Lattice Energy LLC

Commercializing LENRs:
A "Green" Next Generation Energy Source
For Dense, Long Lived Portable Power

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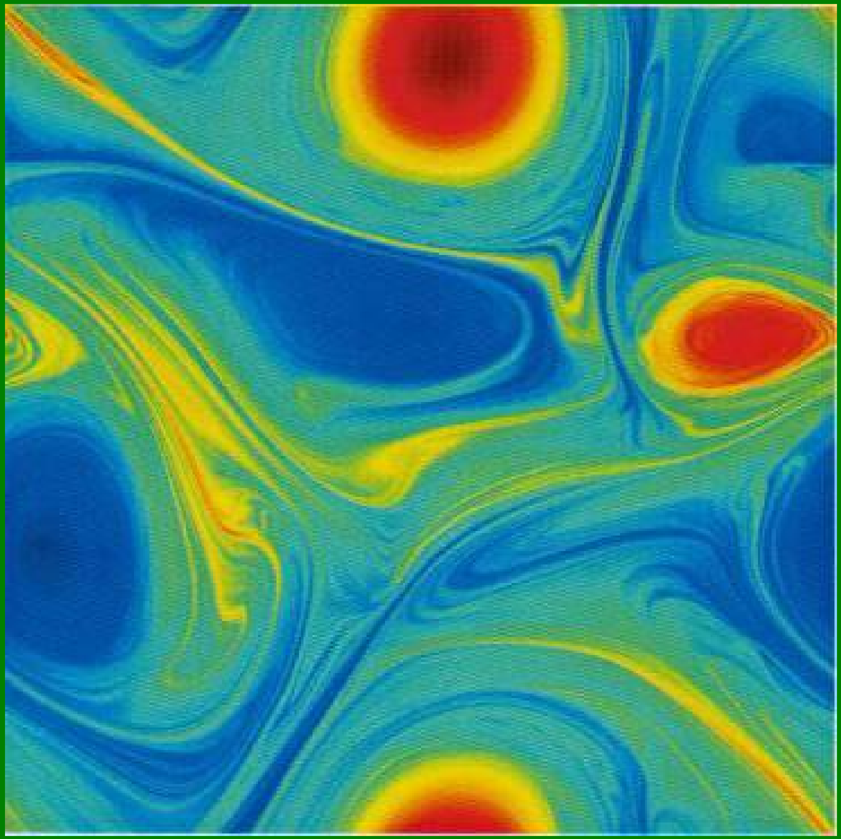
DTRA/ASCO High Energy S&T Workshop
December 12, 2006

Low Energy Nuclear Reactions in Condensed Matter Systems



L. Larsen

A. Widom

Presented at DTRA/ASCO High Energy S&T Workshop

Low Energy Nuclear Reactions Controversial Research I

- Experimental results don't fit well with presently accepted knowledge of nuclear physics, particularly fusion reactions.
- According to accepted nuclear theory, many LENR researchers should have been killed by lethal fluxes of neutrons or hard radiation.

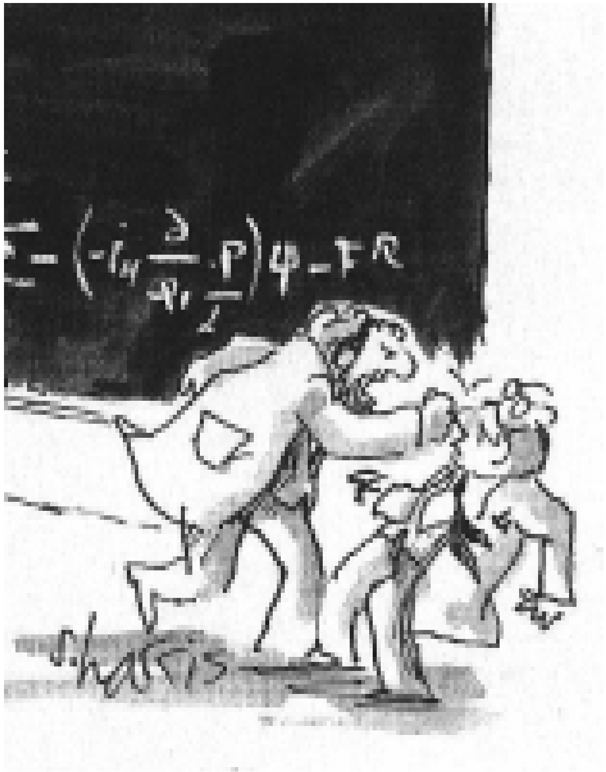
Yet We Live

- Many researchers working in field continue to insist that LENR's are some form of "cold" fusion.
- Reproducibility of many aspects of LENR's is poor, *especially* regarding excess heat.
- Critics have argued that LENR's are "junk" science.

Fact: There is a large residue of experimental data on LENR's that is quite solid and *cannot* be explained away simply as experimental error.

Low Energy Nuclear Reactions Controversial Research II

- **Fact:** **Although the quality of experimental work varies greatly, a significant body of experimental observations are well done.**
- **Fact:** **To date, no LENR researchers have been killed by radiation.**
- **Problem:** **Standard Model nuclear theory was not applied to explain the results.**
- **Solution:** **Develop a theory of LENR's which explain the data without invoking "new physics" beyond the Standard Model.**



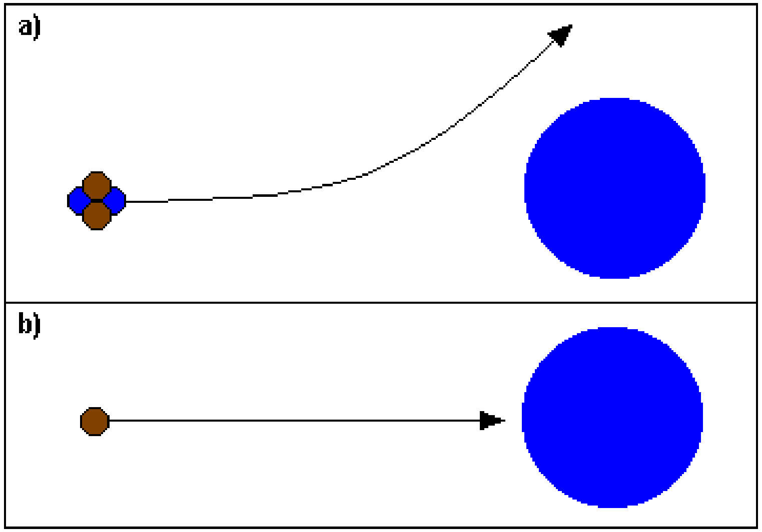
You want proof! I'll give you proof!

Widom-Larsen Theory I

- Explains a broad range of experimental data in H- and D-based systems.
- Answers why there are not energetic neutrons typically produced.
- Answers why there are not significant amounts of hard radiation.
- Answers why there are not Coulomb barriers to the required reactions.
- Explains production of helium isotopes observed in certain experiments.
- Explains production of excess heat observed in certain experiments.
- Explains complex product spectra seen in transmutation experiments.
- Enables calculations of reaction rates in agreement with experiments.
- Creates a road map that solves previous reproducibility problems.
- Predicts new LENR phenomena and also explains anomalous data and phenomena in other fields of weak interaction nuclear physics.

Widom-Larsen Theory II

- LENR's primarily involve the weak interactions (creation of neutrons, neutrinos and beta decays).
- LENR's are not "cold fusion" or other forms of pure strong interactions.
- Explains LENR's in terms of the accepted high energy Standard Model.
- Extends existing electroweak model to include condensed matter collective effects.
- Does not employ any microscopic "new physics".
- Does not involve penetration of a Coulomb barrier. Neutrons have no charge. Electrons and protons attract.

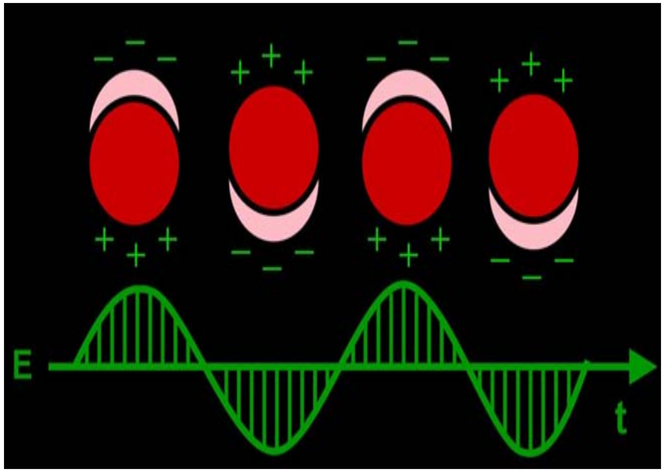


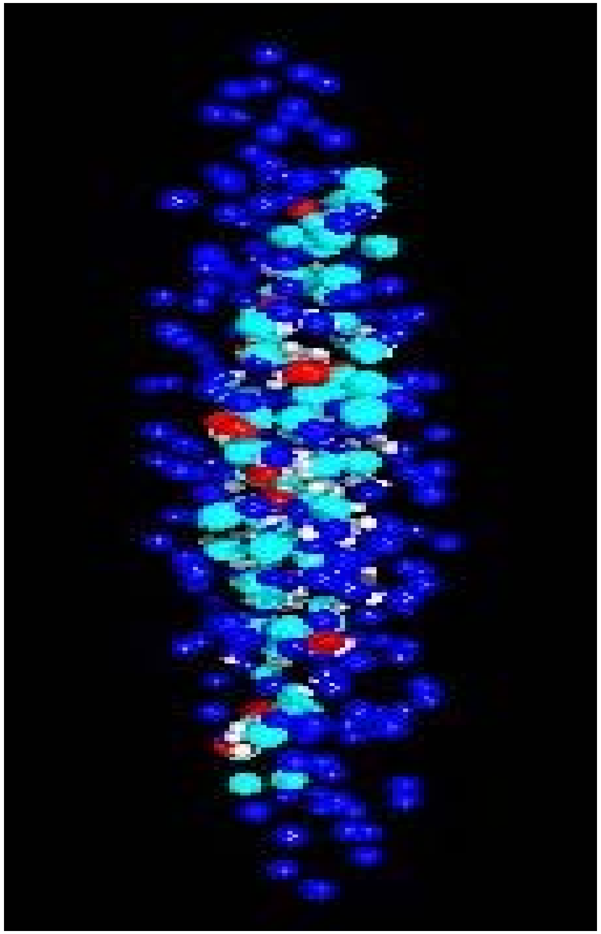
Nucleus bombarded with the a) alpha particle
b) neutron

Only like charges deflect from a Coulomb barrier.

Widom-Larsen Theory III

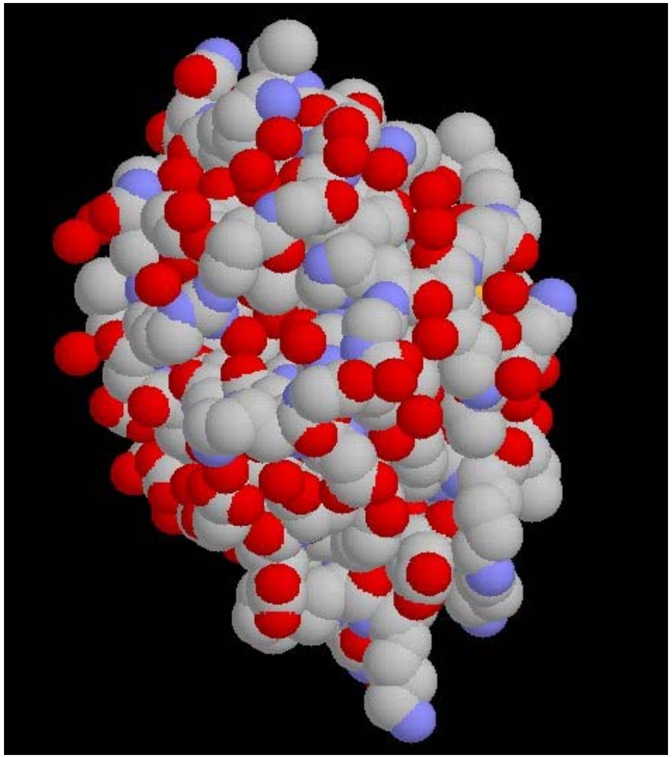
- Does not violate any conservation laws.
- It Is unusually multidisciplinary – it incorporates accepted concepts from a number of different areas of physics, including collective many-body effects.





Widom-Larsen Theory IV

1. **Many-body "patches" of collectively oscillating protons or deuterons form on metallic hydride surfaces "loaded" with hydrogen isotopes.**
2. **Then, the Born-Oppenheimer approximation breaks down in the local region "above" the patches; collective oscillations of the protons or deuterons start to couple loosely to the collective oscillations of nearby Surface Plasmon Polariton electrons (SPPs) commonly found on surfaces of metals.**

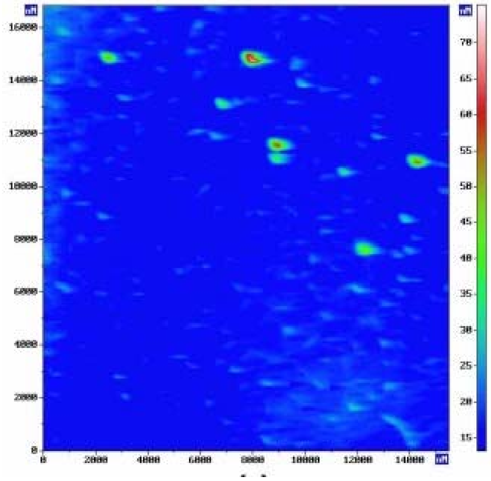


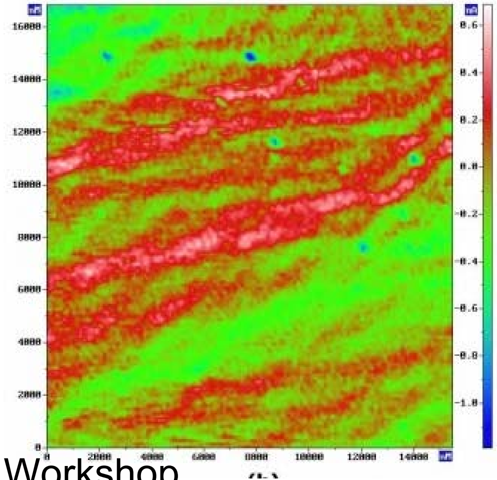
Widom-Larsen Theory V

3. Coupling between SPP's and the patches of protons or deuterons increases the local electric field to values > 10^{11} volts/meter (roughly the same magnitude as Coulomb fields seen by inner electrons in atomic nuclei).

4. Intense local radiation field raises effective mass of SPP electrons so that they can react spontaneously with nearby protons or deuterons to create neutrons.

5. Neutrons created collectively have huge quantum mechanical wavelengths (microns) and are almost always absorbed locally by nearby nuclei.





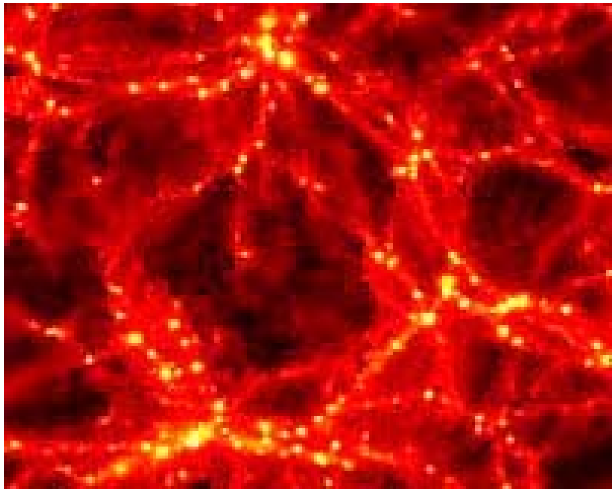
Widom-Larsen Theory VI

- Heavy-mass SPP electrons in condensed matter systems have the unique ability to directly absorb a gamma photon and reradiate it as a collection of much lower-energy infrared and soft X-ray photons (conservation of energy applies).

- Thus, when expected prompt hard gamma photons are emitted as a result of neutron absorption by local nuclei or beta decays, gammas are intercepted by heavy SPP electrons and reradiated as much "softer" electromagnetic energy.

- As a result, LENR systems have built-in "gamma shields" that preclude external emission of hard radiation in the form of MeV + gamma- and X-rays.

- Since there is internal absorption of gammas, no significant shielding is required for conducting safe laboratory experiments with LENR systems.



Widom-Larsen Theory VII

Beginning in May 2005, four papers have appeared on the non-proprietary aspects of the Widom-Larsen theory.

1. **"Ultra Low Momentum Neutron Catalyzed Nuclear Reactions on Metallic Hydride Surfaces", *Eur. Phys. J. C* 46, 107 (2006)**
2. **"Absorption of Nuclear Gamma Radiation by Heavy Electrons on Metallic Hydride Surfaces", cond-mat/0509269**
3. **"Nuclear Abundances in Metallic Hydride Electrodes of Electrolytic Chemical Cells", cond-mat/0602472**
4. **"Theoretical Standard Model Rates of Proton to Neutron Conversions Near Metallic Hydride Surfaces", nucl-th/0608059**

Ultra Low Momentum Neutron Catalyzed
Nuclear Reactions on Metallic Hydride Surfaces

A. Widom
Physics Department, Northeastern University, Boston MA 02115

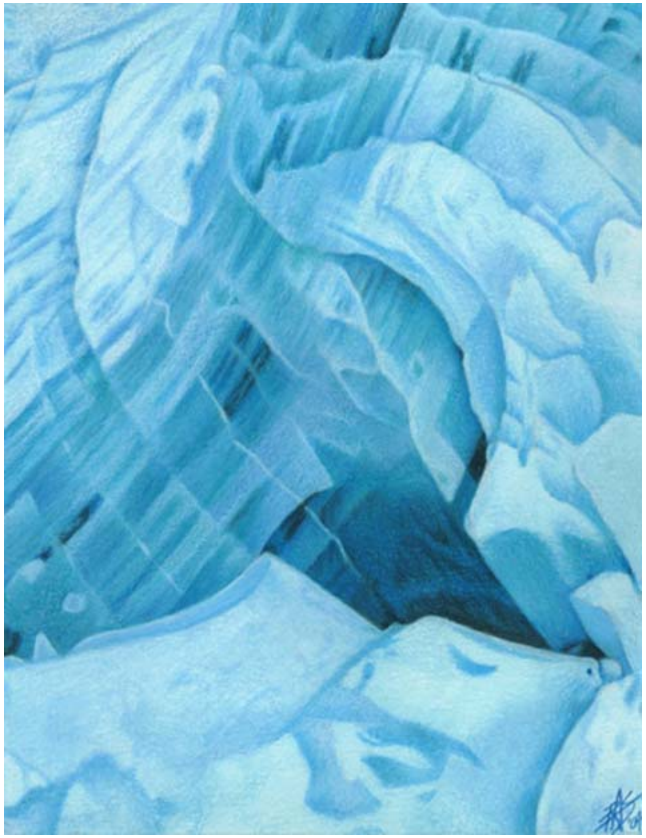
L. Larsen
Lattice Energy LLC, 175 North Harbor Drive, Chicago IL 60601

Ultra low momentum neutron catalyzed nuclear reactions in metallic hydride system surfaces are discussed. Weak interaction catalysis initially occurs when neutrons (along with neutrinos) are produced from the protons which capture "heavy" electrons. Surface electron masses are shifted upwards by localized condensed matter electromagnetic fields. Condensed matter quantum electrodynamic processes may also shift the densities of final states allowing an appreciable production of extremely low momentum neutrons which are thereby efficiently absorbed by nearby nuclei. No Coulomb barriers exist for the weak interaction neutron production or other resulting catalytic processes.

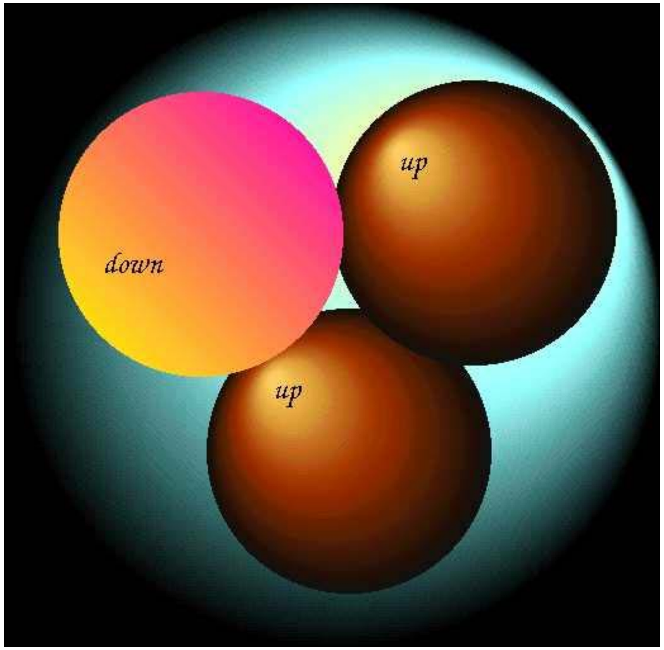
Future papers with new collaborators are in preparation.

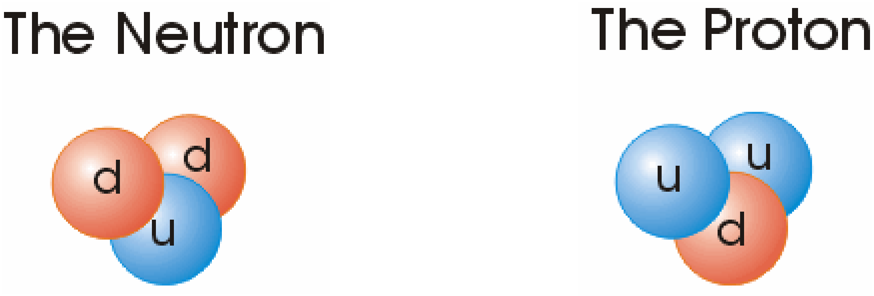
Low Energy Nuclear Reactions

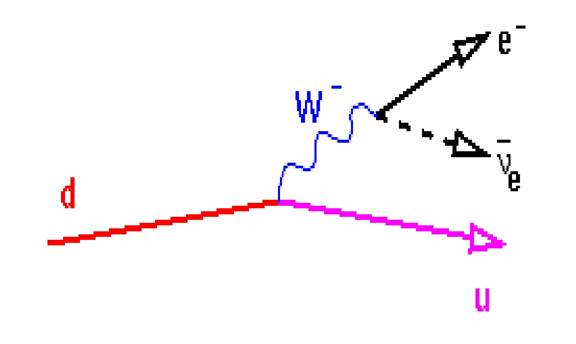
- The Standard Model
- Energy Sources
- Weak Interactions
- Chemical Cells
- Nuclear Transmutations and Abundances
- Exploding Wires
- Total Rates
- Conclusions



The Standard Model







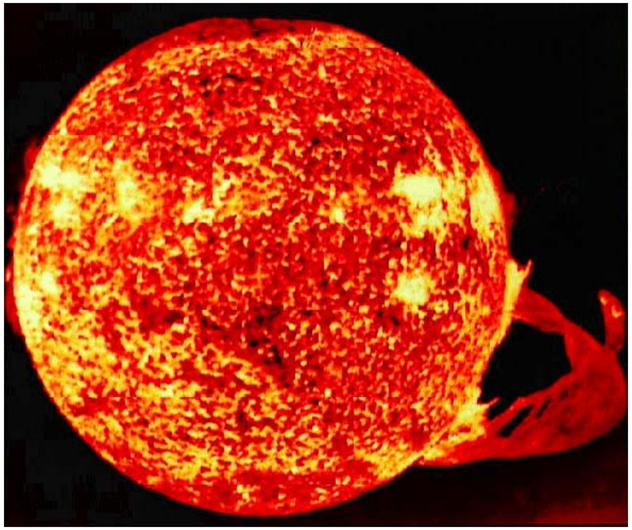
Weak Interaction Decay of the Neutron

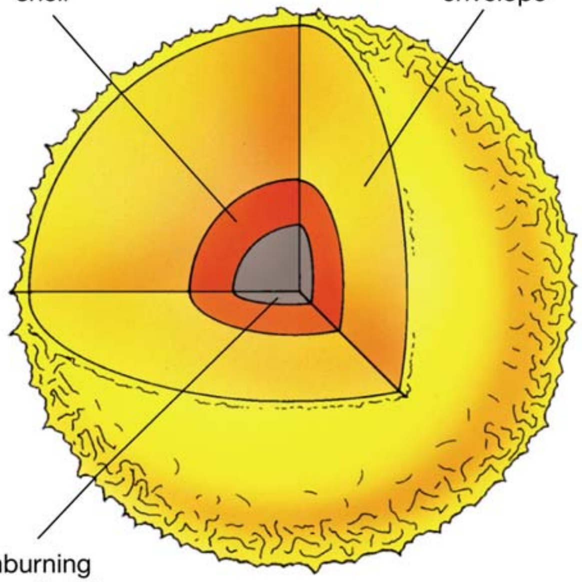
$$n \rightarrow p^{+} + e^{-} + \overline{\nu}_{e}$$

Energy Sources I

“Burning” Hydrogen in the Sun via Weak Interactions. The “Seed” Reaction is

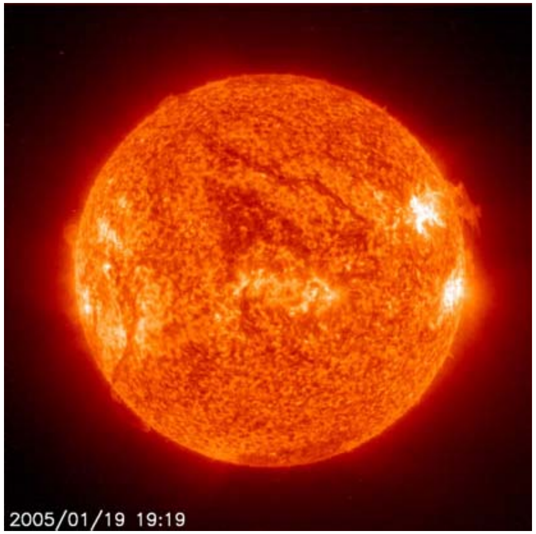
$$p^{+} + p^{+} \rightarrow d^{+} + e^{+} + \nu_{e}$$





Optical Picture and Theoretical Model of the Sun

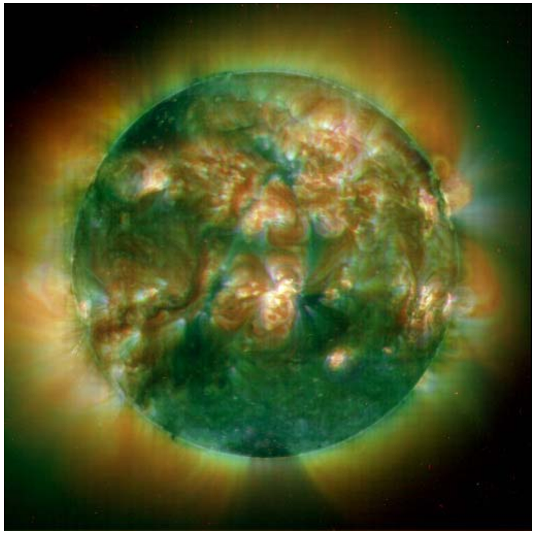
Energy Sources II



Optical Picture

Simultaneously Taken Pictures of the Sun

Outside X-ray Temperatures in the Solar Corona are from Nuclear Reactions of Unknown Origin



X-ray Picture

Our Suggested "Seed" Corona Weak Interaction is the Following:

$$(\text{collective radiation energy}) + e^- + p^+ \rightarrow n + \nu_e$$

Weak Interaction Energy Source

A. Widom and L. Larsen, *Eur.Phys.J.C* **46**, 107-111 (2006)

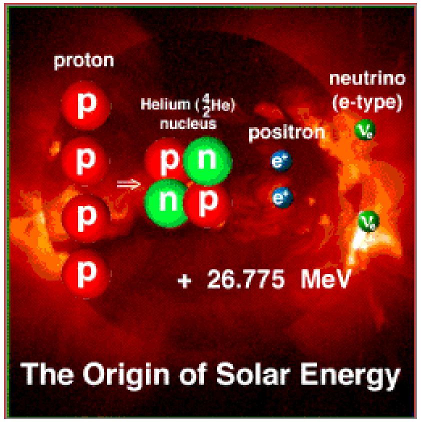
$$\text{(collective radiation energy)} + e^- \rightarrow \text{(mass renormalized electron) } \tilde{e}^-$$

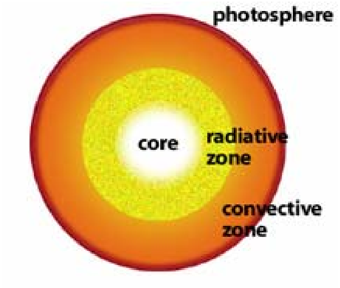
$$\tilde{e}^- + p^+ \rightarrow n + \nu_e$$

net neutron producing reaction

$$\text{(collective radiation energy)} + e^- + p^+ \rightarrow n + \nu_e$$

If there is a large enough neutron flux, then nuclear transmutations yield chemical abundances.

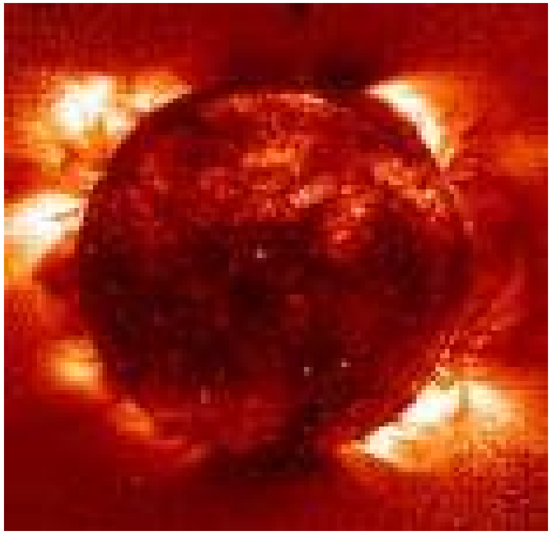




$$\tilde{e}^- + p^+ + p^+ \rightarrow d^+ + \nu_e$$

Possible Seed Reaction

Weak Interaction Energy Source



Nuclear Net Reaction for Burning in the Sun

$$2e^- + 4p^+ \rightarrow \alpha^{++} + 2\nu_e$$

Coulomb Barrier Intermediate Reaction

$$2p^+ \rightarrow e^+ + d^+ + \nu_e$$

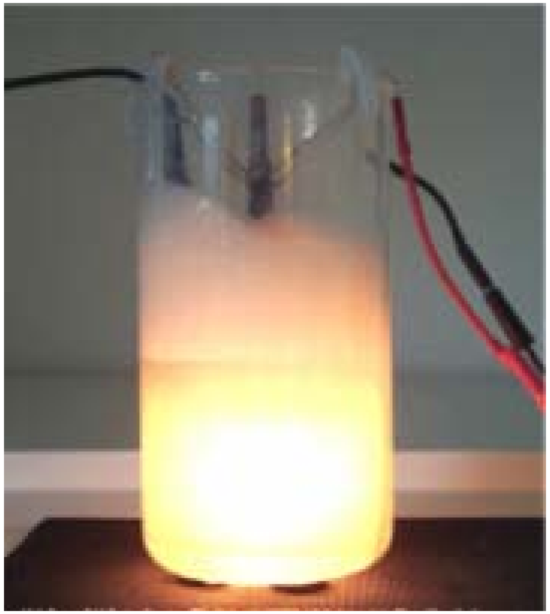
Intermediate Reactions *without* the Coulomb Barrier

$$e^- + p^+ \rightarrow n + \nu_e$$
$$n + p^+ \rightarrow d^+$$

There is always a neutrino flux with weak interactions.

$$e^- + p^+ \rightarrow n + \nu_e$$
$$n + p^+ \rightarrow d^+$$
$$n + d^+ \rightarrow t^+$$
$$n + t^+ \rightarrow \alpha^{++} + e^- + \overline{\nu}_e$$

Chemical Cells I



$$(\text{radiation}) + e^- \rightarrow \tilde{e}^-$$

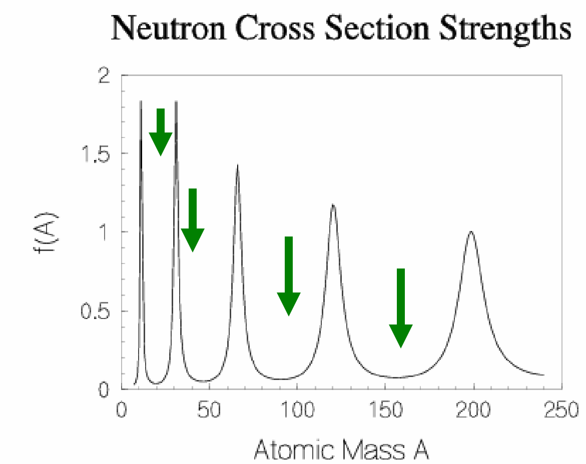
$$\tilde{e}^- + p^+ \rightarrow n + \nu_e$$

$$n + (Z, A) \rightarrow (Z, A+1)$$

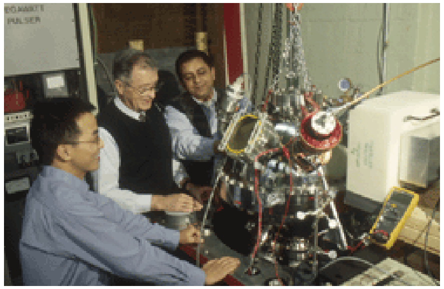
$$(Z, A+1) \rightarrow (Z+1, A+1) + e^- + \bar{\nu}_e$$

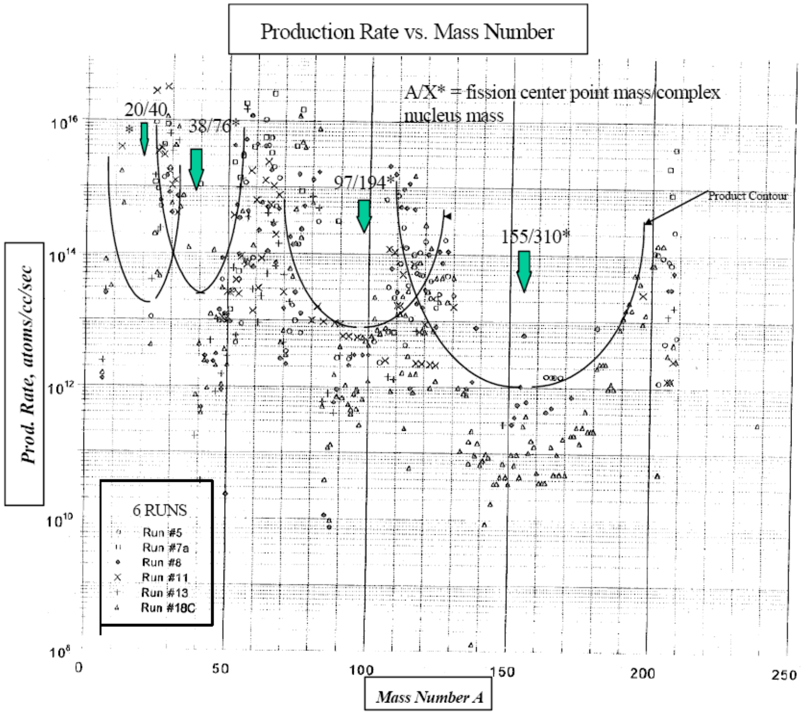
$$\cdots\cdots\cdots\cdots\cdots\cdots$$

Chemical Cells II



Resonances in σ(A)





G. Miley et al.'s Experimental Abundances

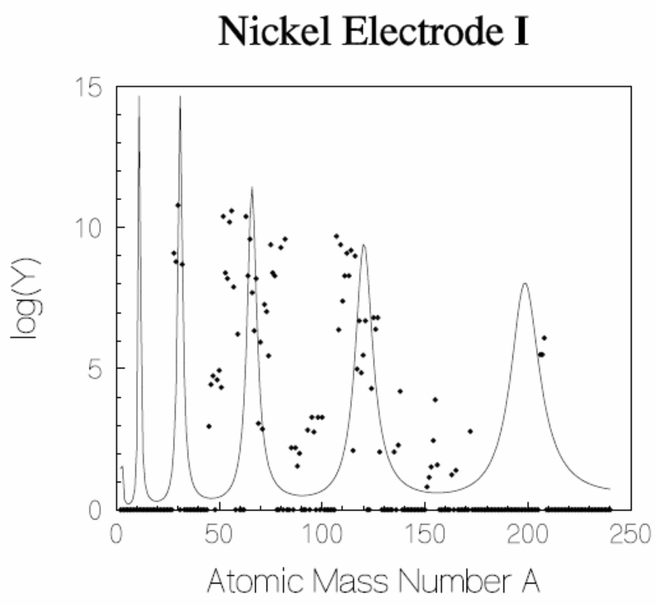
Presented at DTRA/ASCO High Energy S&T Workshop

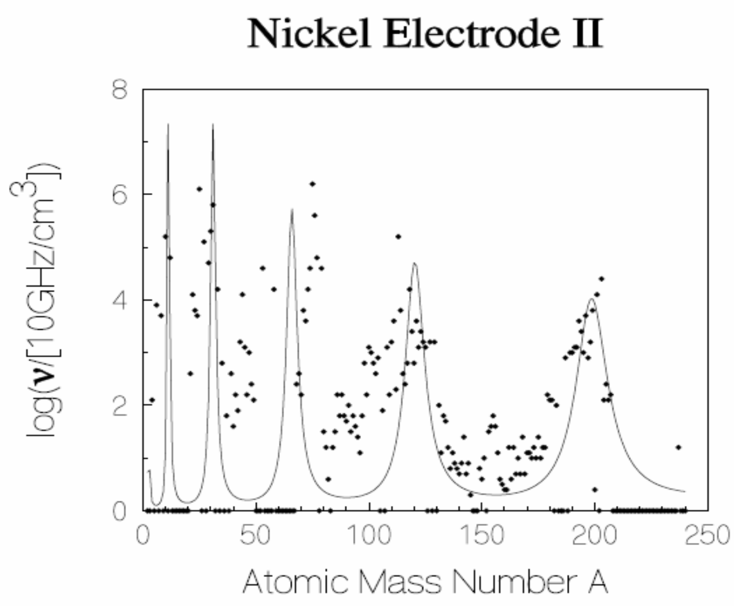
Chemical Cells III

Nuclear Transmutations in Chemical Cells with Light Water and Nickel Electrodes

Abundances taken from the experiments of G. Miley et al.

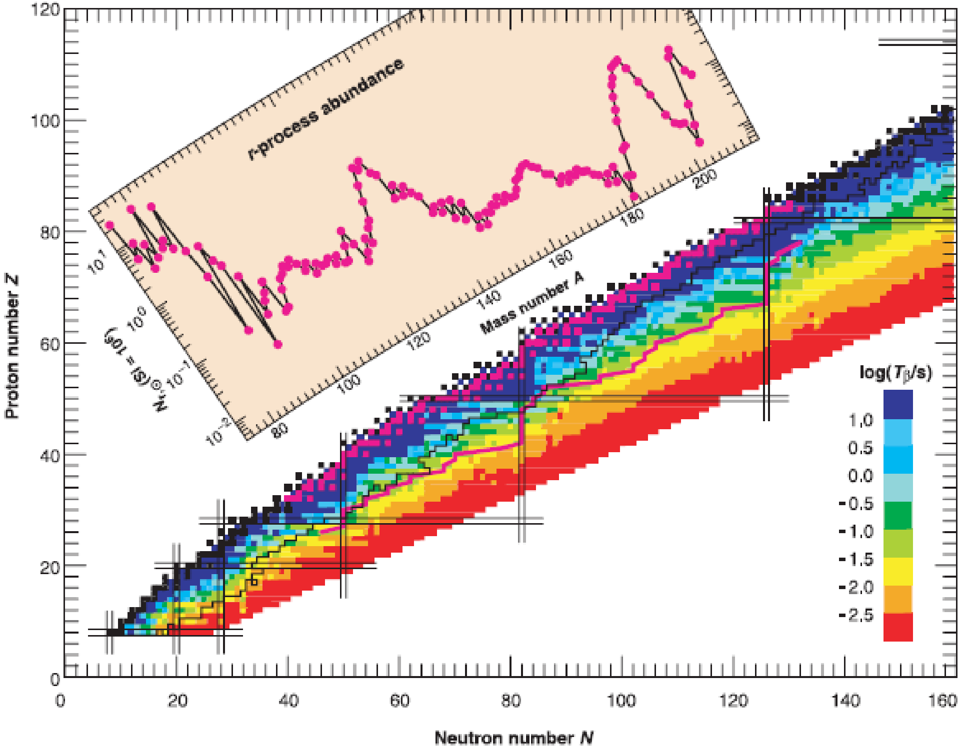
Abundances and Ultra-Low Momentum Neutrons





Presented at DTRA/ASCO High Energy S&T Workshop

Nuclear Abundances I



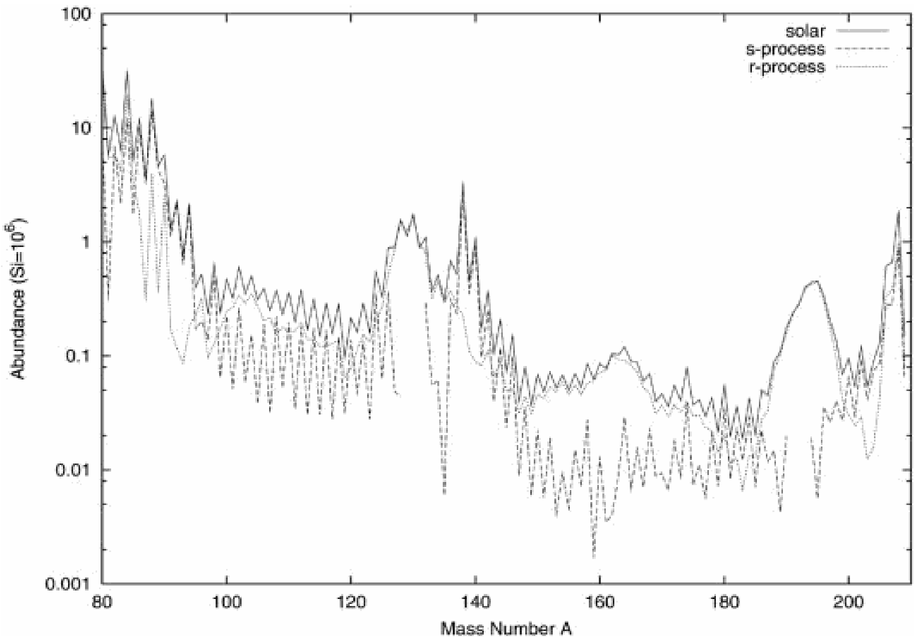
C. Sneddon & J.J. Cowen

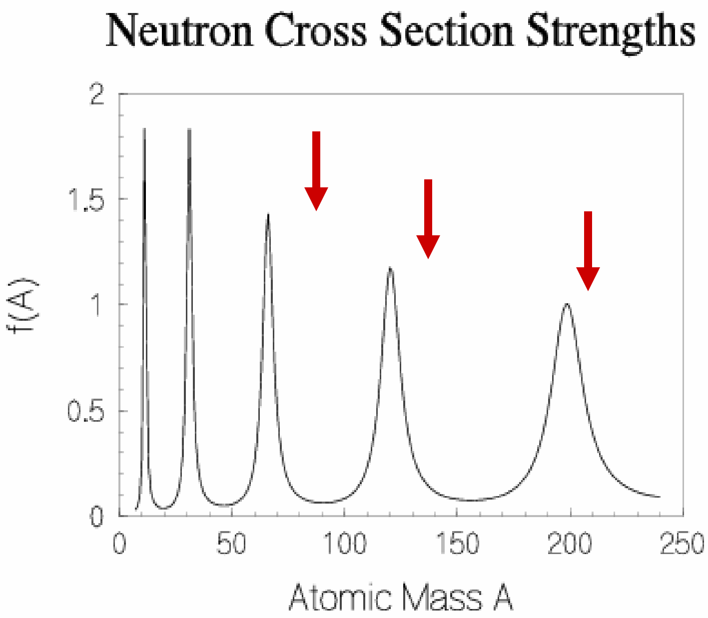
"Genesis of the Heaviest Elements in the Milky Way Galaxy"

Science, **299,** 70 (2003)

The peaks in the solar system abundance distribution around A=88, 138, 208 are formed in the s-process, whereas the broader companion peaks shifted to slightly lower mass number are r-process peaks.

Nuclear Abundances II





Maxima around A=88, 138, 208 are formed in the s-process.

Exploding Wires I

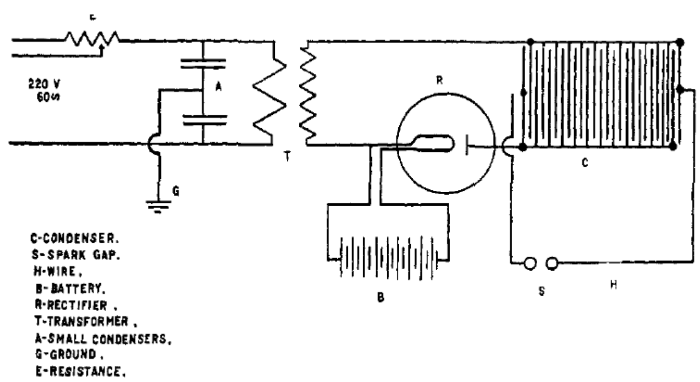
DECOMPOSITION OF TUNGSTEN 1887

[CONTRIBUTION FROM THE KENT CHEMICAL LABORATORY, UNIVERSITY OF CHICAGO]

EXPERIMENTAL ATTEMPTS TO DECOMPOSE TUNGSTEN AT HIGH TEMPERATURES

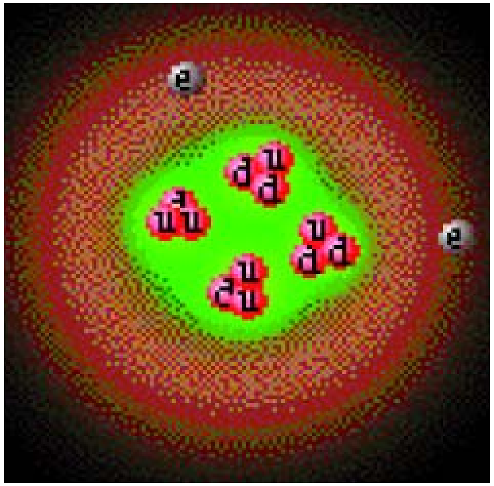
BY GERALD L. WENDT AND CLARENCE E. IRION

Received May 8, 1922



Published In Science

Spectroscopic Detection of α-particles, i.e. Helium atoms



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Exploding Wires II

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1 Sir Ernest Rutherford, in *Nature*.

it is to be anticipated that the additional heating effect due to this liberated energy would be a much more definite and more delicate test of disintegration of heavy atoms into helium than the spectroscope.

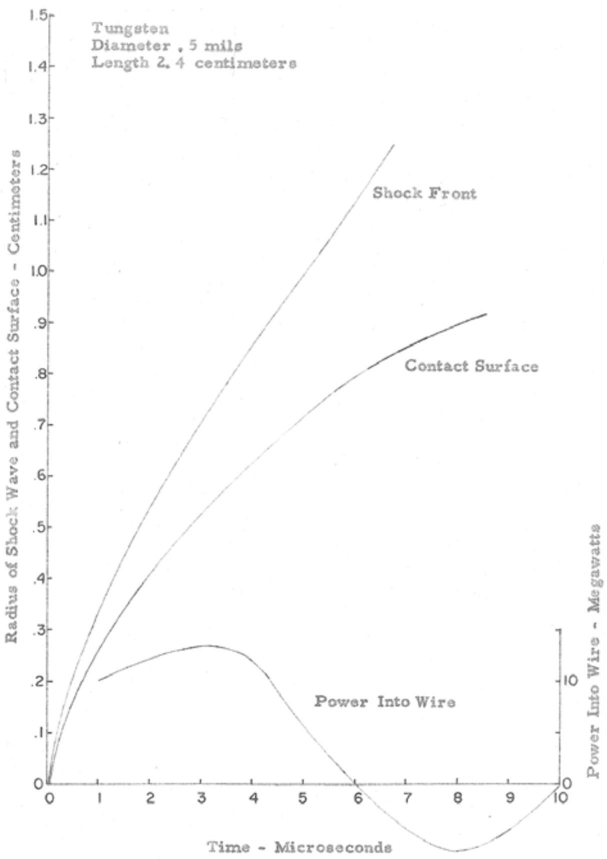
....

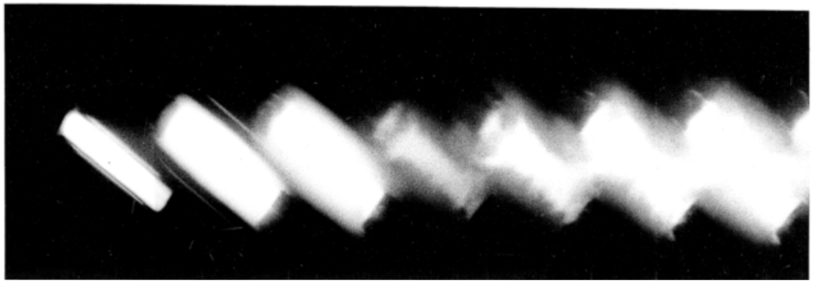
particular, in Coolidge tubes an intense stream of electrons of energy about 100,000 volts is constantly employed to bombard a tungsten target for long intervals, but no evolution of helium has so far been observed.

Rutherford has a big voltage but small current. One poor electron arrives at a time. Rutherford sees nothing.

Wendt and Irion have a small voltage but big current. Many electrons arrive at it collectively. Wendt and Irion see transmutations.

Exploding Wires III





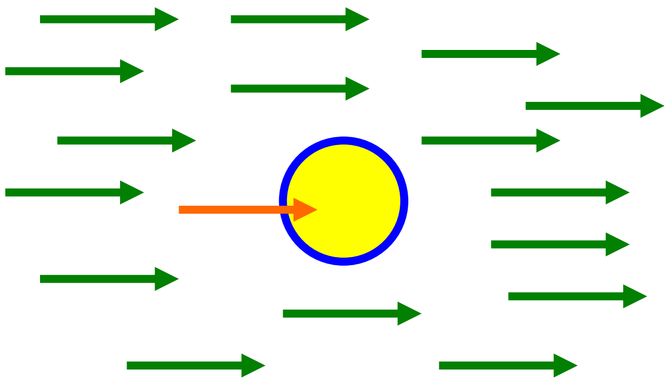
From "A Study of Exploding Wires" by Ben Robert Turner. Ph. D. Thesis, California Institute of Technology (1962)

Power input positive for times 0 < t < 6 μsec.

Power output positive for times 6 μsec. < t < 10 μsec.

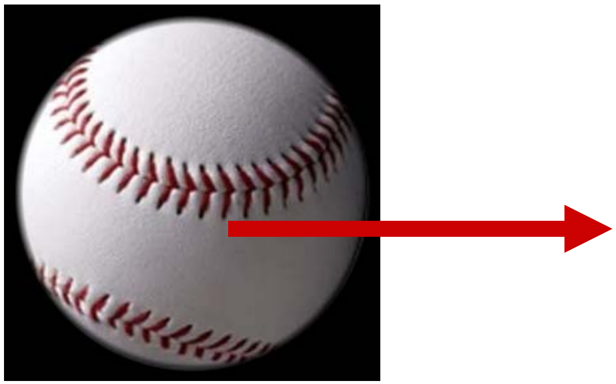
For transmutations in exploding wires also see "Investigation of Arcing in Electrical Fuses" by Robert Ernest Brown. Ph.D. Thesis, School of Engineering, Sheffield Hallum University.

Exploding Wires IV



When many electrons arrive at a proton, only one electron may pierce into the proton's inside. That electron dies. All of the other electrons have but donated a little energy. The plasma modes are collective and in synchronization.

It is not hard to throw a baseball at a target with an energy of 10^{23} electron volts, but (as did *not* Rutherford) one will *not* see transmutations. The electrical currents must be *collective* and the electrons must *transfer energy coherently* and all together.



General Theoretical Formulation I

From conservation law arguments, for every new neutron created (by destroying an electron and a proton) there will be neutrino created. One thereby counts new neutrons by counting new neutrinos. That was the game played in counting neutrinos from the sun. Power sources are derived from weak interactions.

$$S_{weak} = \hbar \int \left(\overline{\nu}(x)\eta(x) + \overline{\eta}(x)\nu(x) \right) d^4 x$$

$$-i\gamma^{\mu}\partial_{\mu}\nu(x) = \eta(x)$$

$$i\partial_{\mu}\overline{\nu}(x)\gamma^{\mu} = \overline{\eta}(x)$$

Weak Interaction for Neutrinos

General Theoretical Formulation II

$$S_{week} = \hbar \int \left(\bar{\nu}(x)\eta(x) + \bar{\eta}(x)\nu(x) \right) d^4 x$$

$$S_{effective} = \frac{i}{2\hbar} \left\langle S_{week}{}^2 \right\rangle_+$$

Weak Interaction for Neutrinos

$$P = \left| e^{iS_{effective}/\hbar} \right|^2 = e^{-(1/c)\int \varpi \, d^4 x}$$

$$\int \varpi \, d^4 x = \frac{2c}{\hbar} \Im m S_{effective}$$

$$\frac{1}{c} \int \varpi(x) \, d^4 x = \Im m \int \int \left\langle \bar{\eta}(x_1)\nu(x_1)\bar{\nu}(x_2)\eta(x_2) \right\rangle d^4 x_1 d^4 x_2$$

$$\left\langle \nu(x_1)\bar{\nu}(x_2) \right\rangle = C(x_1 - x_2) = \text{vacuum neutrino correlation}$$

$$\left\langle \bar{\eta}(x_1)\eta(x_2) \right\rangle = K(x_1, x_2) = \text{condensed matter source correlation}$$

$$\varpi(x) = c \Im m \int C(y) : K\left(x + \frac{y}{2}, x - \frac{y}{2} \right) d^4 y$$

Creation Probability for Neutrinos

$$\varpi(x) = \text{neutrino production rate per unit time per unit volume at } x$$

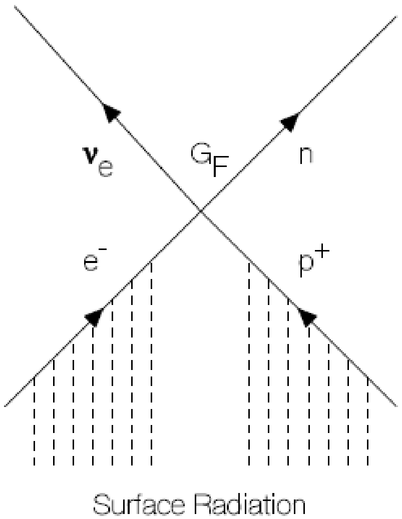
General Theoretical Formulation III

The rigorous source correlation function yielding the total production rate which does not depend on a “two body” correlation function is

$$K(x_1, x_2) = \langle \overline{\eta}(x_1)\eta(x_2) \rangle$$

$$\eta(x) = \frac{1}{\sqrt{2}} \gamma^{\mu} W^{+}{}_{\mu}(x) \psi_{left}(x)$$

$$\overline{\eta}(x) = \frac{1}{\sqrt{2}} \overline{\psi}_{right}(x) \gamma^{\mu} W^{-}{}_{\mu}(x)$$



which allows for the calculation of very high order non-linear electromagnetic processes

Conclusion I

- Weak interactions allow for many of the observed low energy nuclear transmutations.
- Collective surface plasma modes yield the required renormalized electron properties.
- Nuclear transmutation distributions near surfaces can be largely understood.
- Total rates from weak interactions appear to be in reasonable agreement with many observations.

Conclusion II

This laboratory was only funded to the extent that base metals could be converted into gold!