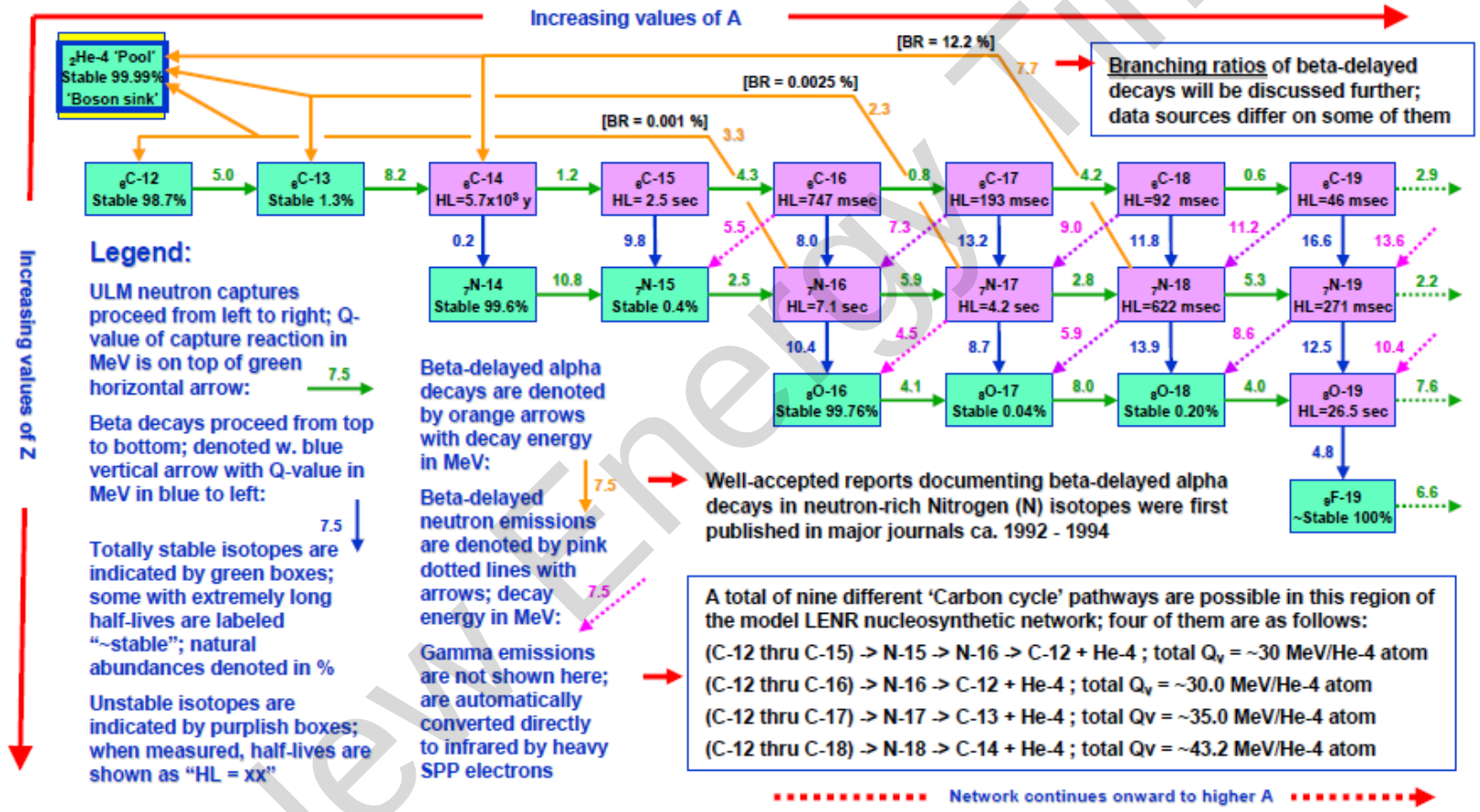
ULMN capture on carbon, neutron-rich isotope production, and related decays



The Widom-Larsen Theory Summary

- The Widom-Larsen (W-L) theory of LENR differs from the mainstream understanding in that the governing mechanism for LENR is presumed to be dominated by the weak force of the standard theory, instead of the strong force that governs nuclear fission and fusion
  - Assumption of weak interactions leads to a theoretical framework for the LENR energy release mechanism consistent with the observed production of large amounts of energy, over a long time, at moderate conditions of temperature and pressure, without the release of energetic neutrons or gamma radiation
- W-L theory is built upon the well-established theory of electro-weak interactions and many-body collective effects
- W-L theory explains the observations from a large body of LENR experiments without invoking new physics or ad-hoc mechanisms
  - So far, no experimental result fatally conflicts with the basic tenets of the W-L theory
  - In fact, an increasing number of LENR anomalies have been explained by W-L
  - In one case, W-L theory provided a plausible explanation for an anomalous observation of transmutation in an exploding wire experiment conducted back in 1922
- Could the W-L theory be the breakthrough needed to position LENR as a major source of carbon-free, environmentally clean source of source of low-cost nuclear energy??

LENR State of Play

- The Widom-Larsen theory has done little to unify or focus the LENR research community
- If anything, it appears to have increased the resolve of the strong-force D-D fusion advocates to circle the wagons
- LENR is an area of research at the TRL-1 level but the community is already jockeying for position to achieve a competitive TRL-8 position, which further impedes the normal scientific process
- Without a theory to guide the research, LENR will remain in a perpetual cook-and-look mode, which produces some tantalizing results to spur venture capital investments but does little to advance the science
- DTRA needs to be careful not to get embroiled in the politics of LENR and serve as an honest broker
  - Exploit some common ground, e.g., materials and diagnostics
  - Force a show-down between Widom-Larsen and Cold Fusion advocates
  - Form an expert review panel to guide DTRA-funded LENR research